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E-Lock
Platino-based Experimenter’s PSU
Motion-Detector Camera Trigger
LED’s Replace That Fluorescent Tube
Microcontroller BootCamp
Current Transformer
Calculations
Precision Adjustable DC Current Source
ATmega on the Internet
Raspberry Pi Emulator
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Unwrapping RepRap
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The Nearly Lost World of Elektor
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From A to M and back in 92 pages

What used to be a hard division, Analog versus Microcontrollers, is mellowing to say the least. Our virtual e-hatchery website www.elektor-labs.com is a fine place to observe the trend: we find all-analog designs like audio amplifiers, bench instruments and radio projects receiving good ratings from the crowd there and progressing quickly to publication in Elektor magazine. On the other hand, totally microcontroller-oriented designers there are jubilant on discovering that a 2 dollar 8-pin IC called an ADC exists and can add considerably to the glory of their product.

As you will be able to confirm from browsing this copy of Elektor, the former sworn enemies A and M are beginning to reach out to each other with good results mutu-

As you will be able to confirm from browsing this copy of Elektor, the former sworn enemies A and M are beginning to reach out to each other with good results mutu-

Evidence of more interfacing between a microcontroller and analog circuitry is found in the Platino Experimenter’s Power Supply on page 16. This clever little benchtop PSU has all the output voltages, currents and cooling typically needed by the microcontroller crowd: 0-15 V adjustable at 1 amp, and 3.3 V or 5 V selectable at .5 amps conveniently on a USB connector. The articles Current Transformer Calculations (page 38) and Precision Adjustable DC Current Source (page 42) are a small and a large jewel of analog design respectively. Now, can we use a RepRap 3D Printer (page 66) to produce a plastic collet for the Elektorized Scope Probe (page 60)? After all, you really can’t separate A and M. Finally, the right-wing engine is not on fire and there is no April spoof in this issue. If you think there is, let me know the page number.

Enjoy reading this edition of Elektor

Jan Buiting, Editor-in-Chief

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E-Lock, the First Elektor Chip

Some Say... E-Lock is unbreakable*

By Eduardo Corral
(Spain);
Developed by Intelligent SoC
(info@soclusions.com)

That coffee machine might be the least of your concerns, but when ‘things’ are valuable, you need take some serious precautions. Elektor has given this a good deal of thought and together with Intelligent SoC developed a highly dedicated chip to protect your ‘things’: meet E-Lock, the first Elektor Chip!

The E-Lock chip allows you to connect your control system to the ‘Network of Networks’ and monitor and control it from anywhere on or around the globe using your computer, tablet or smartphone without having to worry about the security of the connection and in full assurance of protection against intruders.

Remarkably, the levels of security we are applying to our computers and mobile devices has not been extended to the millions of webbed embedded systems out there, which represents a serious risk to the healthy expansion of the Internet of Things (IoT). Who in his/her right mind connects an embedded device to the Internet if it is wide open to attacks by hackers attempting to take control or modify its behavior?

E-Lock is the answer

Enough doom & gloom, let’s get back to technology. We got in touch with embedded security specialists Intelligent SoC [1] and decided to jointly develop E-Lock, a chip—did we mention it’s

If we are to believe all the predictions, 2014 will be the year of the Internet of Things ... All Things! As a consequence all manner of electronic products will start chatting to each other, exchanging information over the Internet, the premise being that communicating with your coffee machine is easier than with your colleagues or neighbors—but how will the coffee machine know it is you and not Barney from next door? S-e-c-u-r-i-t-y, that’s what we’re on here. And we challenge You Hacker.

the first Elektor chip?—specially designed for the IoT based on two fundamental conditions; 1) to allow the management of a device remotely via Internet and 2) do it in a completely secure way. The E-Lock chip is able to establish a secure connection over the Internet (TCP/IP) using the Transport Layer Security (TLS) encryption protocol. The chip also offers a 7-line GPIO (general purpose input/output), four 16-bit ADC channels, one 12-bit DAC and one I²C bus that allow control and communication with other peripheral devices. Figure 1 shows E-Lock’s functional diagram. The E-Lock chip (a SoC) also incorporates a real time clock (RTC) that takes the data from an Internet time server as reference, using the Simple Network Time Protocol (SNTP).

Evaluation board
The E-Lock chip comes in a 100-pin LQFP package, which is not easy to handle for manual assembly. That’s why we designed the Evaluation (and Application) Board introduced here. The Evaluation Board will allow you to test the E-Lock chip while also serving as a basis for your own secure IoT projects. The board is available from the Elektor Store as number 130280-91. Deeply technical descriptions of the board are available for downloading at [2].

As a get-u-going demo the board will allow you to control up to two relays and monitor the temperature of the room in which it is installed in a remote and secure way. Also on board is an expansion connector to host future extensions or simply open the door to developing your own applications. Figure 2 shows the functional diagram of the evaluation board. We can distinguish the following sections:

E-Lock — The heart of the board. The device manages the communications and the operation of devices connected to it. E-Lock consist of two different communication protocols:
• Raw Ethernet configuration protocol; it’s used to configure the main network and security parameters, such as IP address, Gateway address, DNS server, SNTP server as well as certificate, key and CA. It is done by using E-Lock unique MAC address.
• Secure TCP/IP client-server application protocol. Once E-Lock has been successfully configured, it acts as a secure TCP/IP server following the application protocol explained in detail in datasheet document [2].
If you are designing a dead secure

Figure 3.
Full schematic of the E-Lock Evaluation Board.
IoT device, E-Lock is the solution.

If you are designing a dead secure IoT device, E-Lock is the solution.
The basic commands supported by E-Lock to manage on-board devices are:

• Set sensor configuration;
• Set relay configuration;
• Get sensor configuration;
• Read sensor value;
• Get relay status;
• Set relay status.

The commands to act on devices connected to expansion connector are:

• Set Configuration: Initialize GPIOs, ADC channels, DAC channels and I2C devices with specific device parameters;
• Get Configuration: Used to know current device configuration;
• Read: Capture GPIOs, ADC and DAC channels and I2C devices current values;
• Write: Set GPIOs, DAC channels and I2C devices values.

Additional system commands are:

• Set system configuration;
• Get version;
• New Certificate;
• New Private Key;
• New CA (Certification Authority) Certificate;
• EMail notify;
• Bootloader (download new firmware).

Power Supply — The board requires 5 volts for operation, conveniently supplied by a power adapter as used on smartphones, through micro USB connector CN1 or directly by connecting a 5-V stabilized power supply on the CN8 terminals—paying attention to the polarity indicated on the silkscreen.

Ethernet — The board is connected to a 10/100 Base-T Ethernet network through a standard RJ45 connector, which incorporates the corresponding ‘Activity’ and ‘Link’ LED indicators. Between the connector and the E-Lock chip we find the usual transformer block and the Physical Layer Transceiver (PHY) chip.

PoE — The board is Power over Ethernet (PoE) ready, although the version currently available through Elektor Store does not include the 48 to 5 V DC/DC converter.

Output circuit — The board has two output circuits that control two relays: RE1, which is a dual coil latching type, and RE2, which is a non-latching type. Both are configured as SPDT (single-pole, double-throw) switches and contacts are available on the terminals of CN6 and CN5 connectors respectively, where the central terminal is Common.

On the version made available through the Elektor Store only one of these sections is assembled: RE2 relay and its corresponding connector CN5.

Temperature Sensor — The I2C temperature sensor has been separated from the main board to avoid the heat dissipated by the components installed on the motherboard affecting the sensor measurements. Because the TMP275 is an SMD device, it comes assembled on a small PCB and is connected to the main board on CN7 connector using a 7 inch long (approx. 20 cm) patch cable.

Expansion Connector — The goal we have pursued since the beginning of the design process is for the board to be more than a means of demonstration and eventually serve as a platform for our readers’ IoT projects and/or your own extension projects. Thus, E-Lock pins not used for on-board peripherals have been routed to expansion connector CN2. It puts +3.3 V and +5 V supply voltages at your disposal, as well as an additional I2C bus, four ADCs, one DAC, seven GPIOs and the Reset signal.

The practical implementation of the functional diagram is found in the hefty schematic in Figure 3. Rather than a wall poster showing the Things Embedded Dreams Are Made Of, the schematic is printed here in support of all Elektor readers seriously interested in Internet security AND winning $25K in the competition at www.elektor.com/e-lock.

Installation and configuring

Before applying power to the E-Lock Evaluation Board, download the demo software for PCs, which is available on the project page [2] as archive file 130280-W.zip, and unzip it to a folder on your hard drive.

In the ISLElektor folder, find all the files needed to configure and test your board. The ‘doc’ folder contains ‘network-configuration.pdf’, which describes the E-Lock configuration process, and
‘ISLElektor_130280-applicationnote.pdf’, which describes the demonstration application. It is highly recommended to read them before you start using the board.

You need to configure the board before testing it and to do so the board needs to know some information about your network: router IP address, a free IP address for your board and DNS IP address.

After collecting all this information, connect the power supply and Ethernet cable to the board. Then run the application configuration ISLRaw.exe and you hopefully will see the window shown in Figure 4.

The application is able to configure various devices attached to the same LAN. The first step is to identify any MAC addresses by clicking on Scan MAC; doing so, a message will be broadcast by the application and the chart situated at the bottom of the window will be filled with the information given by the devices that are waiting to be configured.

Once all the information has been received select the device you want to configure in the list and the Remote MAC field will be filled automatically. Finally write the desired IP address and press Set Remote IP in order to configure the IP address of the device. If process was successful, the list will be updated with the new IP.

A new window shows up to select security parameters, that is: certificate, key, CA certificate, SNTP server, DNS address and Gateway address. Once all fields mentioned above are filled correctly, press Send to set up the security parameters on E-Lock. You can create your own certificates following the instructions described in the configuration document but for testing the board you will find sample certificates and key files in the certs folder, select ISLserver-cert.pem for the Cert field, ISLserver-key.pem for Key field and ISLca-cert.pem for the CA field.

Demonstration software

Once the setup process is completed, proceed to test the operation of the E-Lock board running the demo application ISLElektor.exe. Figure 5 shows the main window of this application. Before running the application, the temperature sensor board must be plugged into the motherboard. ISLElektor is an application used to interact with the E-Lock Evaluation Board, exchanging information through a TCP/IP channel in Secure Mode,
If the connection process is successful, a Connected tag will appear in the Connection Status box with a blue background, and all the onboard functionalities will be available (Figure 7). If not, an Error tag will be displayed. If so, no sweat, check the IP address, the Ethernet cable and TCP/IP client Certificate and Private Key and then retry the connection. If you are sure all parameters are correct but the error persists, use the factory settings recovery jumper JP3 (install it, remove it) to initialize E-Lock and repeat the above configuration process.

Click on Disconnect to finish the previous connection or modify the IP address field and press Change IP to boot the device with the newly filled IP address. In this last case, it is mandatory to connect again using the new IP address.

Now you can test the operation of all available elements on the board, change their initial configuration, play with the expansion connector ... detailed information about all the possibilities offered by this demonstration software is found in the ‘ISLElektor_130280-applicationnote.pdf’ document found in the doc folder.

The folder called source contains the source files of this application and we encourage you to make your changes or use them as a basis for your own applications. We have used Borland C++ Builder6.

More info ...

We have just skimmed the surface of E-Lock on these pages. Magazine space is at a premium and there is a lot more to describe in terms of what E-Lock has to offer. I highly recommend downloading all documents available on the project page [2] including the PCB design data, the E-Lock board datasheet and demo and support software. Reading these documents will not just enable you to understand the real power of the first Elektor chip, but also provide essentials to win $25,000 in cash [3].

Web Links
[1] www.soclutions.com

About Intelligent Soc

IntelligentSoC was founded in Madrid, Spain in 2011 as a spinoff of the R&D department of Datatech SDA, an engineering company which is specialized in the development and design of communication and data processing systems with a strong focus on security.

The main goal of the company is to design, develop and manufacture IPs, chips and modules with the latest authentication technologies based on elliptic curve math (ECC), Diffie-Hellman algorithms, and various AES 128/256 encryption techniques. IntelligentSoC’s products are currently installed where security is a must-have, such as avionics or military systems, and are currently expanding this technology to other areas like the Internet of Things.
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The small power supply described here was inspired by the “Lab PSU for Embedded Developers” published earlier in Elektor [1]. The obvious shortcoming of that design is that the activity of the microcontroller is limited to the display. By contrast, in the Platino-based PSU described here, the MCU rules over output voltage, maximum output current, and a lot more. And a powerful controller it is: Elektor’s very own “Platino” [2].

**Design considerations**
Designing an MCU into a benchtop power supply is all about adding a few extra parts in order to reduce the number of potentiometers and switches. The process is fraught with problems but thanks mainly to Platino, some Bascom programming and a component called Digital Pot, we were successful and managed to minimize component count and board space.

The PSU delivers the most common outputs for ‘light’ lab work—meaning 0 V to 15 V DC in 0.1-V increments, with a 0 mA to 1000 mA selectable current limit. The PSU also provides for fixed 3.3 V and 5 V voltages on a USB connector with 0 to 500 mA adjustable current limit. The instrument display offers two modes of operation: Setup Mode and Normal Mode.

**Circuit description**
The Platino Benchtop PSU has a hardware and a software component—both interact strongly to guarantee stability and accuracy of user selections and output values. The heart of the project is Elektor’s Platino MCU board powered by an ATMega328p.

Starting with the hardware, let’s do some sightseeing of the schematic in Figure 1. But before hopping on the tour bus, note that the input voltage for the unit comes from a standard 18-VDC adapter normally used with a laptop PC, or an equivalent adapter.

**Main power input and auxiliary supply generator**
The raw 18 VDC input voltage is connected to circuit on PCB terminal block K1. Diode D1 protects the circuit form reverse polarity. The raw DC is applied to regulators IC3 and IC4. IC3, an LM7805, supplies the main 5-V power for the Platino board and all other circuitry operating at the same voltage. IC4, an LM7805, supplies the main 5-V power for the Platino board and all other circuitry operating at the same voltage. IC4, an LM7805, is responsible for the regulated 12 VDC needed by the fan control circuit.

**Negative auxiliary voltage generator**
The circuit around IC5 and IC6 converts +5 V, via a −5 V intermediate level, down to −1.27 V (−VE), which is needed by the positive voltage regulator section to Make its output go down to 0 V. The LM337L negative voltage regulator has its output voltage adjusted to −1.27 V by preset P2.

**Temperature measurement**
Temperature is measured by an LM335 precision temperature sensor, IC7. The output of the
‘335 is applied to Platino’s PC4 input, enabling the MCU to read and process the sensor voltage and then display the temperature. The measured temperature is used to automatically shut the power supply down when the PSU temperature reaches a predetermined high level. You can set the shutdown level in Setup Mode under “Threshold Temperature”.

**Fan control**
A small fan fitted in the enclosure is used to cool the unit and prevent damage by overheating. The 12-VDC fan is powered by a BS170 MOSFET (T1) via Platino’s PD1 port pin. Connector K8 may be used as a jumper to set the fan operation in Manual Mode by applying a permanent High (no jumper) or Low level (jumper installed) at Platino’s PC6 pin.

The operation mode of the fan can be set to Auto or Manual by entering the instrument’s Setup Mode. In Automatic mode the fan is Platino-controlled and is switched on at 20 °C below the user-defined Threshold Temperature value. Below that level, the fan remains off in Auto mode. If Manual mode is selected the software checks the status of K8 to turn the fan on or off.

**Precision reference generator**
An LM336 IC in position IC11 generates the ‘AREF’ reference voltage for Platino, which does all of its calculations related to voltages based on that value. The LM336 is a precision reference generator in a space saving TO-92 package style and requiring a minimum of external components. Preset P1 adjusts AREF to exactly 5.00 V (use a good voltmeter). This is a onetime setting.

**Positive voltage regulators**
The power supply has two outputs, hence two separate positive voltage regulators are used. For the sake of simplicity identical regulators are used. The LM2576 (IC1, IC2) is an adjustable step-down switching regulator used here as a positive voltage regulator on the two sections of power supply. The LM2576 in position IC1 is configured to output 0 V to 15 V at 1 A (max.),

### Specifications & Features
- **Output 1**: 3.3 V or 5 V / 500 mA max., on USB-A connector
- **Output 2**: 0–15 V / 1 A max., on banana sockets
- Both outputs short-circuit resistant
- Power supply output capacity: 17.5 watts
- DC input: 18 V / 2 A laptop PSU
- Readout: 20 x 4 LCD
- Single-knob control
- High temperature automatic shutdown
- Auto or Manual mode for fan & control
- Internal temperature sensor
- Setup Mode for fan threshold and temperature settings
- Normal Mode for V/A adjustment in daily use
all adjustable. IC2 in the other section provides the 3.3 V (500 mA max.) and 5 V (500 mA max.) selectable output voltages on K7. Both sections are quasi-digitally controlled by Platino. The 0 V to 15 V adjustable output voltage is available on connector K6. The negative auxiliary voltage \(-V_E\) is connected to the LM2576’s GND pin (3) to make the output voltage start at 0 V instead of +1.23 V as the datasheet says. Both IC1 and IC2 take +18 VDC after diode D1 as their input voltage. Their output filter circuits follow the same layout with differences in current rating for the coils (L1, L2) and buffer capacitors (C11, C21).

