Overview

- RF Spectrum 0-30GHz
- Wireless Connectivity

Build this

- RFID Detector
- Wireless Microphone
- DVB-T Butterfly Antenna

Elementary Robotics: Walking Bug
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RFID frenzy

Way back in November 1998 we already published an extensive article about active RFIDs — chips that can be interrogated over radio. Since then no major changes have been seen in RFID technology, and yet the popular press now seems to have discovered RFIDs for the first time. The articles are almost invariably grossly inaccurate when it comes to technology, one reporter even claiming that all RFIDs ‘radiate waves’ and by their sheer numbers present a serious health hazard.

Initially I wondered what could have triggered this sudden interest in a technology that’s been around for almost 30 years but then realized that the latest in active RFID equipment fits ‘Big Brother’ scenarios perfectly. Recently, a critical limit must have been exceeded in customer concern about privacy.

Traditionally, RFIDs are applied in logistics (goods tracking) and security systems, for instance, the ignition immobilizer controlled by your car key. Today’s use of RFIDs in the retail trade heralds a new era: RFIDs are invading our daily lives. As opposed to ‘personal’ data carriers like swipe and chip cards, RFIDs can be read and even overwritten from a distance and without the customer noticing. Lots of things can be RFID’ed invisibly: goods and packaging materials, ID cards, plastic cards and even bank notes according to a recent study carried out by the European Bank. There seem to be no limits to what ultra-miniature RFIDs with sub 1-mm2 surface areas can do, except being traced easily! The same applies to the latest radio bugs employing spread-spectrum techniques and consequently being almost impossible to discover — see the article ‘Wireless Connectivity’ in this issue. Curiously, I do not read about the latest in RF bug technologies in the popular press, despite the fact that RF energy is radiated almost constantly whereas an RFID is silent until interrogated by a nearby transmitter. I must be reading the wrong papers.

Jan Buiting, Editor

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**Elementor electronics**

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Wireless data communication is the latest rage. From wireless mice to Formula-1 telemetry systems, digital radio systems are used in many applications, and they are penetrating into many new areas. In this article, we examine the current state of affairs in the 'airwave jungle'.

When the ISM frequency band was made available in Europe for audio applications, Circuit Design, a manufacturer of professional RF modules, decided to develop suitable high-quality transmitters and receivers with a wide dynamic range: these are ideal for use in wireless microphones.
Walking Bug

Making a robot walk instead of drive around on wheels can be a daunting task. The author of the Walking Bug came up with a remarkably simple solution.

RFID Detector for 13.56 MHz

This article describes a sensitive detector that will faithfully produce a sound in response to pulses picked up from an 13.56 MHz RFID tag transmitter, be it large or small, 'portal' or 'portable'.

Butterfly Dipole for DVB-T

Digital terrestrial television (DVB-T) is now available in many parts of the country. Of course, you need a DVB-T receiver and a (new) UHF TV antenna. If you don't have a suitable antenna, the small indoor DIY alternative described here is a simple and economical solution.

Construction Projects

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5 volts Direct from the Mains
Dear Sir — as a qualified engineer, I was rather disturbed to read of Circuit #009 (5 volts from the Mains) in your Small Circuits Collection in the December 2004 edition. Though I am sure that the design will work as intended, this circuit could be potentially dangerous in the hands of an amateur, and, despite warnings in the article, I feel it should not be encouraged as a construction project where it may be read by readers with little appreciation of the dangers of the mains voltages entering the home. As you know, domestic mains voltages are referenced to ground through local earthing at substations. Consequently with a 230 Vrms input supply, it is possible for the circuit to have voltages over 600 volts on its output relative to earth... especially should there be a failure of semiconductors or other components. As we all know, semiconductors can be fickle and it is just for these good reasons that your article mentions the usual use of the isolation transformer in such circuits. Even without the fuse in place, the circuit is still potentially dangerous... primarily due to a lack of mains polarisation. When working with high voltages, it is just as well to remind ourselves that even very small currents can be lethal. The statistics of the high incidence of mortality rates among electronic and electrical engineers should not be ignored.
R.B. Willis (UK)

Although it is stated in the article that constructors must make sure "no conductive parts can be touched when the circuit is in use," we should have added: The circuit powered by the proposed supply must be incorporated in the same, electrically safe, enclosure as the supply in such a way that no component can be touched. Never, under any circumstances, should the proposed supply be used to power external circuits requiring a supply of 5 volts.
The magazine editors and designers apologize unreservedly for this omission and warn inexperienced readers not to attempt building this circuit.
We are grateful to Messrs. R.B. Willis (Kingston upon Thames) and P. Lipscombe (Portsmouth) for bringing this safety hazard to our attention.