**Auto-shutdown control**

Automatic shutdown is implemented for the protection of the power supply and the user. Protection is afforded against short circuits, over temperature and over current. Platino’s PB6 pin is used to effectively switch IC1 on and off via MOSFET T2. Since T2 has the \(-V_E\) voltage at its source terminal, zener diode D8 is necessary to avoid any negative voltage on Platino’s PB6 pin.

Likewise PB7 is used to switch IC2 off in case of a short circuit, over temperature event, or over current detected at its output.
### Feedback & error correction
This section is responsible for controlling the output voltages and currents of both regulators. The main parts in this section are an opamp and a MOSFET. This section generates and controls the feedback of IC1 and IC2 using a control signal supplied by Platino.

For IC1, PW0 is the ‘digital potentiometer’ signal to control the feedback voltage. The current measurement signal gets fed to the MCU via pin PC1; the voltage measurement signal through PC0. In the case of IC2, PW1 is the ‘digital pot’ signal; current measurement is by way of PC3, and voltage measurement by way of PC2.

The operation of the feedback & error correction section is as follows. Opamps IC9a and IC10a compare the voltage at their non-inverting terminals to that at the inverting terminals and then adjust their outputs according to the differences. The outputs determine the impedance seen by the regulator’s feedback pins. Consider a voltage between 0 and 5V at the inverting terminal of the opamp; this will cause the opamp output to drop to a level well below the switching threshold of the MOSFET. Consequently the MOSFET’s d-s path represents a high impedance. In order to meet the 1.23 V at feedback terminal, the regulator drives the output High but this output is again fed back to the non-inverting terminal. This will ramp up the output of the op amp resulting in a lower impedance. Consequently the overall circuits strive to maintain equal voltages at the opamp’s inverting and non-inverting terminals.

The current sensing section consists mainly of opamps IC9b and IC10b. The current flowing through the load is converted to voltage by shunt resistors R5 for IC1 and R16 for IC2. The voltage dropped by R5 and R16 is fed to the inverting terminals of the opamps. The voltages cause the opamp outputs to ramp up, resulting in lower MOSFET impedance, resulting in turn in a voltage drop at the non-inverting terminal. The loop action ideally yields equilibrium between the voltages at the non-inverting and inverting terminals. A voltage drop identical to that across the series resistor is developed across 100-Ω resistor R9 for IC1 and R23 for IC2. Hence the current flowing through the 100-Ω resistor is proportional to the load current, which also flows through 2-kΩ resistor R17 for IC1, and R11 for IC2. The current-proportional voltage makes the microcontroller aware of the current demand on the PSU.

### Output section
The output of regulator IC1 is connected to the load via banana type connectors on the front panel (black and red) by way of PCB-mount connector K6. The output voltage of IC2 appears on a standard USB type connector also on the enclosure front panel, through PCB-mount connector K7.

### Software
The software for the project was written in BASCOM AVR for ATMEGA328P microcontroller. The Platino board can be used for further development of the project. The software part is divided into a number of sections discussed below. The BASCOM program is available for downloading from [3].

### Display section
The display section comprises the Platino board and a 20 x 4 LCD. This section of the program initializes the LCD and first outputs the message: “Platino Instrument series 1.0” followed by the name of the project: “Platino Adjustable Bench Power Supply”. After the initialization and greetings, the display shows the Menu screen with its “Setup Mode” and “Normal Mode” options. Select any option by operating the rotary encoder (R/E) and its integrated pushbutton on the Platino board. At the selected option, press the pushbutton to view the options given by Normal or Setup Mode. A long press of the button returns you to the Main Menu.

### Setup Mode
In this mode you configure the settings of voltage, current, fan and temperature threshold by
Component List

**Resistors**
Default tolerance, wattage: 5%, 0.25 W
- R1 = 240Ω
- R2, R15, R20 = 1kΩ
- R3, R7, R12, R14, R19, R24, R25 = 10kΩ
- R4 = 100kΩ
- R5, R16 = 50mΩ shunt precision resistor, 1% 2W
- R6 = 22kΩ
- R8, R18 = 10kΩ 1%
- R9, R23 = 100Ω 1%
- R10, R22 = 30kΩ 1%
- R11, R17, R21 = 2kΩ 1%
- R13 = 4.7kΩ
- P1 = 10kΩ trimpot
- P2 = 50Ω trimpot

**Capacitors**
- C1, C3, C4, C9, C10, C12, C16, C18, C19, C20, C22, C27 = 100nF
- C2 = 100µF 50V, radial
- C5-C8 = 10µF 25V, radial
- C11 = 1000µF 35V, radial
- C17 = 100µF 25V, radial
- C21 = 330µF 35V, radial

**Inductors**
- L1 = 100µH, 1.4A (2062790)
- L2 = 100µH, 2.6A (2215967)

**Semiconductors**
- D1 = 1N5408
- D2 = 1N5822
- D3, D4, D6, D7 = 5.1V zener diode, 0.4W
- D5 = 1N5819
- D8 = 3.9V zener diode, 0.4W
- T1, T2, T4-T6 = BS170
- T3 = IRL540NPBF
- IC1, IC2 = LM2576T-ADJ (Texas Instruments) (9488146)
- IC3 = LM7805
- IC4 = LM7812
- IC5 = MAX660CPA+
- IC6 = LM337LZ
- IC7 = LM335
- IC8 = MCP42010-E/P (Microchip) (1332110)
- IC9, IC10 = LM358N
- IC11 = LM33682-5.0

**Miscellaneous**
- K1 = 2-way PCB terminal block
- K5, K6, K8 = 2-pin pinheader
- K2 = 8-pin pinheader
- K3 = 12-pin pinheader
- K4 = 6-pin (3x2) pinheader
- K7 = 5-pin pinheader
- Miniature fan, 12V, 40x40x15mm
- 2 pcs. banana socket, 1 red, 1 black, panel mounting (1176431) (1176430)
- USB-A Socket, panel mounting (1667928)
- Enclosure, 75x133x110mm, Bopla ref. 26160000 (1217479)
- Switch, on/off, rocker, panel mount, e.g. Schurter ref. 1301.9205 (1162728)
- PCB, Elektor Store # 130406 Platino board, Elektor Store # 110645

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

Figure 2. PCB design for the supply.
selecting relevant options. A long press on the R/E button returns you to the Main Menu.

**Normal Mode**
In this mode the outputs are switched on for powering the load(s). You can use the rotary encoder to adjust the 0 V to 15 V output as required. A long press of the R/E button returns you to the Main Menu. All outputs are available in normal mode only.

**Measurement Section**
The microcontroller obtains information on the output voltage and current feedback from the Feedback & error correction hardware sections. It also measures the voltage and current relative to the reference signal on the AREF pin. Temperature measurement is carried out by the software, and the result appears on the LCD. Measuring signals are scaled to the 0–5 V range by hardware and sent to MCU's ADC.

**Control section**
Depending upon the ADC input value the MCU generates the control signals for digital pot IC8 to control the output voltage and current. It also generates the auto shutdown signals for IC1 and IC2 depending upon current and temperature values and the limit value set in Setup Mode. It generates the Fan control signal according to the configuration in Setup Mode.

Using suitable software the microcontroller reads the output voltage and increments or decrements the digital pot in order to meet the desired voltage level. It also monitors the current and limits the output voltage if the load current exceeds the current limit. If a short circuit is detected (excessive current) the microcontroller shuts down the particular regulator and resets the digital pot to zero-out. Also the microcontroller shuts down the regulator, if it detects high temperature. The upper current limits and temperature limits can be programmed by the user.

A quick overview of microcontroller pins usage jointly by hardware and software is presented in Table 1.

**Construction**
First build the Platino with its LCD, rotary encoder with pushbutton, ATMEGA328P MCU and all other components, then ‘jumper’ it as shown in Table 2. Refer to [2] for the Platino showoff pages.

The add-on board that forms the actual power supply is constructed next, see the PCB layout and Component List in Figure 2. The board is designed to fit exactly to the back of Platino with the help of pinheader connectors. A Bopla enclosure accommodates Platino with its 20 × 4 LCD, rotary encoder/pushbutton, the PSU board, a small 12 VDC fan, the power jack, on/off switch, banana connectors, and USB (power-only!) connector.

Figures 3 and 4 and various other photographs in this article illustrate the method of construct-

![Figure 3. Looking inside the enclosure from the right. The three boards that make up the little supply (LCD, Platino, PSU) are fitted vertically behind the front panel.](image-url)

<table>
<thead>
<tr>
<th>Table 1. Microcontroller Pins Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pin designation</strong></td>
</tr>
<tr>
<td>PB0–PB2</td>
</tr>
<tr>
<td>PB3, PB4, PB5, PD0</td>
</tr>
<tr>
<td>PB7, PB6</td>
</tr>
<tr>
<td>PC0–PC3</td>
</tr>
<tr>
<td>PC4</td>
</tr>
<tr>
<td>PC5</td>
</tr>
<tr>
<td>PC6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Jumper settings on Platino</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP3</td>
</tr>
<tr>
<td>JP4</td>
</tr>
<tr>
<td>JP5</td>
</tr>
<tr>
<td>JP6</td>
</tr>
<tr>
<td>JP10</td>
</tr>
<tr>
<td>JP9</td>
</tr>
<tr>
<td>JP8</td>
</tr>
<tr>
<td>JP11</td>
</tr>
<tr>
<td>JP12</td>
</tr>
</tbody>
</table>
to keep the 3-board assembly securely in place. In the back panel, make round holes for the fan (approx. 37 mm diam.) and the DC input connector (approx. 10 mm diam.). To assist ventilation, drill 12 2-mm holes in a 40-mm x 40 mm cross shape in the back panel, above the DC input socket.

Internal wiring is limited to the fan, the on/off switch, the USB power-out connector, the 18 VDC input and the red and black banana socket.

Testing
Test your power supply rigorously under full-capacity load conditions, observing all relevant safety precautions. Load the 0–15 V output with 1 amp by connecting a 15-ohm 30-watts power resistor (Figure 5). Load the 5 V output with 500 mA using a 10-ohm 10-watt power resistor. Also run a 1-kHz dynamic load test for 15 V (1A); 10 V (1 A) and 5 V (500 mA). Check the short-circuit recovery and auto-shutdown features by shorting outputs to ground.

Check over-current detection and response by setting the limit value, then dropping the output voltage a little and check if the set current is maintained.

Web Links

Figure 4. A close up of the three boards. The assembly is best tested in this state, i.e. prior to building it in the Bopla case.

The boards sit vertically behind the enclosure front panel, in this order: LCD, Platino, PSU. The front panel requires three rectangular cut-outs: LCD, USB power-out, on/off switch. And three round holes: rotary encoder spindle, banana sockets (2x). Blocking elements like plastic cable feet should be glued to the bottom of the case.

Figure 5. Maximum-output i.e. 15 V @ 1 A test using a 15-ohm 30-watts power resistor. Don’t leave it lying on the desk for too long while the test runs (and don’t pick it up either).
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To purchase: shopwiznet.com or shop.wiznet.eu

"powered by"
I consider the Arduino to be very similar to Lego: you can make all manner of things with it. This is useful and instructive to do, and it results in something useful. You can then use it for a while, and whenever you feel like it, you can take it apart again and use it to make something else. A while ago, I made an infrared remote control for my Nikon D80 using an Arduino. Not because such a remote control is that expensive, but because making one yourself is much more fun and using an Arduino it offers many more possibilities. Moreover, it turned out to be child’s play: An IR-LED, a resistor and a piece of software that I found on the internet, nothing else is required. A considerable advantage of the Arduino, compared to other embedded platforms, is that there is a tremendous wealth of firmware to be found, just free from the Internet.

After this, I wanted to trigger the remote control using a motion detector. There are many nice solutions to be found for this on the DIY market and on the internet, but these usually require an AC power adapter. I didn’t want that, it had to work without any wires. By chance, I spotted at the supermarket a night light powered from batteries, with a motion sensor, for a couple of dollars (Figure 1). That won’t break the bank. It just went with the weekly groceries.
Night light hacking

The first thing you do, naturally, is look what is inside it. This turned out to be much better than expected. No difficult SMD parts or—worse—COBs, but instead an IC with legs, normal resistors and capacitors, a PIR-sensor and a photo diode.

The part number printed on the IC was TL0001. A quick Internet search and sure enough there appears to exist a datasheet [1]. In Chinese, but that is not a problem: just copy the text and paste into Google Translate. This results in an horrendous translation but is still good enough so that you can get the gist of it. There was even an Application Note in there, that although it was not exactly the same is my night light, it was nevertheless very close.

The night light did three things that I didn’t want: it only operated in the dark; it gave a pulse that was several minutes long, while I needed a much shorter pulse and a turned on three bright LEDs when you walked past.

The latter was easily solved. The three LEDs shared one series resistor. I removed two and replaced the series resistor with one that has a higher value (2.2 kΩ, A in Figure 2), so that the remaining LED would still switch on with each trigger, but not as bright.

Then the inhibit-function during daylight. In the example schematic (Figure 3), R3 is an LDR. This I couldn’t find anywhere, but I did find a photo diode, also a device that exhibits a lower resistance as the amount of light on it increases. So I replaced that with a reasonably large resistor (220 kΩ, B in Figure 2). That worked too: Even in bright light the lamp turned on when motion was detected.
somewhat resulted in a modest improvement. The gain stage comprises two steps. 1IN+, 1IN- and 1OUT in the IC are an opamp (see datasheet), the gain of which is about equal to R7/R8. Using 1 MΩ/12 kΩ this became 84 (was 40 with the original 2 MΩ/47 kΩ). The makes the PIR-sensor not more sensitive, of course, but it does amplify small signal more. A consequence was that larger signals would hit the power supply rails. The second stage is also an opamp with a gain equal to R6/R5, originally 100, but with 15 kΩ for R6 this became 67. This solved the clipping problem.

The result is that the sensor is able to detect movement indoors over a somewhat larger distance than before, but that doesn’t mean much by itself. PIR-sensors are especially sensitive at seeing heat differentials. A cat walking past on a frosty day is detected from many meters further away compared to the same cat on a warm summer’s day.

The output of the IC is on pin 2, which is soldered to a wide copper track. It is therefore very easy to attach a wire to it. With another two wires for +5 V (after the switch) and ground the night light had become a PIR-board. Not bad for an investment of € 2.65 and some time figuring it all out. I fully expect that in your part of the world the type of motion detector or night light that you can buy will be entirely different. But the above story has at least shown a method you can use to figure out how it operates and adapt some of the features of the circuit to your needs.

Work horse Arduino

It turned out that connecting the PIR-board to an analog input of the Arduino was more convenient than using a digital input. One digital output of the Arduino is used for the IR-LED with a series resistor, which is used to operate the camera. The three AA-batteries for the night light also serve as the power supply for the Arduino. The circuit is otherwise simplicity itself (see Figure 4).

The timing for the IR-pattern for the camera trigger is borrowed from [3] and [4]. Movement a few meters from the PIR-sensor generates a trigger for the camera, which, in turn, could also be a few meters away from the IR LED. This also works through glass, so you can keep your camera inside and the sensor/remote control outside. I have mounted the IR-LED on a piece of thick electrical wire, so that the LED can be bent into a different direction compared to the direction of the PIR sensor.
My camera, a Nikon D80, turned out to have some unexpected characteristics. When you switch this camera into IR Remote mode it waits a while for an IR-command. If that does not happen it will switch out of IR-mode by itself. Any command after that interval is ignored. For my application (nature photography) this was undesirable. The waiting time can be adjusted in the camera up to a maximum of 15 minutes.

That is why the firmware will give the IR-command ‘stay awake’ if there has been no motion detected for 14 minutes. In this way you can leave the camera for days, waiting for that one rare animal to go by.

This interval can also be made shorter. Without the PIR-board you can then also use it to make time-lapse movies of, for example, flowers that grow and open.

To allow this interval to be changed in the code in a more obvious way, requires a little bit of computation. We are using Timer1, this is a 16-bit timer, so counts from 0 to 65536. If we let the timer start from a timerPreload of 3036 it will count 65536 - 3036 = 62500 clocks and give an interrupt. The Duemillenove runs at 16 MHz; with a prescaler at 1024 this becomes 15625 Hz, so we will have a Timer1-interrupt exactly every 62500/15625 = 4 seconds (ignoring any inaccuracies of the clock). In the code this is implemented as follows:

```c
#define four_sec 1
#define twelve_sec 3 * four_sec
#define minute 5 * twelve_sec
#define quarter 14 * minute
```

This is a quarter of an hour that lasts only 14 minutes, because at 15 my camera would just leave IR-mode. With `timeCounter` we keep track of the time. In the interrupt service routine we give the initial value `timerPreload (=3036)` and increment `timeCounter`. The counter value times four is the time elapsed in seconds.

```c
ISR(TIMER1_OVF_vect) {
    TCNT1 = timerPreload;
    timeCounter +=1;
}
```

In the main loop we take a picture when there is a trigger from the PIR-sensor or when a quarter of an hour has gone by.

```c
if (val > 200 || timeCounter == quarter)
{
    timeCounter = 0;
    takePicture();
    delay(500);
}
```

The source code for the firmware for this project is a free download from the Elektor website [5]. The binary file is only 4 KB, so with an Arduino with 32 KB flash memory there is plenty of spare space for to add your own features. A trigger based on sound would be another possibility.

**Internet Links**

[2] [www.e-ele.net/DataSheet/BISS0001.pdf](http://www.e-ele.net/DataSheet/BISS0001.pdf)
[3] [www.bigmike.it/ircontrol](http://www.bigmike.it/ircontrol)
[4] [http://luckylarry.co.uk/arduino-projects/arduino-ir-remote](http://luckylarry.co.uk/arduino-projects/arduino-ir-remote)
[5] [www.elektor.com/130265](http://www.elektor.com/130265)
LED’s Replace That Fluorescent Tube

The devil is in the detail

By Dr. Thomas Scherer (Germany)

What’s an engineer to do when out on the weekly shop they pass by the Bargain Bin filled with a stash of LED tubes which replace conventional fluorescent tubes? Take a closer look of course. Picking up the long thin box I scrutinize the labeling to check the tech specs. There never seems to be enough information—I finally submit to my hunter-gather instincts and place one in the shopping cart alongside my other finds. They really are a good price. A few minutes later I’m back at the Bargain Bin putting another one in the cart. Who was it that said a bargain is something you don’t need at a price you can’t resist?

Attempt #1

Back at home I plan to fit one LED tube to our bathroom cabinet which I know uses an 18-watt fluorescent tube. According to the label the 10-watt LED replacement tube uses less energy and will produce more light. When all was said and done and the tube was finally up and running I measured (at the same distance) a 30% increase in light output compared to the old fluorescent tube.

I have changed this tube and others like it before. It shouldn’t be difficult—take off the diffuser, rotate the tube through 90°, pull it out, insert the LED replacement tube rotate it back through 90°, refit diffuser, job done... Not so fast!

It can be that easy, but not necessarily—it depends on the type of light fitting you have. Older fittings use a coil or ballast together with a pre-heat starter device, if yours is like this then you should have no problems. Figure 1 shows the wiring in this type of fitting. The tube has a heating filament at each end—when AC power is applied the voltage across the starter unit produces a glow discharge which heats up a normally open set of bimetal contacts. The contacts close, supplying current to the heating filaments at each end of the tube and through the inductive ballast. With the starter contacts closed, glow discharge in the starter unit stops and the contacts cool down. After a second or so they open, producing a voltage spike between the filaments, initiating the main discharge in the fluorescent tube. With this type of fitting it’s normal to hear it click and see the light flash two or three times when you switch on before the tube strikes.

Figure 2 shows the internal wiring of the LED replacement tube; on the left is the LED driver module instead of a heating filament. On the right is just a short circuit instead of the second heating filament. Just fitting this in place of a standard fluorescent tube would most likely cause the lamp to flash until the induced voltage spikes eventually kill the LED driver primary side. It would probably not last too long and any case it wouldn’t make a good restful light to shave by. To get round this, the LED tube comes with its own starter unit (Figure 3) consisting of nothing more than a wire link. Using this instead of the standard starter unit solves the problem: The AC input now connects to the LED driver input irre-
Fluorescent Tube Replacement

With the help of a screwdriver and a couple of terminal blocks the rewiring was complete, the lamp shone forth and the engineer was happy (and clean shaven).

**A cautionary note**

It is possible that sometime in the future someone may want to replace the tube. The modified fitting is now no longer suitable for a fluorescent tube. It’s important to make this clear otherwise it will be a safety hazard. Without a ballast or starter in circuit the filaments will glow continuously bright orange (probably for not very long). Before you fit the LED tube, use a permanent marker and write a cautionary note on the fitting: ‘Only Suitable for LED Tubes!’ Choose somewhere that will be hidden by the tube but can be seen when the tube is taken out.

(130403)
You might ask why you should use a microcontroller when it’s possible to do so much with ordinary analog electronics. At first glance, this looks like a good question. New microcontrollers with more features, higher performance, higher clock rates and even more memory are appearing all the time, but the first demo program for every one of them invariably makes a LED blink. This leads to the justified criticism that you could get the same result by simply taking an NE555 timer IC and adding a couple of resistors and a capacitor. That’s absolutely right, and the comparison is better than you might think because a lot of the elements of an NE555 timer IC can also be found in a microcontroller.

In the Editorial Office we receive a fair number of requests from electronics enthusiasts who are looking for an easy way to get started with microcontrollers. It’s been a good while since we last ran a large series of articles on this subject in Elektor, and the associated hardware is vintage, so it’s high time to run a new series. This series is aimed at our readers who already have some experience with analog electronics and now want to start using microcontrollers in their own circuits.

For comparison: the NE555 timer IC
First of all there’s the output. When you look at the internal block diagram of the NE555 on the data sheet (Figure 1), you can see that it has a push-pull output stage that can actively switch high and low. Microcontrollers have exactly the same kind of outputs. They are called ports, where the name “port” can stand for a set of outputs or for pins that can be configured either as inputs or as outputs. The circuitry connected to the output for a LED blinker application is also the same: a LED with a series resistor, connected either to ground (GND) or to the supply voltage (Vcc). The NE555 also has a second output driven by an open-collector transistor, which can only

Microcontroller BootCamp (1) Arduino and Bascom

By Burkhard Kainka
(Germany)
switch something to ground. Many microcontrollers can also emulate this function. Actually the only difference is that microcontrollers usually have several outputs but the NE555 has only one, since the push-pull output and the open-collector output are not independent.

Next we have the inputs of the NE555, which consist two inputs to a comparator that controls an internal flip-flop. A typical application for this is an astable multivibrator, which hobbyists often call a blinker circuit. You can put all this together in almost no time. You just plug the numbers into a couple of formulas to determine the right component values, and then the NE555 does exactly what you want. Determining the component values for an NE555 circuit and programming a microcontroller are actually comparable tasks. There’s another thing that’s very similar: both devices (NE555 and microcontroller) have a Reset input that you can use to set everything back to the starting point. And with both devices the Reset input is usually high in the quiescent state and must be actively pulled to ground.

Figure 2 shows a simple square-wave generator in the form typically used as an LED blinker. The NE555 data sheet also shows several other basic circuits, including a monostable and a pulse-width modulator—all of which are typical tasks for microcontrollers. If you further consider the countless NE555 applications you can find somewhere on the Internet, you certainly have to agree that in many cases all you need is a 555 timer IC and a microcontroller is overkill. For everything from light curtains to servo controls or processing analog sensor signals, there are many things that can be done with this IC and similar devices. And you can be sure that there are still lots of potential applications that haven’t been worked out yet.

Reducing development time
The similarities between the NE555 and a microcontroller are summarized in Table 1. You could formulate the result of a fair comparison as follows: The microcontroller has a bit more of everything and is therefore generally the better choice for complex tasks. For example, a single microcontroller could probably handle a task that would take ten NE555s. Above a certain level of complexity, the microcontroller solution is also smaller and cheaper than the analog solution. On the other hand, an analog electronics solution is a better and more economical choice for quite a few simple tasks.

Anyone with a bit of experience in microcontroller development can also mention another advantage of microcontrollers: once the circuit is complete, you don’t need to touch the soldering iron again. From that point on, all you do is write and test code. Changes to device functions can be implemented and tested very quickly. Microcontrollers are general-purpose and versatile computation workhorses. The learning curve is worth the effort, since you ultimately save time. Your first exposure to a microcontroller data sheet may put you off, since it can easily amount to 300 pages or more. Fortunately, there are
you don’t entirely understand how it works. The main thing is to have a couple of positive experiences at the beginning, and after that it just goes automatically. That’s doubtless the reason why the first demo task for every microcontroller is a LED blinker. Here as well we remain true to this tradition, if only to maintain the comparison with the NE555.

Arduino and Bascom
Microcontrollers actually come in all sorts and sizes. At the start of a series such as this we are faced with the choice of which system to use, and there are many different options. We spent a long time talking about which microcontroller, which circuit board (existing or new), and which programming language we could specifically recommend for beginners. Our discussions led to the following proposal: hardware: Arduino Uno; software: Bascom.

Arduino has become the most popular system in the hobby environment. The programs are developed on a PC using a simple programming language, and they can be downloaded directly to the microcontroller over a USB connection. A large variety of boards and extension boards (Arduino shields) are also available at amazingly low prices. The entire system is based on the open-source concept, so the software and the hardware are fully documented. The low-cost Arduino Uno board [1] is a good choice for our course because it is equipped with a widely used microcontroller. The ATmega328 is an AVR microcontroller made by Atmel. Programming this device is quick and quite easy. The microcontroller has enough memory to allow relatively large programs to be executed later on (see Table 2).

There is a dedicated development environment available for the Arduino. A development environment in this context, also called an integrated development environment (IDE), is a PC program that is used to develop programs for a microcontroller. In the development environment, the microcontroller programs are typed in using an editor and then converted into bytes by the compiler, after which they are downloaded to the microcontroller.

To ensure that the compiler understands what the microcontroller is supposed to do, you must adhere to the syntax rules of a particular programming language when you write the pro-

---

**Table 1. Comparison of NE555 and microcontroller.**

<table>
<thead>
<tr>
<th>NE555 chip</th>
<th>Atmega microcontroller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching output</td>
<td>Port outputs</td>
</tr>
<tr>
<td>Inputs</td>
<td>Port inputs</td>
</tr>
<tr>
<td>Timing control by RC networks</td>
<td>Internal timer driven by crystal-controlled clock</td>
</tr>
<tr>
<td>Reset input</td>
<td>Reset input</td>
</tr>
<tr>
<td>Comparator inputs</td>
<td>Comparator; analog inputs</td>
</tr>
<tr>
<td>PWM function</td>
<td>PWM outputs</td>
</tr>
<tr>
<td>Analog signal processing</td>
<td>Analog to digital converter</td>
</tr>
<tr>
<td>Flip-flop</td>
<td>Memory cells</td>
</tr>
</tbody>
</table>

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**Table 2. Arduino Uno at a glance.**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>ATmega328</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>5 V</td>
</tr>
<tr>
<td>USB port</td>
<td>5 V supply and device programming</td>
</tr>
<tr>
<td>External power supply</td>
<td>7–12 V</td>
</tr>
<tr>
<td>Digital I/O pins</td>
<td>14 (of which 6 can be used for PWM output)</td>
</tr>
<tr>
<td>PWM channels</td>
<td>6</td>
</tr>
<tr>
<td>Analog inputs</td>
<td>6</td>
</tr>
<tr>
<td>Current per I/O pin</td>
<td>40 mA (max.)</td>
</tr>
<tr>
<td>3.3-V output</td>
<td>50 mA (max.)</td>
</tr>
<tr>
<td>Flash memory</td>
<td>32 KB (with 0.5 KB occupied by the boot loader)</td>
</tr>
<tr>
<td>SRAM</td>
<td>2 KB (ATmega328)</td>
</tr>
<tr>
<td>EEPROM</td>
<td>1 KB (ATmega328)</td>
</tr>
<tr>
<td>Clock speed</td>
<td>16 MHz</td>
</tr>
<tr>
<td>Price (for Elektor Members)</td>
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program. The Arduino IDE uses a simple version of the C programming language, which is the language used by most professional programmers. It also has several special commands that make program development easier. Many users have become familiar with this programming language and have no trouble working with it. Nevertheless, for this course we chose the Basic programming language. There are many reasons for this choice. One is the Bascom Basic compiler for AVR microcontrollers, which is widely used and popular. The learning curve is especially easy, in part because Bascom includes many special commands for sending characters from a microcontroller to a PC, for showing letters and numbers on a display, and much more. However, perhaps the most important reason for using Bascom is that it makes you fit for all AVR controllers. The selected Arduino board (Figure 3) is used here as a learning platform, but in the end you can use any desired AVR microcontroller on other commercially available boards or on your own boards. You also don’t have to limit yourself to ATmega devices. For example, you may be able to manage with the compact ATtiny13, which has only eight pins.

A special feature of the Arduino board is the USB port. In addition to downloading programs to the microcontroller as described below, you can use it to send characters back and forth between the PC and the ATmega328. Among other things, you can use this to control the microcontroller remotely from a PC program or to send measurement values captured from sensors by the microcontroller to the PC and display them on the PC. Another thing is that the board can be powered over USB if you so wish. All you need is a USB cable, and you’re ready to go.

Your first program
One option for putting together a blinker circuit with an ATmega328 is shown in Figure 4. To make it easier to see what matters here, the circuit diagram shows the microcontroller without all the peripheral circuitry of the Arduino board. The LED is already present on the Arduino board, so you don’t have to put anything together. Similar simplified circuit diagrams are also used for the other example applications described later on. The idea behind this is that you can also try out all of these examples using a bare microcontroller, for example on a breadboard or on a piece of prototyping board. This means that if you wish, you can follow the entire course without the Arduino board. However, it’s more convenient and easier for beginners to use the Arduino Uno board.

Listing 1 shows the Bascom program for the LED blinker. It starts off with two directives for the compiler, which define what is called the envi-

```
Listing 1. LED blinker
'-----------------------------------
'Uno_LED1.BAS
'-----------------------------------
$regfile = "m328pdef.dat" 'ATmega328p
$crystal = 16000000       '16 MHz
'-----------------------------------
Config Portb = Output
Do
  Portb.5 = 1     'LED on
  Waitms 500     '500 ms
  Portb.5 = 0     'LED off
  Waitms 500     '500 ms
Loop
```

Figure 4. Blinker circuit with a microcontroller.
The individual line to the LED is switched to the “high” voltage level (close to the supply voltage of the microcontroller) by the instruction \texttt{Portb.5 = 1}. This causes a current to flow through the LED. The port pin is switched back to the “low” voltage level (close to the ground level) by the instruction \texttt{Portb.5 = 0}. There is also a wait instruction to delay program execution. \texttt{Waitms 500} is self-explanatory; it causes a time delay of 500 ms. All of this is built into a loop structure. Everything between “Do” and “Loop” will be repeated indefinitely. The only way to stop the program is to switch off the supply voltage or press the Reset button.

Software: the compiler

So far, so good. But how is the program converted into an executable form, and how do you get it into the microcontroller? The Bascom Basic compiler was developed by Mark Alberts for the 8051 family and for AVR microcontrollers. First you have to get a copy of this PC software. It is available from the website of MSC Electronics [2]. You can opt for the paid full version or the free demo version. The demo version is fully adequate for trying out the software and for getting starting with programming. It is limited to programs that occupy up to 4 KB (4,096 bytes) after compilation. By comparison, the Arduino has room for up to 32 KB. However, 4 KB is not peanuts; it takes a fair amount of programming effort to fill it up. Most of the examples in this series will be much smaller.

Installing Bascom is very easy. After you launch the program, the first thing you see is an empty Editor window where you can type in your own program. Of course, you can also import an existing program into the Editor (see Figure 5). These program files (with the suffix .bas) are plain text files that can also be viewed with Windows Notepad or another editor program. This is called “source code” because the compiler uses the contents of these text files as the source for compilation. The compiled program is called “hex code” because the bytes are often shown in hexadecimal notation, always with two hex characters in the range 0–9 and A–F per byte. Numbers in the form of bits and bytes and the various notations used...
for them will be a frequent topic in this series on microcontroller programming.

You can type in the program in Listing 1 yourself or download it from the Elektor page. The file UNO_LED1.bas is located in the zip folder [3]. Compiling the program is very easy: simply click Program/Compile, click the corresponding icon on the toolbar (a black IC), or press the F7 key. If there is any sort of error in the source text, an error message will be displayed. If there are no problems, a pop-up window shows what percentage of the memory is occupied. In this case it is less than 1%, which is rounded down to 0%. What matters is the resulting hex file UNO_LED1.hex or the binary file UNO_LED1.bin, which are two different file formats with the same content. They contain the executable code for the microcontroller. Now you have to load this code into the microcontroller’s flash memory. There are many ways to do this, and for now we only describe the simplest way. Other options will be described in subsequent instalments.

The simplest way: use the boot loader
This program must be located in the microcontroller’s flash ROM in order to run on the microcontroller. Flash ROM is a special type of memory, similar to EEPROM, in which electrical charges ensure that the memory contents are retained reliably for many decades. Flash ROM can be rewritten repeatedly (“flash” refers to very fast writing), so programs stored in flash memory can always be altered at a later date. Special programming devices are available for programming flash memory. They are connected to specific pins of the microcontroller, and the program bytes are received from the development environment on the PC via the USB link.