Nigcd battery advantages
Dear Editor — your reply to Mr. Price's letter 'NiCd batteries — environment vs. quick profits' in Mailbox, November 2004 should have included a word or two about significant advantages of NiCd cells over NiMH and other battery technologies.
For one thing, NiCd batteries can operate over a large temperature range. This advantage is often exploited in emergency lighting units that must be relied upon to keep working at ambient temperatures approaching 70 degrees C. At such temperatures NiCd battery has hardly any capacity. Also, NiCd batteries can handle heavier loads, which is a 'must' not only in power tools like cordless drills but also in RC models. These characteristics are not (yet) equalled by NiMH batteries. Converting a cordless drill to run from NiMH batteries is sure to end in disappointment. In most cases, replacing NiCd batteries with NiMH counterparts is certainly advantageous, but the above examples go to show that there are a number of applications where NiCd technology continues to 'rule'. In these cases, replacing the battery pack by a NiMH version requires a complete redesign. My reply is not intended as a plea for the continued use of environmentally hostile NiCd batteries, but to supply factual information for an interesting debate.
Mark Vermeulen (Netherlands)

Your additions are much appreciated. Any more views?

Vehicle Battery Jogger
Dear Jan — I downloaded the PCB layout for the Battery Jogger from your website, and I think it contains an error. I believe the connection from the positive (+) connector to the discharge resistor is much too thin for the current involved.
Kåre Gorm Hansen (Denmark)

Karel Walraven replies — If a continuous current of 40 A would flow, this track surely would burn out. However, the duty cycle of the signal being very small the PCB track will easily survive the average current. We did this on purpose because it acts as a fuse. See also 'Exploding Bits' in last month's Mailbox.

DCI PLC goes Internet
Mr. Ivo de Coninck, designer of the popular DCI PLC (Elektor Electronics June 2001) kindly advised us that he is busy writing software that will enable the entire PLC to be accessed from a PC using web pages. The hardware link is formed by the Ethernet network extension card of the Elektor Electronics Micro Web Server (July/August 2004). Further information on http://www.scarlet.be/~dc11cd/dcieth.html

211 Elektors
Dear Editor — I am clearing out my magazines. I have copies of Elektor magazine from issue 1 to 211. Are you or any of your readers interested in them? One condition is that if so they must be col-
lected from my home in Hemel Hempstead.

Mike Pearson (UK)

Interested readers please contact the Editor for Mike’s contact details.

Connector parts (3)
Dear Editor — In the December 2004 Mailbox, Richard Austin was looking for some plugs and a reply was published in January 2005.

For years I have been using Molex units, and cutting the multi-way ones into smaller sizes with a sharp knife. Say getting the biggest (16 ways) and cutting them to whatever size I needed. This saved leaving to keep a whole lot of sizes that were never what you wanted on the day.

A scalpel works fine to cut and trim off any excess and yes you effectively lose one hole when you cut it. I always crimp the wire, using a small pair of needle nosed pliers to shut the crimp over the wire, then a pair of sidecutters to give a final squeeze.

Russell Stevens (New Zealand)

Armed with the information Russell kindly supplied, readers should be able to source these elusive connectors from their national Farnell representatives.

Ear Boggle
Hi Jon — I was interested to read Rev. Thomas Scarborough’s kitchen table project ‘Ear Boggle’ in the November 2004 issue of Elektor Electronics. I will probably build this auditory illusion as a bit of fun. If you want to hear another example of this process, listen to any recording of Tchaikovsky’s 6th Symphony. The tune you hear is not played by any instrument, but ‘bounces’ between the first and second violins making good use of the dichotic effect.

Alan Jones

Thanks for that Alan, I’m sure interested readers will care to get out their Tchaikovsky records or CDs and check the effect of this Easter Egg.

Russian Relief
Dear Editor — I would like to ask Elektor Electronics readers who are replacing their mobile phones, or have in their cupboard an old mobile phone and charger, PDA and expired SIMM cards, to donate them to us behalf of Russian Relief to help the less fortunate children. Some can be used by ambulance crews and doctors in remote areas, others for emergency use by people who are in various forms of danger to summon assistance. Some phones can now be used to make emergency calls even if they have been disconnected from a network. Used laser printer and ink-jet cartridges can also be recycled to help children in orphanages and hospitals. Please mail them to

Russian Relief, c/o E. Palusinski,

105 Bridget St., Rugby, CV21 2BX.
Howard Kettle, G4BAS (UK)

Obsolete electronics for charity instead of the landfill: a great initiative.