However, this can also be done without a programming device. When the Arduino board has a USB connection to the PC as mentioned above, the program bytes can be sent to the microcontroller over the USB link as long as there is a small program running in the microcontroller that receives the data and writes it to the microcontroller’s flash memory. This small program is called a boot loader, which is related to the expression “booting up” for starting up a computer. This term originates from the word “bootstrap” in the saying “pull yourself up by your bootstraps”. Of course, pulling yourself out of the mud by tugging on your bootstraps doesn’t work in practice, and likewise a microcontroller with nothing in its program memory cannot program itself. However, this is possible if a boot loader is already present in memory, and the Arduino comes with a built-in boot loader.

The development environment on the PC also has to be able to download program code using the Arduino boot loader. Fortunately, Bascom developer Mark Alberts already guessed that someone would want to program an Arduino board in Bascom at some point in time, so this capability is already incorporated. After you configure the right settings, everything is quite easy. Here we describe how this works with the demo version, since there is a small difference with the full version.

First you have to install the original Arduino software available from [4], which includes the USB driver for the Arduino Uno board. Then you connect the Arduino Uno over a USB cable. The driver is loaded automatically, after which the Arduino Uno should be visible in the Windows Device Manager window. There you can see which COM port number (e.g. COM2 or COM3) has been assigned to the Arduino Uno. If you wish you can change the COM port number in Device Manager, but this is usually not necessary. However, you should note or write down the COM number. If you wish, you can also open the Arduino IDE and try out a couple of sample programs. However, here we want continue straightaway with Bascom.

In Bascom you can choose from a large variety of programming devices and boot loaders under the menu item Options/Programmer. The right setting is “ARDUINO” (not “Arduino STK500/2”), as shown in Figure 6. It’s also important to con-
Now you’re done, and it’s time for action. As previously mentioned, press F7 to compile the source code. Then press F4 to start the programmer. Alternatively you can click the small green PCB symbol “Program Chip”; the result is the same. In any case, a new Programmer window opens. There the compiled program (UNO_LED1.bin) is already nicely loaded and displayed in the form of hexadecimal numbers (Figure 7).

**Good job: it works!**

After this you can sit back and relax; the rest is automatic. However, you can also do everything yourself. If you opt for this, you must be very careful because there is a function here that can completely erase the microcontroller memory, which means that the Arduino boot loader is also gone. Stay well clear of anything with the word “erase” in it. The only right option is “Chip/Write Buffer into Chip”.

Now you will see a long chain of messages in the programmer window, with the lovely word “Started” at the end. During the programming process you can see from the activity of the Tx and Rx LEDs on the Uno board that a lot of data traffic is going on. At the end the window closes again.

The downloaded program starts running immediately after the end of programming, and the yellow LED blinks. It may be a tiny program, but it’s a big step for you as the programmer. If you’re not quite sure about all this, try making some small changes to the program. For example, you can change the blinking rate. For really fast blinking, change \texttt{Waitms 500} to \texttt{Waitms 100}, or for very slow blinking change it to \texttt{Waitms 2000}.

After editing the code, recompile it and reprogram the microcontroller, and then check the result. If the LED does exactly what you programmed it to do, there’s no room for doubt: it really works! In the next instalment we turn our attention to inputs.

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Current Transformer Calculations
Understanding in-circuit current measurement

By Martin Ossmann (Germany)

To calculate current we normally use a shunt to turn it into a voltage and measure the latter instead. But if we wish to measure the current in isolation, then a current transformer is the thing to use. How you actually do this is what we shall now describe. This method has the disadvantage that direct currents (DC) cannot be measured. Nevertheless there are numerous applications, for example in switch-mode power supplies, where the curve shape is the item of interest and we can dispense with the DC component.

Circular cores are often employed in current transformers. The current being measured is taken through a ring core (Figure 1). A secondary winding is added to the ring core and ‘short-circuited’ using a shunt resistor. The voltage across this shunt is measured with the oscilloscope. Figure 2 illustrates the result of this kind of measurement.

Our pulse voltage source covered in the January/February issue [1] provides the 10 V impulses used here (blue trace). Using a 20 Ω resistor produces 500 mA current impulses, arising from which we get shunt measurement impulses of 50 mV (red trace). The current transformer produces pulses of 5 mV. The frequency is 250 kHz. In fact the result looks very promising, with the current transformer doing a good job of reproducing the shape of the square-wave signal pulses. A problem arises if we drop the frequency to 50 Hz (Figure 3); the current transformer no longer reproduces the square-wave signal correctly (green trace).

The reason for this will be discussed in a moment. Using circuit modeling we can establish how to dimension a current transformer of the kind required.

Equivalent circuit for a transformer
Constructing a current probe with a ring core calls for a good concept model of the current transformer that will result from it. That’s what we will now discuss. A transformer consists of a primary winding (Index 1) and a secondary winding (Index 2). The number of turns in each coil is \( n_1 \) and \( n_2 \). We can measure the so-called no-load inductances \( L_{1o} \) and \( L_{2o} \) (Figure 4). If the primary and secondary windings are fitted to the core in the same way, we can also calculate these with the help of the value \( A_L \). That is to say:

\[
L_{1o} = n_1^2 \times A_L \quad \text{and} \quad L_{2o} = n_2^2 \times A_L
\]

The ratio of the number of turns is then \( N = n_2 / n_1 \). For instance, with a core made of Vitroperm with \( A_L = 80 \mu H / \text{turns}^2 \) the following arises:

\[
n_1 = 1 \quad L_{1o} = 80 \mu H \quad n_2 = 25 \quad L_{2o} = 50 \text{ mH}
\]

\[
N = n_2 / n_1 = 25
\]

Another characteristic of interest with transform-
ers is the coupling factor $k$. We can determine $k$ by measuring the short-circuit inductance. If we short out the secondary, in our example we find $L_{1k} = 0.2 \, \mu H$. On the other hand, if we short out the primary we measure $L_{2k}$. However, this value is not independent of the other three and is in fact:

$$L_{2k} \times L_{1o} - L_{1k} \times L_{2o} = 0$$

This relationship enables us to calculate, for example, $L_{2k}$. In our example this turns out to be:

$$L_{2k} = \frac{L_{1k} \times L_{2o}}{L_{1o}} = 125 \, \mu H$$

The coupling factor arising from this is:

$$k = \sqrt{1 - \frac{L_{1k}}{L_{1o}}} = 0.9987492178$$

In this case it turns out to be very close to unity (1), meaning that a current transformer using a ring core is virtually ideal.

The three characteristics $L_{1o}$, $L_{2o}$ and $L_{1k}$ complete the description of the transformer. To define the relationship of transformer we use an equivalent circuit. The generic form of this is shown on the left-hand side of Figure 5.

It consists of an ideal transfer device (trans -former) with a transfer ratio of 1:$M$. We then have a main (or magnetization) inductance $L_m$, the primary stray inductance $L_{1s}$ and the secondary stray inductance $L_{2s}$. Since the equivalent circuit contains four characteristics, we cannot specify it unambiguously but can select certain characteristics freely. Consequently the elements do not have direct physical counterparts.

From now on we will use the equivalent circuit shown on the right-hand side of Figure 5. This has the primary stray inductance $L_s$ arising directly from the short circuit measurement $L_s = L_{1k}$.

The main inductance $L_m$ results from the no-load measurement / turns formula:

$$L_m = L_{2o} = n_2^2 \times A_L.$$  

The transfer ratio $M$ is worked out as:

$$M = N / k = 25.0313... \approx N.$$  

As the coupling factor is virtually 1, $M$ is almost
Dimensioning

With these insights we can next assess how to dimension a current transformer. If we make \( R \) larger, the voltage signal increases, but so does the lower cut-off frequency, meaning we can no longer measure low frequencies (simultaneously the voltage drop on the primary side increases). The choice of \( R \) is therefore a compromise. Since oscilloscopes often display voltages in the mV range poorly, we should make \( R \) sufficiently large that moderate currents produce a voltage of several tens of mV.

Now we come to the number of turns. Raising \( N \) reduces the transfer impedance and with this, the voltage produced. At the same time, however, \( L_m \) gets larger and that reduces the lower cut-off frequency. Here too we must accept a compromise. Additionally we note that a higher value of \( A_L \) helps, because it lowers the boundary frequency, without affecting the transfer impedance.

Ferrite ring core

By way of example we will calculate the parameters (using a ferrite ring core) with a value for \( A_L \) of around \( 3 \mu H / \) turns\(^2\). If \( R = 0.5 \Omega \) and \( N = 25 \) we get:

\[
R_{TR} = \frac{R}{N} = \frac{0.5 \Omega}{25} = 0.01 \Omega
\]

\[
f_s = \frac{R}{2 \cdot \pi \cdot A_L \cdot N^2} = \frac{0.5 \Omega}{2 \cdot \pi \cdot 3 \mu H \cdot (25)^2} = 42 Hz
\]

The factor of 2 in the denominator for the transfer impedance arises from the two 50 \( \Omega \) resistors \( R_1 \) and \( R_2 \). These match the signal to a 50-\( \Omega \) cable, creating a voltage divider that reduces the signal by half (Figure 7). At a current of 1 A we obtain 10 mV on the oscilloscope, which is not a lot. The lower cut-off frequency is around 50 Hz, so with a ring core of this kind 50 Hz signals can be measured only with significant error.

Vitroperm, a magic material

A German company called Vacuumschmelze GmbH manufactures a material called Vitroperm,
which possesses very high permeability (at low frequencies). Below 1 kHz their ring core (type T60006 L2025-W380) has the $L_I$ value of around 80 $\mu$H/turns$^2$. This reduces, with other parameters, the boundary frequency to around 2 Hz. 

With this kind of core we can now construct a current probe that can be deployed without problem below 50 Hz (Figure 8).

A few words still need to be said on the ‘internal’ resistance of the current probe. Shunt $R$ on the secondary is transformed on the primary side by a factor of $1/N^2$. So if we use $R = 0.5 \, \Omega$ and $N = 25$, the effective resistance on the primary side amounts to precisely 0.0008 $\Omega$, which can be ignored in normal situations. Admittedly there is still a stray inductance $L_1 = 0.2 \, \mu$H in series with this, representing an impedance of 1.2 $\Omega$ at 1 MHz. The viability of the current transformer for higher frequencies is restricted by parasitic capacity and so on, but our simple example will make measurements into the MHz region without any problem.

Web Links

Figure 8. Vitroperm core.
There are numerous ways to build direct-current (DC) sources, mainly depending on the required characteristics: current strength, fixed or adjustable, single or dual polarity, floating or grounded load, precision, anything else?

The lowliest of schematics is no more than a voltage source and a resistor. But as soon as you want some precision regardless of load current, you have to resort to a voltage-to-current converter using one or more operational amplifiers. The reference paper from Jerald Graeme [1] is recommended reading on the subject.

In principle
For our needs—which includes sourcing very low current reliably—the topology should take into account measuring the voltage across the load without stealing current from it. A theoretical configuration as shown in Figure 1 is based on two operational amplifiers. The first one (U1) generates the current and the second one (U2) isolates the measuring circuit from the load. Both amplifiers are unity-gain (×1) connected, hence do not require any precision resistors.

The principle of operation: a secondary current source \(I_1\) feeds reference diode D1 connected to amplifier U1’s input with the diode return con-
nected to amplifier U2’s output, whose input is connected to the load. A resistor \( R_s \) is connected between amplifier U1’s output and the load. Disregarding errors in the amplifier, the output voltage on each of them is the image of their respective input voltage. So the voltage across \( R_s \) becomes equal to the reference voltage \( V_{\text{ref}} \) from D1. This constant voltage developed across \( R_s \) induces a constant current

\[
I = \frac{V_{\text{ref}}}{R_s}
\]

sourced by amplifier U1 and flowing exclusively through load \( Z_{\text{load}} \), provided the bias current with amplifier U2 is insignificant. Manual switching of different values for \( R_s \) affords outputting any current across a very large range.

The reference voltage selection is all but trivial. Appearing like a wasted voltage, you could attempt to make it as small as possible, but this is defeated by multiple error sources. First of all, the amplifiers “suffer from” initial offset voltage and common mode rejection ratio (CMRR). Actually, the voltage developed across \( R_s \) resistor is not exactly the same as that present at the reference. More precisely, this voltage could even deviate up to the following value:

\[
V_{(R_s)} = V_{\text{ref}} + V_{\text{os}(U1)} + V_{\text{os}(U2)} + \frac{V_{\text{ex}}}{\text{CMRR}(U1)} + \frac{V_{\text{ex}}}{\text{CMRR}(U2)}
\]

where

- \( V_{\text{os}} \) = initial offset voltage;
- \( V_{\text{ex}} \) = common-mode voltage;
- CMRR = common-mode rejection ratio.

For example, if both amplifiers are specified for an offset voltage of 2 mV and a common mode rejection ratio of 78 dB; and if voltage extension is 20 V, we could obtain in the worst case: \( V_{(R_s)} = V_{\text{ref}} + 9 \text{ mV} \), and if we choose \( V_{\text{ref}} = 100 \text{ mV} \), we can have an error up to 9%!

Fortunately, because all terms of the sum are polarized and may compensate themselves, this worst-case deviation is statistically unlikely, but it gives a good idea about a possible loss of precision.

Secondly, it is important to take into account the mechanical switching of the resistors defining the output current. For example, to obtain a current value of 20 mA, again using the 100-mV reference will require a resistance \( R_s \) of 5 \( \Omega \). If the rotary switch represents a contact resistance of 100 m\( \Omega \), this yields an additional 2% error, to which we should add the error induced by intrinsic printed circuit track resistance. Conversely, if we choose a higher reference voltage, say 10 V, added to some wasted energy, we will be faced with the difficulties inherent to tiny currents. First there is the value of \( R_s \): to obtain, say, 10 nA (nanoamps) we’ll need a 1-G\( \Omega \) resistor—expensive and not easy to find with a tight tolerance. Next, at the resistor switching level, the finite insulation resistance of the rotary switch will be in parallel with this very large resistance and affect the required value. And still here, do not forget that the printed circuit itself is not a perfect dielectric.

Finally, we should reject any “exotic” value for the reference voltage (for example 1.235 V) because this value inevitably leads to “exotic” values for the \( R_s \) resistors themselves. In this project, the reference voltage was chosen at 1.00 V, a satisfactory compromise.

---

**Main Specifications**

- Low Ranges (10): 10nA – 10µA
- High Ranges: (10) 10µA – 20mA
- 3.5 Digit LCD Readout
- Battery Powered (4x AAA)
- Extendable as a High Impedance Voltmeter (optional)
- Microcontroller Free

---

**Figure 1.**
Theoretical model of a near perfect current source.
Into the schematic

Figure 2 shows the schematic of the instrument. Its design is Analog Electronics Paradise and deserves a thorough discussion. Not a microcontroller in sight.

References

The current needed by the floating source reference is obtained from a current mirror comprising transistors T2 and T4. The master current of 215 μA through T2 comes from resistor...
This circuit contains a FETish diode

chain R55, R67 shunted with P4, and R68. R67 minimizes impact from the large tolerance of pot P4, which delivers the output limiter adjustment voltage typically spanning 0.8 V – 20.4 V. The 1:1 ratio of the current mirror output at T4’s collector supplies the bias current for reference diode D4. T2 and T4 not being matched, emitter resistors R50 and R51 counteract a possible unbalance. The resistor divider made up of R56, P3 and R60 allows precise adjusting of the source reference to 1.000 V. We’ve chosen an LT1004CZ voltage reference from Linear Technology, but it is also possible to use a slightly less temperature compensated type like the LM385BZ-1.2 from National Semiconductor.

Measuring amplifier

The bias current of measuring amplifier IC8 being an error term algebraically added to the source current, it is important to keep it insignificant relative to the minimum output current of 10 nA. For this reason, the amplifier is an AD820AN from Analog Devices which has JFET inputs having an extremely low bias current. It’s quite a vintage device (20-year old), but possibly the only one to accept a single supply up to 30 V with rail-to-rail output and rather high precision. Very likely, it’s still available because of that, even in a DIP package.

Neglecting the offset voltage, the output voltage of the unity-gain connected amplifier is the image of its input voltage. This output sinks the return current from the voltage reference. It sources some current for the voltmeter input attenuator and also for the negative branch of voltage limiter indicator’s differential amplifier.

In the measuring circuit, diode D5 inserted between load return and Ground plays an important role, assuming in fact a triple function. Its main object is to raise the load return potential of a few hundreds millivolts, allowing the measuring amplifier IC8 to always work in a linear region. Everyone knows that operational amplifiers exhibit a lot of defects when approaching supply rail levels, especially the open-loop gain which collapses drastically. This causes an output offset voltage of a few up to hundreds of millivolts, depending on amplifier design and load conditions, mainly if the output has to source or sink current, the latter being the worst case around ground rail potential.