Corrections & Updates

USB/I2C Interface
December 2004, p. 52-58, 040334-1.

In Figures 2 and 4, the inputs and outputs of IC1 have been transposed. In both diagrams, pins 2 and 3, and 6 and 7, should be swapped over.

In the circuit diagram in Figure 1, the outer connection of the mains power socket is shown connected to ground while the centre pin carries the positive supply voltage. On the PCB designed for the project, these connections are the other way around.

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2/2005 - elektor electronics
World's smallest microcontroller

Microchip has introduced revolutionary 6-pin Flash devices in an ultra-small form factor SOF23 package. These devices provide an ideal solution for many markets and uses not typically served by microcontrollers today, including 'electronic glue' to enable, for example, easy bug fixes for ASIC and printed circuit board (PCB) designs, and to replace standard logic and timing components or traditional mechanical timers and switches. The PIC10F 8-bit Flash microcontroller family debuts with four members: PIC10F200, PIC10F202, PIC10F204 and PIC10F206 that offer 256 or 512 instructions (12-bit program words) of Flash program memory and 16 bytes to 24 bytes of data RAM memory. These devices also feature a precision 4 MHz internal oscillator, 33 instructions, two stack levels, 25 milliamp source/sink current I/O, low power (100 nanoamp) sleep current, a wide operating voltage range from 2 to 5.5 volts, one 8-bit timer, a watchdog timer, In Circuit Serial Programming\textsuperscript{TM} (ICSP\textsuperscript{TM}) technology, power-on reset, powersaving sleep mode and (in the PIC10F204 and PIC10F206 only) an analogue comparator module. With only six pins, they are extremely easy to use and have a short learning curve for anyone not experienced in designing with microcontrollers. Through ICSP technology, Microchip's 6-pin devices can be programmed after placement on a circuit board. ICSP technology enables field-upgrades, system calibration during manufacturing and the addition of unique identification codes to the system. The PIC10F family is supported by Microchip's world-class development tools, including the MPLAB\textsuperscript{R} In-Circuit Debugger (ICD2) development tool. The MPLAB ICD2 is a powerful, low-cost run-time tool that offers cost-effective in-circuit Flash programming and debugging from the graphical user interface of the true MPLAB Integrated Development Environment (IDE) software. This enables a designer to develop and debug source code by watching variables, single-stepping and setting break points. Running at full speed enables hardware tests in real-time. The MPLAB ICD2 uses a header board module to support the new PIC10F family. The PIC10F200, PIC10F202, PIC10F204 and PIC10F206 are offered in 6-pin SOF23 packages.

FireWire audio chip opens the way to affordable, high quality external sound

Providing PC and Mac\textsuperscript{R} platforms with up to eight audio output and now two audio input channels via a single FireWire connection, the latest version of Oxford Semiconductor's OXFW970 FireWire audio controller IC allows next generation audio systems to be easily added to desktop and notebook systems.

Harnessing the high bandwidth and quality of service characteristics of FireWire (IEEE1394A) and FireWire800 (IEEE1394b), OXFW970 high quality, multichannel audio solutions avoids the need to install separate sound cards in desktop computers. In addition, FireWire's power carrying capability means that smaller speakers will not require external power supplies. Linked to a FireWire bus by an IEEE1394 PHY, OXFW970 handles serial audio data conforming to the IEC61883-6 transmission protocol and AMB24 audio format. Sampling 24-bit audio packets at 96 kHz, the chip provides four 25 stereo audio outputs, producing eight high quality digital audio outputs for 7.1 surround sound speaker systems, and two audio inputs for musical instrument and microphone line inputs required in emerging GarageBand\textsuperscript{TM} applications. The 100-pin TQFP packaged OXFW970 is a highly integrated, low cost device that features an embedded ARM7 processor, high-speed buffer manager, RAM and 512 kilobytes of on-board Flash memory. Firmware upgrades are simply implemented using the FireWire interface and programming utilities provided by Oxford Semiconductor. Eight GPIO pins further extend the device capabilities, enabling for example control of an external DAC using a serial control interface.
**Integrated Linear Battery Chargers**

Microchip have released single-cell and a dual cell versions of a fully-integrated, charge-management controller featuring a charge-safety timer and a temperature monitor. These devices are introduced alongside the company's range of DC-DC Converters, Linear Regulators and PowerSmart battery managers and monitors.