The sourced current—even the tiniest—always flows through D5, except when using the instrument as a voltmeter only. In that case, there is nothing except the current caused by the voltmeter’s input attenuator, unfortunately proportional to measured voltage. In order to get a significant voltage drop across the diode, a tiny current is added, made up of two components: the collector current from T8, defined by the input resistance R58 + R63 with differential amplifier IC7B (and inversely proportional to the clamping voltage), and on the other hand the current sourced by amplifier IC7A through R66 (and proportional to the clamping voltage). The sum of these currents is nearly constant and about 20 microamps, causing a minimum voltage drop of approximately 420 millivolts.

Secondly, the voltage drop across D5 compensates for the voltage drop across ‘clamping diode’ (FET) T9 of the voltage limiter, thus making the clamping voltage across the load independent of the current sourced. Actually, this is not perfect because this compensation is only effective for currents above the smallest current forced through D5 as previously described. Also, the characteristics of diodes T9 and D5 are slightly different. That’s why D5 is a type 1N4001, its voltage vs current slope resembling that of clamping diode T9 closer than a small signal diode like a 1N4148. Ideally, D5 would be identical to T9, but considering the cost of the latter, this is not essential because that compensation is only a secondary parameter.

Finally, in the case the instrument used as a voltmeter only, D5 together with resistors R61 and R64 protects the components against external voltages up to about 30 V, irrespective if the instrument is powered or not.
Normally, a high-impedance voltmeter is only used with high-impedance sources themselves and having such a low short-circuit current suggests inability to cause damage, but one never knows...

**Current generator**
Output current is obtained from amplifier IC6, the same type as that used for the measuring amplifier (AD820AN), the characteristics needed being nearly the same. It is unity-gain connected and buffered by transistor T6, the amplifier itself being unable to source the maximum required current of 20 mA.

Neglecting the amplifier offset voltage, the output voltage on T6’s emitter is the image of the reference voltage at the wiper of P3, and this output is connected to the high-end common point of current selection resistors. On the other hand, through unity-gain measuring amplifier IC8, the low-end of the reference voltage is itself the image of the voltage present at the low end of the current selection resistor. Thus, the voltage across the current selection resistor is the image of the reference voltage, and this very voltage is applied to that resistor which in turn generates the required current.

Base-emitter resistor R59 with T6 implements a selection according to the output current. For currents up to 100 μA, the amplifier alone sources the current through this resistor, and then starting from 200 μA, the transistor operates as a buffer. Moreover, R59 sinks the leakage current of transistor T6 if it is greater than the required output current. This phenomenon may appear under exceptional circumstances, like if the instrument outputs the maximum current of 20 mA for some time into a zero or almost-zero load—the transistor dissipates about 460 mW, which raises its junction temperature of nearly 115°C, causing significant leakage current. If immediately afterwards you want the instrument to output the minimum current of 10 nA, the leakage current may be temporarily greater than this value, requiring the amplifier not to source current, but rather to sink the excess.

**Surge current limiter**
When the ratio between ‘open-circuit’ and ‘load-applied’ voltages is significant, the resulting surge current may vastly exceed the final value during the few microseconds needed for the amplifiers to stabilize. Despite more than 10 years experience on the previous instrument version without any damage on checked components, a surge limiter is included here in the form of a JFET transistor which acts by momentarily cutting off the load from the current generator. JFET transistors are subject to large tolerance in terms of electrical characteristics. Consequently users have to check that the transistor to be mounted is able to fulfill its function. This can be done easily with the test circuit described further on.

Another simple and efficient but more constraining way to eliminate the surge current consists of adjusting the voltage limiter to the minimum...
Precision Adjustable DC Current Source

Voltage limiter
Voltage limitation is done by the unity-gain connected amplifier IC7A buffered by complementary transistors T7 and T8, the output being connected to the load through T9 acting as a clamping diode. Voltage limiting is adjustable with the front panel mounted potentiometer P4 from approximately 1 V up to 20 V.

Transistor T8 begins to sink the output current as soon as the voltage across the load is greater than that present at T8’s emitter, the clamping diode T9 getting forward biased. Transistor T7 is only useful during the reverse recovery period of T9 to extract the charges previously accumulated.

This time, the chosen amplifier is an LT1490A from Linear Technology (everyone has to live), a micropower dual version with rail-to-rail input and output, operating off a single supply up to 44 V and still available in a DIP package.

Like the measuring amplifier input, the leakage current of FET-ish diode T9 is an error term which must be insignificant up to a reverse voltage of 20 V. In the previous instrument version, this diode was an ultra-low leakage type BAV45, but unfortunately it is today quite impossible to find. A good alternative is to use the gate-source diode from JFETs like 2N4391..4393 or J201...203 (source connected to drain being the cathode). Caution! Unless having them selected, do not use the plastic case series PN4391...4393, which are specified with a gate reverse current up to 10 times higher.

Voltage limit visual indicator
The voltage limit indicator is comprised of differential amplifier IC7B, transistor T3 and LED D3. By way of unity-gain connected amplifier IC8, the differential amplifier measures the voltage across “diode” T9. This amplified voltage appears between amplifier output and the positive supply rail, and not ground as you might expect. The arrangement saves energy, the LED current being drawn from the supply current of amplifiers IC7 and IC8 (about 1 mA total), these amplifiers suitable for powering with a voltage slightly smaller than that required for current source amplifier IC6. The only requirement is to use a high efficiency red LED with an intrinsic low...
forward voltage (about 1.6 V at 1 mA). By means of resistors R52 and R54 this configuration referenced to the positive supply rail also provides one of the components needed for the minimum current required through D3. If T9 is reverse biased (limiter off), the output of IC7B swings high, switching T3 into conduction, effectively shorting out the LED. Conversely, as soon as T9 becomes forward biased at about 250 mV, the amplifier output voltage drops low, switching the transistor off and causing the LED to light. This 250-mV threshold across the diode corresponds to a current of about 10 pA, equal to 0.1% of the minimum output current. Consequently the LED lights as soon as there is a hint of voltage limiting going on.

It’s fair to ask why have gain on the differential amplifier IC7b and then kill it by a resistor divider to drive T3. Why not have the composite gain and a direct drive of the transistor? It’s merely because the output of the amplifier cannot go beyond the supply rail and so cannot drive the base of the transistor more positive than its emitter, meaning the LED would remain on all the time. Another reason for the presence of the resistor divider is to not approach the avalanche voltage of T3’s base-emitter junction if the amplifier output drops low. When the instrument is used as a voltmeter only, this could occur if the voltage limiter disconnect option is installed and the limiter not adjusted to the maximum value. Exactly in that case the LED indicator could even be used as a voltage threshold indicator by adjusting the limiter accordingly.

Component List

Resistors

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Value</th>
<th>Tolerance</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1, R55</td>
<td>12kΩ</td>
<td>5%</td>
<td>400mW</td>
</tr>
<tr>
<td>R2, R40</td>
<td>180kΩ</td>
<td>5%</td>
<td>400mW</td>
</tr>
<tr>
<td>R3, R10</td>
<td>50MΩ</td>
<td>1%</td>
<td>1W</td>
</tr>
<tr>
<td>R4, R15</td>
<td>10MΩ</td>
<td>1%</td>
<td>600mW</td>
</tr>
<tr>
<td>R5, R6, R7, R11, R12, R13, R16, R21, R22, R57, R58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R6, R6 = 1MΩ</td>
<td>1%</td>
<td>500mW</td>
<td></td>
</tr>
<tr>
<td>R17</td>
<td>1MΩ</td>
<td>0.1%</td>
<td>250mW</td>
</tr>
<tr>
<td>R8, R14, R26, R27, R67</td>
<td>100kΩ</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>R19</td>
<td>100kΩ</td>
<td>0.1%</td>
<td>250mW</td>
</tr>
<tr>
<td>R9, R54</td>
<td>56.2kΩ</td>
<td>1%</td>
<td>600mW</td>
</tr>
<tr>
<td>R18, R53, R56</td>
<td>4.64kΩ</td>
<td>0.5%</td>
<td>250mW</td>
</tr>
<tr>
<td>R20, R25, R44, R47, R48, R65</td>
<td>660kΩ</td>
<td>5%</td>
<td>500mW</td>
</tr>
<tr>
<td>R23</td>
<td>1.1kΩ</td>
<td>1%</td>
<td>250mW</td>
</tr>
<tr>
<td>R24</td>
<td>10kΩ</td>
<td>0.1%</td>
<td>250mW</td>
</tr>
<tr>
<td>R28, R29, R30, R37</td>
<td>10kΩ</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>R31, R32, R33, R38</td>
<td>1kΩ</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>R34, R35, R36, R39</td>
<td>100Ω</td>
<td>1%</td>
<td>400mW</td>
</tr>
<tr>
<td>R41, R42, R43</td>
<td>22kΩ</td>
<td>5%</td>
<td>500mW</td>
</tr>
<tr>
<td>R45</td>
<td>0.47Ω</td>
<td>5%</td>
<td>1W</td>
</tr>
<tr>
<td>R46, R49</td>
<td>11kΩ</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>R50</td>
<td>1MΩ</td>
<td>0.1%</td>
<td>250mW</td>
</tr>
<tr>
<td>R51</td>
<td>1MΩ</td>
<td>1%</td>
<td>600mW</td>
</tr>
<tr>
<td>R52, R60</td>
<td>330kΩ</td>
<td>1%</td>
<td>330kΩ</td>
</tr>
<tr>
<td>R61, R64</td>
<td>3.6kΩ</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>R62, R63</td>
<td>68.1kΩ</td>
<td>1%</td>
<td>600mW</td>
</tr>
<tr>
<td>R69</td>
<td>0.1Ω</td>
<td>1%</td>
<td>500mW</td>
</tr>
<tr>
<td>P1, P3</td>
<td>1kΩ</td>
<td>multiturn preset</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>50kΩ</td>
<td>multiturn preset</td>
<td></td>
</tr>
<tr>
<td>P4</td>
<td>1MΩ</td>
<td>miniature cermet potentiometer</td>
<td></td>
</tr>
</tbody>
</table>

Inductors

<table>
<thead>
<tr>
<th>Inductor</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>680µH</td>
<td>980mA, 0.46Ω</td>
</tr>
<tr>
<td>L2</td>
<td>100µH</td>
<td>580mA</td>
</tr>
</tbody>
</table>

Capacitors

<table>
<thead>
<tr>
<th>Capacitor</th>
<th>Value</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>47pF</td>
<td>5%</td>
</tr>
<tr>
<td>C2, C14, C17, C19, C20</td>
<td>100nF</td>
<td>20%</td>
</tr>
<tr>
<td>C3</td>
<td>10nF</td>
<td>10%</td>
</tr>
<tr>
<td>C4</td>
<td>470nF</td>
<td>5%</td>
</tr>
<tr>
<td>C5</td>
<td>47nF</td>
<td>1%</td>
</tr>
<tr>
<td>C6, C9</td>
<td>100µF</td>
<td>35V radial 20%</td>
</tr>
<tr>
<td>C7, C10, C11</td>
<td>1µF</td>
<td>63V 10%</td>
</tr>
<tr>
<td>C8</td>
<td>2.2nF</td>
<td>100V 10%</td>
</tr>
<tr>
<td>C12</td>
<td>22pF</td>
<td>200V 5%</td>
</tr>
</tbody>
</table>
Power supplies
The instrument is runs off 6 volts nominal supplied by four alkaline 1.5-volt AAA cells. Three internal voltages are generated: \(+23.8\) V for the current source, \(+4.2\) V and \(–4.2\) V for the voltmeter. The \(23.8\) V voltage is the minimum value required to ensure correct operation in the worst case. This voltage is obtained by a classic switching regulator type LM3578A from National Semiconductor, and it is adjustable with trimpot P2. Additional output filtering by L2 and C11 reduces the ripple on the supply rail.

The \(+4.2\) V supply is obtained from an LP2951 micropower adjustable linear regulator from National Semiconductor. The output voltage is fixed by resistors R49 and R53. This regulator also includes a comparator, switching whenever the output falls out of regulation by about 5%. The comparator output is used to activate the Low Battery indicator on the voltmeter display. The \(4.2\) V level causes the LO BATT indicator to be turned on when the battery voltage falls below \(4\) V, which leaves a comfortable time margin, the instrument remaining fully functional down to approximately \(3.5\) V.

The \(–4.2\) V rail also needed for the voltmeter supply is obtained from the \(+4.2\) V section by means of an ICL7660 charge pump converter from Intersil.

Integrated voltmeter
The integrated voltmeter is a very classic 2-Kcounts type. It is based on an ICL7136 A/D converter from Intersil, directly driving a \(\frac{1}{2}\)-inch
The measuring reference voltage is obtained from an LT1004CZ reference diode, the same as that used for the current source. The resistor divider made up of R9, P1 and R18 allows precise adjustment to 100.0 mV. The front panel accessible trimpot permits voltmeter calibration without opening the case.

Quadruple XOR gate IC2 is required for the display to drive both the decimal points and the Low Battery indicator. The latter is driven by the comparator in IC5, via T1 doing the level conversion.

Voltage measurements at the instrument terminals capitalizes on the intrinsic capability of differential inputs on the A/D converter, the load return not being grounded, but instead connected to the anode of diode D5.

The 4-position rotary switch coupled with an input attenuator allows selection of either the 2 V or 20 V range for output/input voltage, and the 20 V range for limiter voltage and battery voltage.

Thanks to its current source disconnection capability, the instrument can be used as a voltmeter only with a very high input impedance. However, this function comes with the following restrictions:

- the current selector must be in the “OFF” position;
- the voltage limiter must be adjusted to the maximum value of 20 V (except if the voltage limiter automatic disconnect option is installed);
- the voltage to be measured must respect the instrument polarity (however, it is still possible to measure a reverse voltage up to approximately 400 mV);
- the input voltage must not exceed 20 V (nevertheless, the instrument powered or not is protected against voltages up to about 30 V).

Construction
The care and precision used in designing this instrument should be reflected fully by your construction on board # 130287-1 of which the two overlays (front side and rear side) are pictured in Figure 3, together with the Parts List.

For obvious reasons the range selector section should not exhibit high contact resistance, jitter, leakage resistance or stray capacitances.

The + input of the instrument is a star junction with components connected in the air rather than to lossy PCB tracks.

A microswitch attached to the PCB and wired into the circuit creates a high-impedance voltmeter option on the instrument.

The board and the front panel are secured with hex PCB spacers to make up a solid assembly.
Hence the switches high-end types you should not attempt to replace by cheap devices. Basically for the same reason the 10-MΩ and 50-MΩ resistors are directly wired on the rotary switch contacts. What you see in Figure 4 is a not a quick & dirty fix but a necessity. A star point is available at K2, the + measurement terminal of this circuit. Look at Figure 5. A red, insulated banana socket is mounted on the front panel. There is a hole in the PCB close to that for the red socket. A PTFE (Teflon™) test terminal is press fitted into this hole and the following connections are soldered to it:

- the gates of T5 and T9;
- R64, which is ‘mounted in the air’ between this terminal and IC8. Note that pin 3 of IC8 is bent out of its socket terminal to solder straight to R64;
- a wire to the common contact of S3;
- a wire to the red terminal on the front panel.

Components are mounted on both sides of the PCB—check the PCB overlays and the pictures in the photographs at various places here to see which component goes where. The LCD is mounted on top of IC1 using two stacked socket strips to get it at the correct height. Some remarks on S4—this switch can be used to use the circuit as a high-impedance voltmeter. Note: S4 is drawn in ‘current source’ position in the schematic. The most elegant solution (also mechanically most complicated) is to use a microswitch that registers position 1 of rotary switch S3. This microswitch is attached to the PCB or mounted to the back of the front panel. An extender attached to the shaft of S3 (discussed below) actuates the lever on the microswitch. Luc Lemmens at Elektor Labs glued two M2 bolts to the PCB—it’s a bit tricky to get the microswitch to register in the correct position, but it can be done, see Figure 6. Another, slightly less com-

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plicated option is to add an extra SPDT (slide) switch for S4 to the front or side of the case. If the voltmeter feature is not wanted or needed, a simple jumper wire on the PCB can short S4 to permanently set current source mode. The shafts of rotary switches S1 and S3 are too short to protrude through the front panel. Extensions for 1/8” shafts are difficult to find, although suitable ones may be found in RC model shops. Diameters of 1/8” are commonly used there for shafts and spindles—Luc found some couplings there but these were too high to fit between the switch and front panel. Therefore we used an old, simple trick by removing the plastic from a small screw terminal block and using its metal parts as a coupling between the shaft of the switches and a 3.2-mm diameter metal shaft (a decapitated M3 bolt will do too). Space between PCB and front panel is tight; you may need to file the ends to make the coupling fit there. On S3, the shaft extender coupling can be used to actuate microswitch S4.