The MCP7368X devices monitor charge and temperature status, giving the user full control and sophisticated protection. With an overall accuracy of ±0.5 percent, these devices maximise system runtime between charges and ensure that the battery-cell capacity is fully utilised without cycle-life degradation. Onboard safety timers and thermal monitors provide time- and temperature-based charge termination, protecting applications from defective batteries and increasing the battery safety. The devices also feature reverse-blocking protection, preventing an incorrectly installed battery from damaging the application. The MCP7386X family features a built-in pass transistor, which minimizes the number of external components and the overall footprint. In addition, these controllers extend battery life with a reverse leakage current of less than 0.4 microamps (typical) and supply a programmable fast-charge current up to 1.2 amps.

The MCP73861 device is specified from 4.5 V to 12 V; the MCP73862 device from 8.7 V to 12 V and both operate over a -40°C to +85°C temperature range. They are available in 4.1 V/4.2 V and 8.2 V/8.4 V to support one- or two-cell Lithium Ion / Lithium Polymer batteries (with coke or graphite anodes).

The MCP7386X devices are offered in a Pb-free 4x4 mm QFN package, which features excellent power dissipation, and therefore supports shorter charging times. Samples and volume production are available now. For more information, visit the Microchip website at www.microchip.com/mcp7386x.

**Battery Authentication and Safety**

Following recent news of "exploding" mobile phones, due to the use of counterfeit batteries, Microchip today announced that its KEELOG secure algorithm, as used by leading automotive manufacturers worldwide, can now be readily used for battery authentication in portable applications. The technology allows an application simply and securely to differentiate between genuine and counterfeit batteries.

Counterfeit batteries may violate both mechanical and electrical safety and security requirements relating to short-circuit protection, charge safety and other specifications and this can lead to a potentially dangerous situation for the end user.

Integrating Microchip’s PIC® microcontrollers into the host system, and one of their PowerSmart battery fuel gauge devices into the battery pack provides one of the industry's most secure authentication solutions.

Using the concept of IFF (Identify Friend or Foe) where the 'Friend' is an genuine battery, and the 'Foe' is a counterfeit one, KEELOG, with its proprietary encryption and decryption algorithms, provides a high level of security without adding excessive complexity to the system.

For more information on Microchip's PowerSmart battery fuel gauge devices, visit www.microchip.com/battery.

And for more information on Microchip Ltd., Microchip House, 505 Eksdale Road, Wimersh Triangle, Wokingham RG41 STU, Tel. (+44) (0)118 921 5869, Fax (+44) (0)118 921 5820, Website: www.microchip.com.
Battery-free Radio Modules

Using piezo and solar energy

Simply attach light switches or thermostats wherever or on whatever surface is most convenient. No worries about cutting channels for cabling or changing any batteries. These energy efficient, maintenance-free radio modules with built-in power converters are now opening up new possibilities for architects and interior designers. They have even found an application inside the humble car tyre.

Conventional wire-free sensors in office environments rely on a replaceable battery to provide power. This works fine for small buildings but for larger installations with a corresponding increase in the numbers of sensors/transmitters this can give rise to problems of data corruption when more than one unit transmits at the same time. Maintenance costs of battery equipment are also a consideration. For example a relatively large installation using 4000 sensors will on average require at least one battery replaced daily if the life span of each battery is assumed to be 10 years.

Energy for free

The modules from EnOcean do not need any batteries; instead they convert other forms of energy such as movement, light, heat or radiation into electricity. EnOcean currently employs piezo and solar energy sources but thermocouple and resonant piezo generators are also in development for use in vehicle tyre pressure sensing.

All of these sources only provide a small amount of energy because the transducers are required to be as small as physically possible to fit into standard switch enclosures. The Piezo converters used here supply approximately 200 μW each time the switch rocker mechanism is operated and we cannot expect much more than about 20 μW from the small Solar cell (10 mm × 20 mm) at 400 lux. Thermocouples are also unlikely to offer significantly more so it is important to ensure that the electronic circuit is as efficient as possible.

Saving strategies

The key to achieving low power consumption in the radio module is to use efficient design, ensuring that the electronics is activated only when necessary and for as short a time as possible. A table at the end of the article indicates typical values of power consumed for each activity performed by each of the modules currently available from EnOcean. RF power output is limited to 10 mW max, giving a range of up to 300 m. A short switch-on time also contributes to power saving along with:

- optimal radio protocol;
- high data rate (120 kbit/s);
- efficient modulation method.

The radio protocol is optimised to achieve low power consumption together with a high level of communication security while using minimum hardware. The modulation method used is incoherent ASK modulation and is particularly power hungry because each digital ‘0’ is represented by the HF oscillator turning off completely. Careful design ensures that the oscillator is stable again within 1 μs of switch on. Modules communicate using the ISM frequency band of 868.3 MHz in Europe while 915 MHz is used in the USA and 2.45 GHz for most of the rest of the world.

<table>
<thead>
<tr>
<th>Table 1. Energy needs for each module function and mean power requirements of EnOcean radio modules in typical applications.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
</tr>
<tr>
<td>Energy for measurement event (μW)</td>
</tr>
<tr>
<td>Energy for sensor control, interprocess (μW)</td>
</tr>
<tr>
<td>Energy for RF transmission (μW)</td>
</tr>
<tr>
<td>Total energy needs for measuring and transmitting</td>
</tr>
<tr>
<td>Transmissions per minute</td>
</tr>
<tr>
<td>Power consumption</td>
</tr>
</tbody>
</table>

12
Modules
The PTM 100 piezo powered module shown in Figure 1 transmits on 868.3 MHz with a maximum power output of 10 mW. This module replaces a standard wall-mounted light switch. The RF link was specially designed for switching in the field of building control. The module size ensures that it fits inside the type of enclosure used by the majority of electrical suppliers. The light switch seen in the picture background is fitted with an RF module. Each module contains pre-installed software enabling simple control for the following applications:

- One, two or four gang light switch.
- Toggle switch function.
- Dimmer (integrated PWM output).
- Motor controlled window blinds.
- Serial data output for bus connection

The corresponding receiver module can be linked via a bus or fitted into a wall outlet, meter cupboard or light fitting.

Another versatile module is the solar powered STM 100 shown in Figure 2. The block diagram Figure 3 shows that there are three analogue inputs useful for measuring variables such as temperature, pressure or force etc. In addition there are four digital inputs that detect switch positions. The heart of the module is a very low power analogue timer circuit built using discrete components. This runs continuously so it is important for it to use as little power as possible, in fact it only consumes around 20 nA [1]. The [Goldcap] reservoir capacitor stores enough charge to keep it running for one week in complete darkness. The 1 x 2 cm solar cell only generates around 6 µW when exposed to a light intensity of 100 lux but because of the low power design it is sufficient to provide enough power for the complete module and also charge the Goldcap (see table). In addition to the two modules described here EnOcean also produce others powered more conventionally from a 5 V supply. These include two receiver modules, a repeater and a bi-directional radio module with modem function.

Further information from: www.enocean.com

Figure 1. The battery-free piezo transmitter module PTM 100 (on the switch plate). Individual components are seen in the foreground: Piezo converter (left), mechanical energy converter and PCB with Antenna. (source: EnOcean GmbH)

Figure 2. The STM 100 has three analogue and four digital inputs. Energy comes from a solar cell and is stored in a high value Goldcap capacitor.

Figure 3. Block diagram of the STM 100.
Wireless data communication is the latest rage. From wireless mice to Formula-1 telemetry systems, digital radio systems are used in many applications, and they are penetrating into many new areas. In this article, we examine the current state of affairs in the 'airwave jungle'.

![Figure 1](image_url)

*Figure 1: An excerpt from the international frequency allocation table.*

The enormous popularity of wireless communication is a direct consequence of international agreements to designate certain regions of the radio spectrum as 'ISM bands', since widespread use of wireless connectivity would otherwise never have been possible. The demand for unrestricted mobile communication is the driving force behind the rapid development of technologies such as Bluetooth, WLAN, HomreRF, and other new technologies with resplendent names. When we talk about WLAN or Bluetooth, we’re talking about applications employing ISM. 'ISM' stands for 'Industrial, Scientific & Medical', which means radio services in these fields. The ISM bands can be used without a licence, and they are subject to relatively little regulation. The only restrictions relate to the maximum transmitted power and (naturally) the bandwidth, which must be kept within certain limits. Besides the traditional 27-MHz ISM band (used for CB radio), there are now ISM bands in the 433 MHz, 868 MHz, 2.4 GHz and 5.8 GHz regions. The currently used bands and their individual characteristics are summarised in Table 1.

Naturally, the fact that the ISM bands are subject to minimal regulation is both a blessing and a curse. As there are no restrictions on the number of transmitters and no defined protocols, reliable data transmission cannot be guaranteed if simple data transmission techniques are used. The fact that the ISM bands must share the airwaves with other users, as well as the existence of other potential sources of interference, can be readily seen from the poster-sized international frequency allocation chart. Figure 1 shows the allocations for the 2.4-GHz and 5.8-GHz ISM bands, which are the most important bands for wireless networking. The complete chart can be obtained free of charge from [http://www.ntia.doc.gov/osmhome/osmhome.html](http://www.ntia.doc.gov/osmhome/osmhome.html).