The PCB is mounted to the front panel using four hex studs (12 mm height). We glued them to the backside of the panel with 2-component glue (for aesthetics’ sake on the pictures). Sure, countersunk bolts through the panel present a more durable solution. We used some washers between the studs and the PCB to be able to mount the LCD flush with the backside of the front panel. The finished board and front panel assembly is pictured in Figure 7. The arrangement of controls on the front panel is shown in Figure 8.

Slide switch S5 (power) is originally a DPDT type, but we cut off three pins of the second switch to save space on the PCB. Two battery holders in series for two AAA cells each power the current source. One is mounted on the bottom of the case to the left and one to the right of the capacitors underneath the LCD. In a taller enclosure one holder for four batteries (even AA types) may do the job too.

Reference


Figure 8.
Suggested front panel layout printed here at actual size.
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At the end of last month’s instalment we had a microcontroller connected to a Raspberry Pi board over a serial link, and we used it to blink an LED under the control of a terminal. Controlling the demo program on the ATmega microcontroller using a keyboard and monitor connected to the Raspberry Pi is pretty close to remote control. However, if you really want to control your own electronic devices remotely your best option is to use your home LAN, or the Internet if you want access from anywhere in the world. Here we tell you how it works.

**Secure shell / SSH**

The terminal remote control arrangement described in the previous part can be extended to a LAN and to the Internet by using a secure shell (SSH). In the simplest case, SSH allows command lines from one computer to be transferred over a network and appear on another computer. Data exchange with SSH is encrypted and is relatively secure. The term SSH stands for a network protocol and for the programs that use this protocol. The SSH program running in the background on the Raspberry Pi is the SSH server. It provides the SSH service. The service offered by the server is used by an SSH client. The computer hosting the client may be located in the same LAN as the Raspberry Pi or somewhere else, linked over the Internet. If you do not have Linux on your remote control computer, you can simply boot with a Linux Live CD. These CDs are often included with popular computer magazines. With the usual distributions you can open a console without any special installation and run the SSH client as described below. The Linux system on the Raspberry Pi has a built-in SSH server. It can be activated under raspi-config (see Part 1).

**SSH on the LAN**

Naturally, a Raspberry Pi does not offer all the features of a full-fledged desktop PC. Nevertheless, for some applications it makes sense to operate devices on the LAN under remote control via SSH without a monitor or keyboard. A LAN is a private local network, typically with Internet access, in which a network router such as the FRITZ!Box looks after all the details. The same protocols are used on LANs as on the Internet: TCP and IP. Devices on a LAN (called nodes) typically have their own private IP addresses. The router separates the LAN from the WAN, which means the Internet. In this way it screens the LAN and protects it against access from the Internet. Only the router appears on the Internet as a node with a public IP address (host). Although we focus on the German FRITZ!Box in this article, it is certainly possible to use other Internet routers with similar capabilities for the purpose described here.

The detailed settings for the Raspberry Pi can be configured in the user interface of the FRITZ!Box. Its IP address can also be seen there. You should configure the router so that the Raspberry Pi is always assigned the same local IP address. If the settings are configured as shown in Figure 1, the SSH client can be called from a Linux computer on the LAN by typing the following command:

```
ssh user@ip_address
```

where `user` is the user name and `ip_address` is the IP address of the Raspberry Pi.

All you need for remote control of an ATmega32 microcontroller from your home LAN or the Internet is a second computer connected to the ATmega32 microcontroller over a serial link. Here the second computer is a bare-bones design in the form of a Raspberry Pi. In this instalment we show you how to integrate the hardware described in the first part of this series into your home LAN and into the Internet.
command line:

```
ssh pi@192.168.178.28
```

Another option is:

```
ssh pi@raspberrypi
```

The command line prompt of the Raspberry Pi appears after the user enters the password `pi`. Next you should launch `picocom` on the Raspberry Pi. If the demo program `suidemo1.c` is running on the ATMega32, the lines with three blinking asterisks shown in part 1 will appear on the monitor. After closing `picocom`, you can type `exit` to close the `ssh` program.

**SSH on the Internet**

Establishing a SSH link over the Internet is basically the same as on a LAN. However, the settings for this are considerably more complex because you have to connect a SSH client on the Internet to the SSH server on the LAN. This works the opposite way as the usual situation in which a browser on the LAN, acting as a client, requests pages from a web server and these pages are sent to the client over the Internet. The Internet router is prepared to receive incoming data because it comes in response to a request from the LAN.

By contrast, unknown data arriving from the Internet, such as data from a SSH client somewhere else in the world, represents a security risk. For this data to be received, it must pass through ports that are normally blocked on LANs. As components of complete internet addresses, ports correspond to numbers that are assigned to services on networks. For example, the standard port for SSH is 22. To allow “unexpected” incoming SSH data to be forwarded to port 22 on the Raspberry Pi, the router must be explicitly configured to enable forwarding for this port. The SSH server of the Raspberry Pi then listens to this port.

**Figure 2** shows the FRITZ!Box port forwarding enable page for the SSH server on the Raspberry Pi. Remember to disable port forwarding when you no longer need it.

Along with the number of ports for which forwarding has been enabled, the public IP address of the FRITZ!Box is shown on the overview page of the router configuration. When an SSH server on the Internet issues a call with this IP address (with the remainder of the address as previously described), it gains access to the SSH server of the Raspberry Pi. The same call also works on the LAN to which the Raspberry Pi belongs because the FRITZ!Box sends it to the Internet and then receives it as the addressee.

The fly in the ointment here is that with a dial-up Internet connection, the IP address of the FRITZ!Box changes almost every time a link is established (depending on the provider). Even a permanent connection does not prevent this, since the connection is normally broken every day by the provider and this results in the assignment of a new address.

Unfortunately, the IP addresses of routers are not recorded in the public Domain Name System.
special configured or retrofitted. For example, the Android app \texttt{vSSH} comes with an extended keyboard.

**Final remarks**

Naturally, there’s no reason for going to the trouble of setting up remote access to an ATmega32 program from the Internet unless it runs a program that does something genuinely useful, instead of the simple demo program.

The program \texttt{mmdemo1.c} (which can be downloaded free of charge from [1]) implements a serial user interface with four sample communication scenarios. It needs roughly 300 lines of code for this. It can also be extended to do other things if you maintain the structure of the program. One of its features is support for communication between a terminal and several microcontrollers over a low-impedance wired-AND bus, which also makes large distance between the bus nodes possible. This program is described in detail in the comments at the end of the code section.

**Another important note:** If you want to use this approach for remote control of real devices instead of just a couple of LEDs, you can increase the security by requiring a second password entry before allowing remote access to the hardware, in addition to the password required for SSH access to the Raspberry Pi. You shouldn’t ignore security, as otherwise it’s entirely possible for jokers and people with dubious intentions to do unpleasant things while remaining anonymous.

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**Web Link**

[1] [Elektor web page for this project: www.elektor-magazine.com/130481](http://www.elektor-magazine.com/130481)
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Many Elektor readers will have become acquainted by now with the Raspberry Pi through the various Elektor Post-articles distributed to Members every 14 days [1] or the Elektor book ‘Explore the RPi in 45 Electronics Projects’ [2]. For those of you who have not yet acquired an RPi but are nevertheless keen to play with this multifaceted system, we describe here the possibility of emulating the Raspberry Pi on a Windows-PC. Of course, this emulation will not be 100% correct because some hardware is not physically present, but this method will still give you a very good impression of the possibilities.

To make it easy for you, all the necessary software can be downloaded from the Elektor website.

- Go to the Elektor website [3] and download the Qemu software package and the program DiskImager. Both programs are suitable for Microsoft Windows (tested with Win7 64-bit).
- Make a new folder, for example c:\qemu and unzip both software packages into this folder. You do not need to install the programs.
- Use the DiskImager program to make a copy of the SD card from the book. (When starting the program it is possible that Windows will ask whether you agree to allow this program to make changes to your computer. Answer with ‘yes’. After that it is possible that a nasty error message appears, you can ignore that one; in spite of this the program will operate correctly.) Name the copy rpi-bookbertvandam.img and store this in the qemu folder.
- Start the program fix.bat in the qemu folder by double-clicking it. The emulation will now begin and stops with the final line reading: root@(none):/#
  This is the Linux prompt.
- Enter the following command:
  nano /etc/ld.so.preload
  This starts the text editor, which contains the following line (or something very similar):
  /usr/lib/arm-linux-gnueabihf/libcofi_rpi.so
  Insert the hash (or pound) symbol (#) in front of this line and subsequently press Ctrl-X. The press Y followed by the Enter key.
  The editor will now close again and you are back at the prompt: root@(none):/#
  Now enter the command halt, press Enter and wait until the prompt reappears (ignore the error message). Close the window using the small red cross at top right.
- Start the program run.bat in the qemu folder by double-clicking it. The program will now automatically load the copy of the SD card

By Bert van Dam (Netherlands)
and after a short time the famous Raspberry Pi screen will appear. The message ‘failed’ when loading the file system and error messages when loading libmod are normal. These are caused by certain hardware that is not available but is expected by the software (and which of course is present on a real RPi).

You can now experiment to your heart’s content in the emulation window. It is even possible to go through the first few chapters of the ‘Raspberry Pi’ book. Of course you cannot make any of the electronics projects from the book, because Qemu only emulates the Raspberry Pi and not the electronics from the book.

When you use the mouse in the emulation window all its commands are used for the Raspberry Pi emulation. You can return the mouse to Windows by pressing the key-combination Ctrl-Alt.

The emulation program requires quite a bit of computing power from your PC, so it is possible that everything is running and reacting somewhat slower compared to a real Raspberry Pi.

From now on you can start the emulation using run.bat and stop it using the command sudo shutdown -h now in a terminal window or via the task bar (the red power symbol on the far right) and then ‘Shutdown’. Wait until the message system halted appears before closing the window.

With thanks to xecdesign for the preload information.

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Measuring high-speed digital signals with probes is prone to produce errors. The ground connection of the probe has special significance. If the standard flying-lead-and-croc-clip is used, the scope images often show wild overshoots definitely not present in the signal. More expensive probes have a “ground spring” to establish a ground connection that’s as short as possible. Such a ground spring is eligible for Elektorizing!

Measuring signals with an oscilloscope is daily bread and butter to an engineer either at work or in their spare time. The output from a signal generator can generally be directly connected to a scope input using a coax cable with a BNC plug at either end. For low-frequency signals such as audio it isn’t necessary to terminate the cable with its characteristic load. Higher frequency signals such as video or digital signals generally need a load termination at the end of the cable—ideally the scope will have a switchable load option built into its input stage or else use a 50-Ω feed-thru terminator.

In most cases for circuit debugging, a high-impedance scope probe is used to trace a signal path through a circuit. Any part the circuit will ‘see’ the probe tip as a 10-MΩ impedance to ground. This is made up of a 9-MΩ series resistor in the probe body (in parallel with a capacitor of around 10 pF) and the 1-MΩ scope input impedance. Altogether these two impedances form a 10:1 voltage divider network so that the signal at the scope input is only one tenth of its actual value.

The signal is sampled with the tip of the probe and the Earth connection is a flying lead, usually around 10 cm (4 inches) long terminated in a crocodile clip. It is assumed that the scope probe has already been tweaked for optimal response using the scope test output signal.

When measuring fast digital pulses you notice that the signal shown on the scope changes depending on where you attach the Earth lead, particularly noticeable on overshoot at the signal edges. The suspicion is that the displayed waveform is not a true picture of what is happening in the circuit (Figure 1).

More expensive probes such as those made by Agilent or Tektronix provide a tip ground or ground spring option. This removes the long Earth lead and improves the waveform by allowing a
shorter Earth connection nearer to the point of measurement (Figure 2). The resulting waveform is shown in Figure 3.

The author hasn’t seen this type of earthing feature on any of the standard low-cost probes, but luckily they do have an Earth collar just back from the probe tip which can be used for this purpose. Wind a length of bare copper wire around the collar a few times and twist the ends to make it grip the collar (Figure 4). For convenience this Earth connection can be temporarily soldered into the circuit under test. It costs practically nothing and if it falls off it only takes a minute to replace.

**Bandwidth**

These improvements will not alter the fact that the scope probe bandwidth usually limits high frequency measurements.

To check this out use a square wave generator and measure the rise or fall time on the scope display first using a BNC to BNC coax with a terminator load and then with the scope probe. If the rise time is slower with the probe then you can be sure the probe bandwidth is having an effect. Professional solutions include probes with an input impedance of 500 or 1000 Ω. These at first seem very low compared to standard 10 MΩ probes, but at high frequency the probe’s input capacitance has a greater influence on signal loading. Also signals in this range tend to be in the 1 Vpp range and the ICs can easily drive the extra load.

The cost of such a probe is in the region of $100 Euro, which is rather a lot if it only gets occasional use. You can build a test probe with similar characteristics quite cheaply. First take a length of 50-Ω coax fitted with a BNC connector at one end (alternatively cut a 2 m (7 ft.) BNC to BNC cable in half to make two probes). Trim back the insulation from the cut end and solder a resistor to the center conductor. A small length of heat shrink sleeving will cover the joint and resistor. Tease out the shielding wire strands and solder to a short length of wire to make the Earth connection on the PCB. Another length of heat shrink over all the bare wires will finish the job (Figure 5). The value of resistor used here can be either 450 or 950 Ω. Together with the 50 Ω termination resistor at the scope input these resistor values produce a 10:1 and 20:1 voltage division of the measured signal. The non standard resistor values are available from component stockists. Failing that you can use values of 470 and 1000 Ω and accept that the voltage division ratios will be slightly out. If something breaks, it’s a simple job to trim the cable back and make another.

Figure 6 shows a low-impedance scope probe from HP. In the white plastic shell is a swappable resistor. Connection to the scope is via an SMA connector and a length of SMA cable (the cost of this probe puts it in the ‘Professional Use only’ camp). Using an SMA connector, cable, a resistor, wire and some heat shrink sleeving it should be simple to produce something similar (providing you have some SMA-diameter cable and a BNC adapter).
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Big Brother Be Gone

The search function on Elektor.Labs has switched to DuckDuckGo, an Internet search engine claimed to provide real anonymous search. Our first impressions are very positive: fast, accurate and clean results without tracking. No more Big Brother following you around the Internet. Why don’t you give it a try?

Collecting information is easy; making it accessible is difficult. Since its launch Elektor.Labs has collected quite a lot of useful information about electronics and projects, and obviously good tools are needed to exploit this data. Since Elektor.Labs is a laboratory we can experiment with search engines to find out which solution suits us best. The Elektor.Labs website started out with the default search engine integrated in the website’s ‘Drupal’ content management system. This search engine works fine as long as you know exactly what you are looking for. Punch in the search phrase and you will be rewarded with all the articles containing that exact phrase. Typo? Nothing found. Wildcards? Not allowed.

While investigating the rationale behind the absence of wildcards we discovered that there are (at least) two schools of thought for search engines: few accurate results versus many less-accurate results. Our website adhered to the first school whereas we preferred the second, which we felt would be more suited for people not too sure about the exact term they are looking for. So we replaced the default search engine by Google’s Site Search. Initially we got spectacularly precise results; we found everything we wanted and even some fans of the first school were impressed with the quality of the pages returned. OK, Google added some commercial links to the results, but the precision of the results outweighed this inconvenience. However, as we were soon to discover, Google Site Search turned out to be too much of a good thing—it even presented pages we didn’t know the existence of, like site-wide lists of new posts. At first we thought that that was all right, but quickly these listings started to outnumber the useful results. Deactivating these listings did not solve anything because Google had memorized them all and so we pulled the plug on Google Site Search.

Enter DuckDuckGo. This is a rather recent search engine that boasts anonymous search while trying to limit spam to a minimum. They offer a site search function as well, although not as neatly integrated as Google. When you click the Elektor.Labs search button you are taken to our DuckDuckGo site search page. Try it and be amazed by its lightning speed. There is still a trifling inconvenience though: make sure you do not delete "site:www.elektor-labs.com" from the search box.

By Clemens Valens
(Elektor.Labs)

www.elektor-labs.com/node/3795
What’s up with this cap?

Loyal readers will be aware that Elektor have been offering printed circuit boards, programmed microcontrollers, kits and modules et cetera for some considerable time as a complementary (not: complimentary) service to Elektor Magazine. This service we hope increases the chances of success when assembling your own circuit at home or in your workspace. While we cannot fly over and assist with your soldering, at least our semi-kits ensure that the correct components are available to those interested. One of my duties at Elektor Labs is to randomly check these semi-kits for completeness and make sure everything is in agreement with the published BOM when they arrive from our suppliers.

For our recent ADAU1701 Universal Audio DSP Board ([1]) we had one of our trusted suppliers do the parts picking for the semi-kit. When the kits arrived at our warehouse I randomly checked a couple for correctness and completeness. I then stumbled upon something very odd with the 100-nF (0.1 µF) capacitors. The picture shows two of them, each from a different side. Now I’d like to believe I’m not a complete knucklehead on electronic components, but this capacitor included in the kit had me flabbergasted. It was supposed to be a 100-nF capacitor, but as you can see in the photo, it has a “105” marking on one side and cheerfully “104” on the other side. Every 100-nF capacitor in every sample kit I checked showed the same 104 / 105 print as shown here, so it was not just a misprint on one of them, and it’s a long time to April 1.

Trawling the net for a possible explanation didn’t result in an answer, nor did any of my colleagues at here at Labs know what was going on here. According to our LCR meter (the fancy one we published about in the March, April and May 2013 editions [2]), the capacitor is indeed 100 nF. Your DSP kit should be okay.

So here’s my call out to you, our well-informed reader and/or omniscient professional, to explain what’s going on with this component. Is it just an ex-factory misprint? Or is there a method to the madness?

Send your insights to editor@elektor.com, subject: madcap.

Web Links

A couple of weeks ago Labs took delivery of RepRap 3D printing machine [1] from RS Components / Allied Electronics [2] to experiment with. Here were cover the unpacking and assembling of the mini manufacturing machine.

The first thing you come across after opening the box is a packing list, which should be checked thoroughly to make sure all items listed are present and intact. All parts that make up the kit are packed in transparent bags, and on every bag there’s a content list, which is very useful. The letter of introduction that comes with the kit includes a link to the online Assembly Manual [3]. Initially we looked for clues to a printable version of the manual, but it soon dawned upon us that there is no such thing. The disadvantage of this approach is that you need to have a computer with Internet access up and running while assembling the printer. But it didn’t take long for us to see the benefits of the online-only manual: for example, the images are displayed at a higher resolution after you click on them, offering more detailed visual support.

The manual provides all the details needed for an easy step-by-step assembly procedure. It features lots of pictures, loads of useful tips and in general is well structured. We reckon anyone who ever played with Lego or built something from Ikea drawings can assemble this 3D printer. Check our time-lapse video of the steps to assembly at [4].

A nice touch of the RepRap concept is that all the parts printed by a 3D printer are available as open-source 3D designs and the links to their locations on the web are included. So, if you feel up to it, you can download the files and print (spare) parts yourself. This can be useful in case a part is worn out or when an improved version of the part becomes available. Imagine, downloading upgrades and (3D-)printing them yourself for the purpose of improving your own 3D-printer... ain’t that a blast?

Web Links
[1] www.reprap.org

Unwrapping RepRap

By Patrick Wielders
(Elektor Labs)
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Last time we started a PCB board outline for a Hammond 1551N enclosure. We started by importing the enclosed STEP model into DesignSpark Mechanical and then we modeled the circuit board to make sure it would fit. Today we are going to finish importing the board into DesignSpark PCB so that we can the board ready for components.

**Fixing the import**

*Figure 1* shows where we left off last time. The PCB outline is correct but the mounting holes are obviously wrong. I tried some other packages and they correctly imported the DXF file we created last time. Exporting the DXF from those packages would also import properly into DesignSpark PCB so something in our DXF file must be confusing it.

After some experimentation I found that there are a couple of errors with the model I had created in DesignSpark Mechanical. The first problem is that the mounting holes weren’t really holes in the board model because they are covered by a thin plane. It was hard to see until I rotated the model a bit and saw that the bottom of the holes were shaded instead of being white. The second problem is that DesignSpark PCB doesn’t think the board shape is a closed shape since it raises a warning after the import. Moving the corners showed that two of them aren’t connected properly because the unconnected lines won’t resize properly.

So let’s start by fixing the mounting holes in the DesignSpark Mechanical PCB model. The first step is to use the pull tool to pull the PCB outline 1.6 mm upwards from the sketch plane which creates a solid PCB object. Then select the circles from the original sketch plane and delete them like in *Figure 2*.

The trick is make sure that you select the circle covering the mounting hole has a solid and not just circle outline otherwise you won’t be able to
delete it properly. You will know when hole is clear because you will see the white background show through the hole. Once you’ve cleared both holes right click on “Curves” heading in the PCB outline structure and select delete to remove the extra lines that we don’t need anymore.

Before you export the new DXF you have to select the top view of the PCB (Design→Orient→Top). Otherwise DesignSpark Mechanical will export the DXF as a 3D perspective of the PCB which won’t work. Figure 3 shows what the corrected board looks like in DesignSpark PCB with the new DXF. It still raises the same import warning but that’s due to the mounting holes—not a problem since we’ll be deleting them later anyways.

Adding the mounting holes

I usually like to set up my mounting holes so that they’re unplated and without any copper pads under the screw head to avoid tearing the copper off of the board when tightening the screw. These types of holes are usually made as a library component because they require copper keepouts on the outer layers. DesignSpark PCB can do this but it’s difficult because you can’t add keepout elements to a DesignSpark PCB library component. Instead you would have to manually add them to every hole you make. Today we’ll just use a plated hole since they’re much easier to use in DesignSpark. You can make them unplated as well but be careful that the copper pads don’t tear off the PCB.

Start by creating a new PCB symbol for our mounting hole. We’re going to use ANSI #2 screws so add a pad with a 2.5-mm hole and a 5.5-mm pad which corresponds to the recommended size [1] for a pan head screw and nut. For all practical purposes these sizes suit the metric M2 screw also. Once you finished editing the pad save it your library. Next
you will need to create a PCB only component for the mounting hole. You do that by adding a new component to the library like usual except that you uncheck the “Schematic Symbol” box in the “New Component” window. Alternatively you could add it to the PCB technology file instead but if you use multiple technology files then you would have to copy to each technology file. Using a library means there’s only one copy of the hole. Now we can add the two mounting holes to the design. I manually placed them on the PCB and then adjusted them to the correct locations by manually entering the hole co-ordinates to be the same as the imported hole co-ordinates. You can get the co-ordinates of the imported holes by right clicking on them, selecting “Properties” and noting the center co-ordinate shown. Then you can set the mounting hole component co-ordinates by right clicking them, selecting “Type Coordinate”. After the new components are placed properly you can delete the old imported holes.

Adding the keepout areas
The last step today is to add the component keepout areas for the mounting bosses. You do this in DesignSpark PCB by adding the keepout information to a documentation layer and making sure we don’t violate the keepout while working on the design. DesignSpark cannot check for violations via a DRC.

First we’ll need to use DesignSpark Mechanical to create a cross section of where the board meets the enclosure mounting bosses just like in Figure 4. Then we can create a new component with the board outline, mounting holes and mounting bosses. There’s no point in making it a 3D shape this time so just export a DXF of the 2D shape even though there will be some errors with the mounting holes after the import. Make sure to select the bottom documentation layer in the “To Design Layer” field when importing the DXF into DesignSpark PCB.

After a little bit of editing the final result in DesignSpark PCB will look like Figure 5. The mounting holes now have clearance for the screw heads and the keepout areas are visible on the bottom documentation layer which is shown in pink.

Conclusion
Today we fixed our import issues and finished adding the necessary mechanical information to our PCB. Next time we’ll import it back into DesignSpark Mechanical to make sure we didn’t make any errors.

Web Link
Nixie displays are great for retro style clocks but they were actually developed back in the vacuum tube era. For a long time they were one of the only ways to display ‘sort of’ alphanumeric characters. They’ve since been replaced by seven-segment LED displays but they’re still fascinating. Nixie displays are a lot of fun but they operate at around 170 V\text{DC} which can be lethal. Play safe and follow high voltage safety rules [1].

A modern seven-segment display uses seven LED segments that can be used to represent a character. It makes a nice and compact display but the downside is that a decoder (hardware or software) is required to convert a character to its 7-segment representation. This isn’t a problem with modern electronics but back in the 1950’s and 60’s this was a lot harder. Nixie displays solve this problem by having one control line per digit. So for example a numeric display would have one control line for each number between 0 and 9.

Internally a nixie display tube has a bunch of stacked elements. The topmost one is the anode or where the positive voltage is applied. Below that is a plate for each character which is then brought out to their respective control lines. This construction gives the nixies their nostalgic character shapes and friendly orange glow.

Nixes operate on the same principals as a neon bulb. You apply a large enough DC voltage to the nixie anode and cathode and once you reach the neon breakdown voltage the currently selected character will illuminate. The trick is that you have to either use a current limited anode power supply or an anode supply with a series resistor because a nixie tube will act like a zener once it starts to conduct. Otherwise it will fail. The required DC voltage to make a nixie conduct is quite high (usually over 150 V) which makes the numerical device a little tougher to interface to modern digital logic but there are lots of examples available on the Net and in Elektor magazine, like the Sputnik Time Machine (Figure 1) [2] and various thermometers [3],[4].

The anode current is a critical parameter for nixie tubes. If it’s too high or too low it can drastically reduce the tube operating lifetime. It also controls the brightness and focus of each digit. But with the correct drive circuitry a long life type tube can last up to 200,000 hours or over 20 years.

Figure 2 shows an illuminated Russian IN-12A nixie display tube which is common in clocks and is also still used in some nuclear power plants. I used a 170 V\text{DC} power supply and a 40-kΩ resistor connected to the anode and I grounded the pin to illuminate the number 7. In it you can see the anode grid at the top and then some of the numbers that are stacked on top of the seven but not illuminated.

It’s amazing that it’s still possible to find brand new nixie tubes (New Old Stock; NOS) from various online sources. And the growing clock enthusiast community is making it even easier to try and use nixie tubes.

Web Links


By Neil Gruending
(Canada)
Industry

90-°C Oven Controlled Xtal Oscillators

Precision Devices Inc., a member of the Avrio Technology Group LLC, has announced the high temperature (to +90°C) VN01 and VN03 series of Oven Controlled Crystal Oscillators (OCXO). This product is ideal for applications like satellite communications and a variety of military systems where extremely high temperature operating environments are the normal. “Many harsh environment applications require higher operating temperatures than the typical +70 or 80 °C products generally available in the market. Moving to 90°C is not a trivial thing,” according to Barry Arneson, Director, Oscillator Engineering. “Due to the nature of how an SC cut crystal functions in conjunction with the oscillator, this is a significant step forward.”

www.pdixtal.com  (130448-III)

Electronic Component Selector Updated

Würth Elektronik eiSos have released a revised and expanded version of their free Component Selector. Six new modules have been added to the four existing ones, making this selection tool one of the world’s most comprehensive component databases to be provided by a single manufacturer. In the field of EMC components, cable ferrites and common mode chokes are now available in addition to PCB ferrites. These modules allow users to analyze and compare technical values and impedance curves for all products. Within the component characteristic curve, filters help users find the right components quickly and easily. In the power inductors module, the right inductor for non-insulated DC/DC converters can easily be determined. The Component Selector also calculates wire and core losses and, based on these losses, calculates the temperature increase of the component. In the field of power supplies, there is also a module to help quickly and easily configure flexible transformers for isolated DC/DC converters to suit the relevant input and output values. For use in active PFC circuits, there is now also a module for determining the right PFC choke. The most significant extension of the software was for signal and communications products. As well as the existing RF inductor module for selecting components according to frequency, for adjusting antenna for example, three further modules have now been introduced. For signal and backlight LEDs, by entering the resistance and input voltage values for every freely definable forward current, the expected brightness of the LED can be displayed. A particularly practical addition is the module for discrete LAN transformers or integrated RJ45 LAN transformers, which enables users to search and filter components by the internal connections or land pad. This means that the right solutions for existing products can be found in no time at all. Users can also save and store existing settings for component selection. Within all the modules, the relevant data sheet can also be consulted online and S-parameters can be downloaded. The integrated online update function ensures that the product database is kept up to date at all times. Users without an internet connection can get updates from the manufacturer’s website at any time and install them manually. The Component Selector is designed to be self-explanatory and easy to get to grips with. Elektor readers can install the free Component Selector by downloading the software from the link below.

www.we-online.de/component-selector  (130448-VI)

High Accuracy Snow Depth Sensor

The newly released MaxBotix snow depth sensors are rated to operate in temperatures between –40°C to +65 °C with a maximum range of 5000 mm. Our sensors have been proven and optimized, yielding design solutions that previously hindered competing sensors, in a real world snow environment tested at Maxbotix’facility located in the heart of Minnesota. MTBF of 200,000+ hours and the low power consumption easily allow the sensor to operate in battery based systems for extended periods of time (or solar powered systems indefinitely) easing maintenance requirements and allowing for remote installations. At a low cost of $149.99 (MSRP) the use of these new snow sensors include improved performance during heavy snowfall conditions, responsive accurate temperature compensation, and continued performance during high wind conditions. The sensors are equipped to apply to any of these interface controls: pulsewidth, analog voltage, serial data - RS232 (MB7354) or TTL (MB7374).

www.maxbotix.com/snow  (130448-IV)
PicoScope oscilloscopes now run on Linux

Pico Technology has just released a beta version of the PicoScope® 6 oscilloscope software for Linux. This is in response to requests from a large number of customers in the scientific and educational fields where Linux is widely used. PicoScope 6 is a powerful application that converts your PC into an oscilloscope, FFT spectrum analyzer and measuring device. On-device buffering, using deep memory on some devices, ensures that the display is updated frequently and smoothly even on long timebases. The most important features from PicoScope for Windows are included—scope, spectrum and persistence modes; interactive zoom; simple, delayed and advanced triggers; automatic measurements; and signal generator control—and we are working on adding more. You can save captures for off-line analysis, share them with other PicoScope for Windows and PicoScope for Linux users, or export them in text, CSV and Mathworks MATLAB 4 formats.

The only additional hardware you need is a compact, economical USB oscilloscope from the PicoScope range. PicoScope oscilloscopes are available with bandwidths up to 1 GHz, up to 4 input channels, hardware vertical resolutions up to 16 bits, sampling rates up to 5 GS/s, buffer sizes up to 2 GS, and built-in signal generators. Other features available on some models include flexible hardware resolution, switchable bandwidth limiters, switchable high-impedance and 50 ohm inputs, and differential inputs.

The new software is packaged for easy installation on the following distributions:
- Debian 7.0 (wheezy) i386/amd64
- Ubuntu 12.xx/13.xx i386/amd64
- Any other Debian-based distribution with mono-runtime >= 2.10.8.1

PicoScope includes drivers for all current scopes from the PicoScope 2000 Series to the 6000 Series and we are working on adding support for some older devices. The drivers can also be used on their own to create custom applications. A number of customers are already using the new beta and contributing to a lively discussion on the Pico forum at http://www.picotech.com/support/.

www.picotech.com/linux.html
Microchip Analog Front Ends Offer High Accuracy for 3-Phase Smart Meters

Microchip Technology Inc. announce their next-generation family of energy-measurement Analog Front Ends (AFEs) with industry-leading accuracy. The MCP3913 and MCP3914 integrate six and eight 24-bit, delta-sigma Analog-to-Digital Converters (ADCs), respectively, with 94.5 dB SINAD, –106.5 dB THD and 112 dB SFDR for high-accuracy signal acquisition and higher-performing end products. The MCP3914's two extra ADCs enable the monitoring of more sensors with one chip, lowering cost and size. Additionally, the programmable data rate of up to 125 ksps with low-power modes allows designers to scale down for better power consumption or to use higher data rates for advanced signal analysis, such as calculating harmonic content. These AFEs also feature a CRC-16 checksum and register-map lock, for increased robustness.

As the energy-metering infrastructure is being upgraded worldwide, designers are demanding increased AFE accuracy, performance and flexibility to develop the latest generation of smart meters. These features are also required by the designers of advanced power-monitoring systems for applications such as server power supplies and power distribution units, uninterruptible power supplies, smart power strips and data-acquisition products in the industrial and commercial markets. Microchip's new AFEs improve application performance with their industry-leading accuracy, while providing the flexibility to adjust the data rate to optimize each application's rate of performance versus power consumption.

Microchip also announced two new tools to aid in the development of energy systems using these AFEs. The MCP3913 Evaluation Board (part # ADM00522) and MCP3914 Evaluation Board (part # ADM00523) can each be purchased today for $99.99.

www.microchip.com/get/EUJ9 (130458-IV)

Philips LUXEON Lime LEDs break 200 lm/W Barrier

Lime, the newest addition to the widely renowned LUXEON color portfolio of LEDs from Philips Lumileds, enables lighting designers to take the next step in delivering the highest quality, tunable white light in bulbs and fixtures. LUXEON Rebel ES Lime is the proprietary LED technology in the revolutionary Philips hue bulb, where it combines with LUXEON Rebel Red-Orange and Rebel Royal Blue emitters to deliver over 16 million color options—all controlled from an iOS device. Philips hue can use color tunable Light Recipes to help set mood and energy level in the home, office, retail, classroom and hospital environments.