As you can see, a large number of other radio sources are also active in these bands, with amateur radio transmitters being the most prominent. Microwave ovens and radar signals can also do a good job of polluting the airwaves in these bands and making reliable data transmis-
sion more difficult. This means that techniques for avoiding and overcoming mutual interference are necessary if these bands are to be widely used for data traffic.

**Spread-spectrum techniques**

This problem can be solved relatively easily by taking a peek at the techniques used by the military and copying their well-proven strategies. The magic word here is 'spread spectrum', which amounts to modulating a narrow-band information signal in order to significantly increase its bandwidth while at the same time considerably reducing its level. An outstanding signal-to-noise ratio is obtained when the signal is recovered, even if the level of the spread-spectrum information signal is below the general noise floor before recovery. As a rule of thumb, the increase in the signal-to-noise ratio corresponds to the ratio of the transmitted bandwidth to the bandwidth of the information signal. It's hardly any wonder that the military are so fond of this technique: not only does it allow them to send messages undetected, since the radio signals disappear into the noise of the airwaves, but it also enables them to obtain considerably better transmission quality than with conventional systems.

Two methods for generating spread-spectrum signals have come to prevail, and both of them are presently used commercially.

**Direct Sequence Spread Spectrum (DSSS)**

This technique for increasing the bandwidth occupied by the signal is essentially simple: the information signal is modulated by passing its data bits through an exclusive-OR gate along with a pseudo-noise-code (PN code) signal before they reach the antenna (Figure 2). This causes the transmitted power level to drop below the noise limit, so the signal can only be picked up by receivers that use the same PN code. To give an example, if a 2-Mbit/s signal is spread using an eleven-bit PN code, the resulting RF signal has a bandwidth of 22 MHz.

One example of an ISM transmitter IC using DSSS frequency spreading is the Micro Linear type ML2724 (Figure 3). This 32-pin IC, which operates from a 3.3-V supply voltage, works in the frequency range of 2.400–2.485 GHz using simple FSK modulation, and it contains all the functional elements (VCOs, mixer and data slicer) needed to construct a functional radio system using only a few additional components. Using DSSS, it achieves a sensitivity of −90 dBm, which gives it a free-space range of significantly more than 100 meters in actual use. The transceiver is normally used without a transmission protocol, with the user data being simply fed serially into the Tx input and taken from the Rx output without any pre-conditioning or processing for data security. This is adequate for pumping data over the airwaves at up to 1,500 kbit/sec. Although the ML2724 is used in large quantities for game pads and wireless telephones, it also has more tricks up its sleeve. Its spread-spectrum capability makes it multiport-capable, which means that several ML2724 transceivers can communicate with each other concurrently. This capability is characteristic of all spread-spectrum techniques, and applications such as Bluetooth, WLAN and the like would not be possible without it.

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**Table 1. Commonly used ISM bands**

<table>
<thead>
<tr>
<th>ISM Band</th>
<th>Frequency range</th>
<th>Bandwidth</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISM 1</td>
<td>26.957–27.283 MHz</td>
<td>326 kHz</td>
<td>No persistent interference sources, low power consumption</td>
<td>High noise level due to CB radios</td>
</tr>
<tr>
<td>ISM 2</td>
<td>40.660–40.700 MHz</td>
<td>40 kHz</td>
<td>Relatively large bandwidth, good propagation, moderate price</td>
<td>Bandwidth too small, difficult to make antenna compact</td>
</tr>
<tr>
<td>ISM 3</td>
<td>433.050–434.790 MHz</td>
<td>1.74 MHz</td>
<td>Relatively large bandwidth, low occupancy, duty cycle limited to 10% in most of the band</td>
<td>High occupancy in certain areas (radio amateurs, radar)</td>
</tr>
<tr>
<td>ISM 4</td>
<td>868–870 MHz</td>
<td>2 MHz</td>
<td>Very large bandwidth</td>
<td>More expensive than 433 MHz due to dual superhet technology</td>
</tr>
<tr>
<td>ISM 5 Bluetooth etc.</td>
<td>2.4–2.483 GHz</td>
<td>83 MHz</td>
<td>Very large available bandwidth</td>
<td>Propagation problems (quasi-line-of-sight), interference from microwave ovens</td>
</tr>
</tbody>
</table>

*Others* | 5.8 GHz, 24.250 GHz, 122.5 GHz, >150 MHz

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**Figure 2**

Commonly used ISM bands

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**Figure 3**

Direct Sequence Spread Spectrum (DSSS)
Code Division Multiple Access (CDMA)

With the DSSS technique, frequency spreading is achieved by modulation using a pseudo-noise signal. This signal is also called the 'PN code', since it identifies an individual transmitter just like an identification code. The information signal can only be filtered out of the airwaves using the same PN code, with all other signals remaining below the noise limit. This makes it possible for several DSSS transceivers using different PN codes to share the same frequency band and communicate with each other concurrently without causing any problems. This technique is called 'code division multiple access' (CDMA), which essentially means 'multiple channels using code separation'.

Frequency hopping

The other important technique besides DSSS is frequency hopping (FH). As the best-known representative of this technique, Bluetooth divides the ISM band between 2402 MHz and 2483.5 MHz into 79 channels, each with a width of 1 MHz. The signal hops (jumps) between channels in a cyclic pattern at the rate of 1600 hops per second. This means that typical narrow-band interference sources can cause only minor damage to the transmitted data. Figure 4 shows how several Bluetooth nodes can share the same frequency band using different frequency-hopping sequences. In principle, the frequency-hopping sequence for the FH technique corresponds to the PN code for DSSS, since in each case mutual interference among the individual nodes is prevented by using a different spread-spectrum sequence for each node.

The FH technology used for Bluetooth demands quite precise channel frequency settings, with a tolerance of ±2.5 kHz, and exact compliance with the scheme of hopping to a new frequency every 625 ns. Due to these technical demanding requirements, it took several years of intensive development work before the first single-chip Bluetooth transceiver reached the market at a price suitable for mass-consumption products.

Wireless local area networks

Now that you understand the techniques described above, we can enlighten you a bit regarding the various types of wireless networks currently in use. As can be seen in Figure 5, frequency hopping is the technique used by Bluetooth and the original primitive WLAN standard, which bears the IEEE designation '802.11'. The more recent 802.11a, 802.11b and 802.11g standards are based on DSSS, since this spread-spectrum technique is easier to implement. Naturally, other types of radio links using conventional AM or FM modulation can also be used in the ISM bands; they are typically used for applications such as remote garage-door controls and other types of remote-action systems (using narrow-band FM).

Fourteen years after work began on developing the 802.11 family of standards, rapidly increasing market penetration of WLAN products can be seen in the form of public 'hot spots' in airports and railway stations, as well as wireless networks inside companies. The ranks of technology addicts and enthusiastic readers of Elektor Electronics have even anticipated this technology, with some rather remarkable results. What would you say to the idea of a WLAN antenna for less than €5? It's actually quite easy. All you need to make a working directional antenna is an empty tin, a few screws and a coaxial RF connector. This little marvel is called 'a cornenna', which is a combination of corn and antenna (Figure 6). Using inexpensive materials from a DIY...
shop, you can build an 802.11b antenna with a range of more than 50 km.

Currently, the most widely used standard is 802.11b, which employs the licence-free ISM band from 2.4000 GHz to 2.4835 GHz using the DSSS spread-spectrum technique. The range is 30–100 m with a transmitted power of 100 mW, which is adequate for most applications, although the raw data rate of 11 Mbit/s leaves something to be desired, since the value obtained in practice is rarely more than 4–6 Mbit/s. An additional drawback arises from the fact that in most WLAN networks a large number of clients want to communicate with each other, so the number of available channels can be quickly used up. The 802.11b standard defines 14 channels with a bandwidth of 22 MHz per channel, beginning with channel 1 at 2.412 GHz. Channel 2 starts at 2.417 GHz, offset from channel 1 by 5 MHz. The channels overlap, so they cannot all be used at the same time in a single network (Figure 7). If several access points are needed in a WLAN, it is possible to use (for example) channels 1, 7 and 14 concurrently.

More bandwidth
This means we need more bandwidth and more channels. The standardisation committee satisfied this need in 1999 with the introduction of the 802.11a standard. It utilises the 5.0 GHz ISM band and employs a modulation technique called ‘orthogonal frequency-division multiplexing’ (OFDM). This yields a raw data rate of 54 Mbit/s, although the range is only half as large. The total available bandwidth allocated to this band is 455 MHz, from 5.150 GHz to 5.725 GHz. Up to 19 non-overlapping channels are available, allowing the same number of access points to be used without mutual interference. Two years ago, the OFDM modulation technique was also introduced for the 2.4 GHz band via the 802.11g standard (2.4 GHz OFDM PHY). This means there are presently three ‘air interfaces’ available – 802.11a,