Lime is the highest efficacy LUXEON LED manufactured to date. Therefore it enables highly efficient color mixing by providing a convenient above-blackbody color point with optimal standalone efficiency of 200 lm/W at 350 mA and 85°C. The spectral output of Lime is closely aligned with the wavelength that human eye cones are most sensitive to, 555 nm. In addition to LUXEON Rebel ES, the Lime technology is offered in the LUXEON Z format, an undomed, 2.2 mm² LED that is 75% smaller than most high power LEDs. In spotlight and downlight applications, the LUXEON Z enables tighter packing density and better color mixing control. The LUXEON Z Lime can be combined with Red and Blue LEDs to achieve a broad spectrum of saturated colors. Alternatively, tunable white light with high efficacy can be achieved from 1800-6500K along the blackbody curve.

New Items from Parallax

**ActivityBot (# 32500) (rrp: $199.00)**
Learn real-world engineering skills with the friendly, capable, and peppy ActivityBot. It’s a great option for first-time robot-builders, as well as for an intro to technology and engineering courses in high schools and colleges.

Step-by-step web tutorials take you through programming its multicore Propeller chip in C, wiring circuits on a breadboard, and building sensor systems so your robot can navigate on its own. Following the checkmarks gets you to the fun fast, with optional links for added learning.

**Key Features:**
- Easy to program in C on Windows, Mac, or Linux with the SimpleIDE software and custom Simple Libraries
- Multicore Propeller control board makes it quick to integrate sensors, motors, and more
- High-speed servo motors with optical encoders provide fast, consistent maneuvering
- Breadboard and 3-pin headers let you experiment with common electronics parts, no soldering or proprietary connectors required
- Component kit makes navigation systems that use touch, visible light, infrared light and ultrasonic sensors
- Built-in SD card slot and microSD card are ready for data-logging and file storage

**Y-6 Multicopter (# 80100) (rrp: $799.00)**
The Elev-8 Y-6 Multicopter is a flying robotics platform that is lifted and propelled by six fixed pitch rotors. Unlike other ‘Tri-copter’ platforms, the Y-6 has a motor mounted on the top and bottom of each boom. This ‘double-stack’ of the motors gives you added payload capabilities, and makes your system redundant in case of a sudden motor loss, making the platform safer to fly.

Aircraft stabilization is electronically controlled by the HoverFly board with Parallax’s Propeller multicore microprocessor. The benefit to this system is a stable platform with no mechanical linkages, for a small, maneuverable, and agile aircraft.

**Key Features:**
- Open underbody for accessory and camera mounting
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www.parallax.com /[item #]  (130448-II)
Atwater Kent Model 30 Radio (1926)

By Gerard Fonte
(USA)

In the mid 1960’s I was a teenager and getting interested in electronics. I had just read about rebuilding old radio receivers (Popular Electronics May 1964) when I saw a mammoth Silvertone console radio on the curb, just waiting to be collected by the “sanitation engineers”. Unfortunately I couldn’t ask the school-bus driver to stop. I probably couldn’t have gotten it on the bus anyway. It was about four feet tall (1.3 m), two feet wide (0.6 m) and weighed at least 50 pounds (20 kg). But, being a resourceful student, I called my parents from school and begged and pleaded for them to pick it up for me before someone else did or it got trashed. I was well rewarded for my histrionics. With some help from a friend, I was able to replace the shorted filter capacitor that was making the regulator tube’s plates get red hot. (For those unfamiliar with vacuum tubes, or “valves”, only the filaments were supposed to glow.) The radio had fantastic tone and volume. But better still, it had several shortwave bands—very important for a budding engineer in those times. With such a fantastically successful start, I continued collecting old radios and suchlike.

Buying Blind

Some time later I went to my first auction and there was a large console radio that was in very sad shape. It had been stored in the barn for many years and the wood was falling apart and the back was closed up. I couldn’t see any of the electronics. The bidding started at two dollars. Not knowing any better, I bid two dollars. Nobody else said anything. So, I got it for two dollars. One bid and one auction win! Pretty good for my first time. The thing was nearly as big as me and as I was dragging it to the car, I realized that something was loose inside. When I got it to the car I pulled off the backing. Inside was a pristine Atwater Kent Model 30 radio. I don’t know what it would have auctioned for, but I am pretty sure it would have been a lot more than two dollars—which was about all I could afford.

AK-30 Basics

The Atwater Kent model 30 was built around 1926. It’s a six-tube, Tuned Radio Frequency (TRF) type of receiver. What that means is that is pretty much an amplified crystal radio. Looking at the redrawn schematic, Figure 1 [1] (original also available, Ed.), there are three stages of tuned RF amplifiers, followed by a “grid-leak” detector, followed by two Audio Frequency (AF) amplifiers. This makes six stages with one tube for each stage.
The tuning of the three RF amplifiers is nothing more than a parallel L-C (inductor/capacitor) network (exactly like a crystal radio). The three air-variable capacitors were adjusted for tuning. Putting three identical tuned amplifiers in series increases gain (obviously) and selectivity (i.e. the ability to separate signals close in frequency). Each tuning stage narrows the passband considerably. With three stages, the selectivity is pretty good. Of course, there weren’t all that many broadcasters to interfere with each other at that time. This also meant that each capacitor had to be properly adjusted to tune in a station. The Model 30 was the first Atwater Kent to use only one dial to adjust all three simultaneously. The capacitors were connected with pulleys and a metal band to accomplish this (more on this later). There was an RF gain control that varied the filament voltage to the three RF amplifiers.

The grid leak detector (inset) was a very simple and cheap way to demodulate the RF signal. The procedure was to place a small bias on the grid by connecting a high value resistor to ground. The resistor in the model 30 was about 2 megohms. The effect is to change the operating point of the tube to only amplify the negative half of the signal. In this way there was detection as well as amplification. And while this did work, there were many things that affected the performance. This included signal strength, tube degeneration and leakage! Drip-drip!

The real grid leak resistor lead directly to the development of the fictitious “grid leak (drip) pan” that was used to collect all of these electrons and keep them from falling on the floor and creating a mess. Like the left-handed monkey wrench and the board-stretcher, great enjoyment was had by all (except the victim) in the futile search by the new-hire in the radio repair shop. There are rumors that these pans did exist and that some unscrupulous souls would actually sell these grid leak pans to the unsuspecting public. There are currently “audiophile” AC power cords that sell for $1699.99. Perhaps, more reasonably, parts vendors and distributors may have given pans away as humorous promotional items.

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**Retronics**

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

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**Leakage! Drip-drip!**

The real grid leak resistor lead directly to the development of the fictitious “grid leak (drip) pan” that was used to collect all of these electrons and keep them from falling on the floor and creating a mess. Like the left-handed monkey wrench and the board-stretcher, great enjoyment was had by all (except the victim) in the futile search by the new-hire in the radio repair shop. There are rumors that these pans did exist and that some unscrupulous souls would actually sell these grid leak pans to the unsuspecting public. There are currently “audiophile” AC power cords that sell for $1699.99. Perhaps, more reasonably, parts vendors and distributors may have given pans away as humorous promotional items.

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**ESTP 2004**

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grid-resistor variation (these resistors changed with temperature and humidity).

After the leaky-grid stage came two stages of audio amplification. The final result was a signal that could drive headphones well or a loud-speaker poorly. Of course the loud-speakers of that era were really not much more than a headphone attached to an acoustical horn. The volume control varied the voltage on the filament of the detector rather than the input voltage to the AF amplifier stages (as is normally done today).

**My AK-30**

As you can see from the pictures in Figures 2 and 3, the case was nearly perfect and all the tubes were in place. However, there were some problems. The most significant was that the metal pulleys connecting the variable capacitors were crumbling (Figure 4; thanks Allen [2]). I had never seen (and still haven’t) anything like this before. I suspect that it was due to metal fatigue. Especially since the metal appeared to be sintered rather than cast or machined. (Sintered metal starts as a powder that is pressed and heated into its final shape.) Cycling between a hundred degrees in the summer and zero degrees in the winter (40 °C to –20 °C) could certainly do that.

The second problem was that one of the tubes had an open filament. This is not a major problem today. It’s easy to go to eBay or to one of the many antique radio sites on the internet to find a replacement. However, when I got this the internet didn’t exist. Trying to locate a tube
power for the filaments usually came from a 6-volt automobile battery. Filaments were wired in parallel, so there was no problem with substituting different tubes which had different filament ratings.

Tubes had to be devoid of oxygen. Otherwise the filament would oxidize (burn!) and fail. There were two general methods for accomplishing this. The first was to put a vacuum into the tube. Unfortunately, vacuums of the day weren’t all that good. So, in order to eliminate the remaining oxygen a “getter” was inserted into the envelope. The getter was a chemical that reacted and bound up all the free oxygen. Getters caused the discoloration on the inside of the tube envelope. Different getters created different colors. Generally the color was silver-black. But some were bright blue and others were iridescent.

The second method was to place an inert gas into the tube—typically argon. This eliminated the getter and the glass envelope is perfectly clear. Of course, the problem with argon is that it breaks down at high voltage and glows a nice blue (very similar to the classic neon lamp). For some reason, detector tubes (UX-200A) usually used argon and RF (UX-201A) tubes used getters. Perhaps because detectors used lower voltages and there was less chance of breakdown/ionization.

The last problem wasn’t really a problem. The two AF tubes were not the ones specified. They were apparently substitutes. All of the tubes of that time were simple triodes and many were interchangeable. They could amplify by a factor of about 8. (The minimum gain of a 2N2222 transistor is 50.) Instead of the two UX-201A tubes, there was a UX-200A and an SX-112A tube (Figure 5). The SX-112A was a newer tube designed for audio output. It could provide a whopping 200 milliwatts of power.

Batteries

The Model 30 needs five direct voltages: 90, 67.5, 22.5, 6 and −4.5. These are supplied by batteries. The 90 volts is used to drive the head-phones. The 67.5 volts goes to the plates of the RF amplifiers and the first AF amplifier. The detector tube uses the 22.5 volts. The 6 volts powers the filaments. The −4.5 volts biases the final AF amplifier. (It draws no appreciable current and can last for years.)

Obviously, batteries had to be replaced on a regular basis. So, the operating costs of an early radio were significant. It wasn’t until a few years later that AC powered sets became widely available. And that was because of the development of rectifier tubes that could handle the power requirements.

Construction Details

There are some interesting construction details surrounding the RF coils. The back of the case is routed out in three places by about a quarter of an inch to provide clearance space for the
Regulars

coils. Figure 6 shows the chassis removed from the case. This seems like a design error. I would think that the case would normally be designed to accommodate the coils to begin with. The second detail is that the three coils are mounted at right angles to each other (Figure 7). This is done to reduce inductive coupling between them. Without this, there would probably be leakage that would feedback and initiate oscillation. Oscillation was a significant problem in early radios.

Lastly, the RF coils are actually transformers. There is another winding inside of the coil. I do not know if this was the standard method at the time or if this is associated with Atwater Kent. It is certainly an unusual technique.

Turning the Page

The battery-operated TRF radios were pretty much gone by 1930. They were replaced with regenerative circuits that provided high gain and selectivity with fewer tubes, or with superheterodynes that were similar to today’s radios. AC operation became standard and the prices for radios plummeted.

Unfortunately, my collection of huge radios didn’t survive my going to college and living in a small apartment. Of the three special pieces I had (the Silvertone, the AK-30 and the Ediphone) I was only able to keep the AK-30 and Ediphone. I gave the colossal Silvertone to my older sister. However, I don’t think she appreciated the gift. It was gone in a year or so. Too bad. Currently the going price for that in near perfect physical and electrical condition is about $1000.

Web Links

[1] www.atwaterkent.info
ORDERING INFORMATION

To order, contact customer service for your region:

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During Elektor’s 60+ years’ existence the lab and editorial teams must have built, handled and demoed hundreds of prototypes for the projects that made their magazine famous. A lot of hardware built in the old days got junked in 2007 during a move to new offices. A few items escaped our cleansing frenzy though, mainly thanks to a few headstrong and proud guys from the lab aided and abetted by a zealous Retronics Editor.

In the huge attic here at Elektor House we still cherish a small collection of Elektor hardware and projects and related stuff that defined the his-
tory of the lab, the magazine and the publishing company as a whole.

We hope you recognize some of the old stuff here: we have the Formant, the Elektor Junior Computer, the ‘Mondrian’ Plotter, items from high-end audio series, the Edwin amplifier, the Filmnet Decoder, The ElektorScope, a whole pile of vintage measurement equipment and more.

The picture is available at high resolution on www.elektor-labs.com/attic so you can browse the shelves from the comfort of your chair .... only look, don’t touch!

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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.

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A good product for a good price is the hallmark of success. But an inferior product, at any price, will have a difficult time. It cannot be overstated that the quality of a new product must be exceptional. You’re challenging existing products so your ePod must stand out in some way. It must clearly superior in performance or else sell for considerably less than similar products. Customers must get more bang for their buck or else they will not change their buying habits. Examine your own buying habits. What will it take for you to change your grocery store?

A product that has bugs or performs poorly is devastating in two major ways. The first is that it immediately clobbers your sales volume. You’ll get few sales and a lot of returns. (Which you can’t re-sell as a new unit. But many start-ups do anyway. Can you say bad management?) The second is that it gives your business a poor reputation. So even if you correct the product, you’ve alienated your customer base. Never forget—your customers give you money! Cherish them and cultivate them. People expect and deserve a professional quality product. By going into production you’ve said to the world that you’re a professional and that your product is just as good, or better, than competing products. If you can’t deliver that, don’t try. All that will do is frustrate you and give your company a bad name.

Pricing
Start-ups often have difficulty in pricing their product. For example suppose your product costs $25 in parts and takes you an hour to assemble. Should your minimum selling price be $50 or $100? If you said $50 you’ll be out of business very quickly. Here’s why. Suppose you get an order for 1000 ePods. That’s 1000 hours of assembly time or 25 weeks of full-time effort. Very few customers are willing to wait half a year for delivery. So you will have to hire and train assemblers. Setting up your own company with employees, offices, insurance, equipment, taxes, etc. is not fast or cheap. An hour of technical labor plus overhead will be at least $25 an hour. So, right out of the gate, all your mark-up is gone. Even if you raise your price for other customers, you will have no profit from sales for at least six months. That’s a huge financial hurdle to overcome. Alternatively, you could contract out the assembly, locally. This will save you the set-up time, labor and overhead costs. However, the contractor is now paying for salaries and overhead. He expects to see a profit, so he will charge you more than what he is paying. Again you will see no profits for half a year. It’s very possible that you will actually lose money.

Finally, you could contract with an overseas assembly house. Their labor costs are very low and nowadays they are fairly easy to work with and no longer require huge volumes (10 Kunits or more). Of course, there are the problems of language, import/export rules, contract negotiation, shipping costs, etc. Then there is the concern of intellectual property protection. It is not unheard of for these contracting houses to manufacture your product and sell it for themselves. With their name on it! It’s no fun competing with your assembler. Initiating an international lawsuit is ridiculously expensive and time-consuming. Lastly, these cheap assemblers are notorious for poor workmanship. The bottom line on pricing is to assume a minimum cost of $25/hr for labor (which is still quite low). Your MINIMUM selling price should be twice the parts and labor costs. If this means that your selling price is not competitive, then you have a problem.

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This book on Digital Signal Processing (DSP) reflects the growing importance of discrete time signals and their use in everyday microcontroller based systems. The author presents the basic theory of DSP with minimum mathematical treatment and teaches the reader how to design and implement DSP algorithms using popular PIC microcontrollers. The author’s approach is practical and the book is backed with many worked examples and tested and working microcontroller programs. The book should be ideal reading for students at all levels and for the practicing engineers who may want to design and develop intelligent DSP based systems. Undergraduate students should find the theory and the practical projects invaluable during their final year projects. Similarly, postgraduate students should be able to develop advanced DSP based projects with the aid of the book.

428 pages • ISBN 978-1-907920-21-9
£44.90 • € 49.90 • US $72.50
Arduino Experimenter’s Shield

To perform simple experiments, such as those in the newly started Microcontroller BootCamp course, Elektor Labs developed a small experimental PCB for plugging on to practically any Arduino board. The shield contains two buttons, two LEDs, one potentiometer and level shifters for adjusting the logic levels of the Arduino board. In addition, the shield is equipped with a universal ECC connector.

Mini RGB Lamp with IR Remote Control

Lighting circuits with colored LEDs are all the craze nowadays. There are plenty of such RGB lamps for sale, but an electronics engineer naturally designs and builds such a device himself. This circuit is small and employs four LEDs connected in series and powered at just 5-V thanks to a simple voltage converter. The control is effectively via a standard RC5 remote control that allows, among others, color and brightness to be adjusted.

Touchfree Display Control

The Ootside Box mentioned in the March 2014 installment of Elektor World is a smart circuit that lets you detect hand movements from a distance by means of a metal frame around a tablet computer. The system allows you to operate programs and games with simple gestures. Next month we present the hardware and software designed for this purpose.

We regret that ‘Intelligent Cuelight System’ and ‘433 MHz Gateway’ could not be published in the current edition as scheduled.

Article titles and magazine contents subject to change, please check www.elektor-magazine.com for updates.
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