<table>
<thead>
<tr>
<th>Table 2. Radio standards for WLAN and WMAN*</th>
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<tbody>
<tr>
<td><strong>Standard</strong></td>
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<tr>
<td>---------------</td>
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<tr>
<td>SWAP 1.x, 05/1998</td>
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<tr>
<td>SWAP 2.x, 07/2002</td>
</tr>
<tr>
<td>802.11, seit 1997</td>
</tr>
<tr>
<td>802.11a, 09/1999</td>
</tr>
<tr>
<td>802.11a, 09/1999</td>
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<tr>
<td>802.11b, 07/1999</td>
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<tr>
<td>802.11g, 06/2003</td>
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<tr>
<td>802.11h, 09/2003</td>
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<tr>
<td>802.11n, (anticipated 2005)**</td>
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<tr>
<td>802.16, 12/2001</td>
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<tr>
<td>802.16a, 01/2003</td>
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<tr>
<td>802.16e, 2004</td>
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<tr>
<td>802.20, 2004</td>
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<tr>
<td>HIPERLAN/1, 07/1998</td>
</tr>
<tr>
<td>HIPERLAN/2, 04/2000</td>
</tr>
<tr>
<td>HIPERACCESS</td>
</tr>
<tr>
<td>HIPERMAN</td>
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</tbody>
</table>

* 'WMAN' stands for 'Wireless Metropolitan Area Network', which is a WLAN for a relatively large region (city or district of a city). A WMAN is larger than a WLAN but smaller than a WAN (wide area network). Just as the Wi-Fi Alliance strives (and still strives) to achieve compatibility and interoperability for 802.11-based WLAN systems, the WMax forum, founded in 2001, pursues the same objectives for WMAN equipment compliant with the IEEE 802.16 family of standards. Starting in 2006–07, WMAN could become a competitor for UMTS.

** Draft version; standard unlikely to be approved before 2007.
that most of the emitted RF energy goes unused. That may be a reasonable approach for mobile systems, but in fixed installations the transmission distance can be considerably increased by using directional antennas. There are several ‘classic’ antenna designs that yield directional characteristics, such as Yagi antennas and dipole arrays. However, a much simpler solution is a waveguide enclosed at one end, in which a standing wave is generated by suitable mechanical dimensioning. Figure 8 shows the basic design of such a 'tin-con' antenna. Here, \( L_0 \) is the length of the standing wave in the antenna (with the maximum being located at \( L_0/4 \)), and \( L_0 \) is the wavelength of the carrier frequency in free space. The size of the tin and the frequency jointly determine the length of the standing wave. Instructions for building a Contera like this and the calculation of \( L_0 \) can be found on numerous Internet sites, such as http://www.turnpoint.net/wireless/conterahowto.html and http://www.saulolafj fed/antenna2.html. With careful construction, it is certainly possible to achieve a respectable antenna gain. Measurements show that the range can be increased by at least a factor of two.

**MIMO**

Increasing antenna gain by a few decibels is by no means the only trick that can be conjured out of the magic box of RF technology. Multiple-input, multiple-output (MIMO) technology is also proposed as a means to significantly increase range and data rates without increasing RF power. What lies behind this name is a sophisticated antenna technology called 'phased-array antennas', which originates from radar systems. A phased-array antenna consists of a two-dimensional array of dipole elements, which produces a radiation pattern with a strongly focussed lobe. If the dipoles are driven in phase by an RF signal, the antenna radiates a plane wave perpendicular to the array. This yields a considerable increase in range and eliminates multipath effects at the receiver.

If the relative phases of the RF signals fed to the individual dipoles are modified in a suitable manner (Figure 9), the direction of the lobe can be steered in almost any desired direction without making any mechanical changes. The only thing that is necessary for implementing an antenna that can emit a beam of RF waves in almost any desired direction, similar to the beam from a lighthouse (Figure 10), is the ability to control the phase relationships of the individual elements of the antenna. Although this technique does not increase the total amount of energy radiated by the transmitter antenna (which means it still complies with the regulations), it considerably increases the amount of energy arriving at the receiver antenna.

**Antenna diversity and receiver combining**

Up to now, we have concentrated on the transmitter end in our efforts to boost the performance of our WLAN. However, MIMO also encompasses improvements at the receiver end to raise the total physical capability of the system. The initial objective is to solve the problem of multipath effects. Especially in enclosed spaces, radio waves do not travel to the receiver antenna along only one path, but instead along many different paths that result from multiple reflections. The reflected signals are offset in phase from the main signal, and the net result of superimposing the reflected signals on the main signal can dramatically reduce signal quality and thus decrease the usable range. This makes antenna position a decisive factor, and changing the position of the antenna by only a few centimetres can be enough to make good recep-
tion considerably worse or dramatically improve poor reception. For this reason, current WLAN implementations already have two receiver antenna paths, which are demodulated in two independent RF front ends of the WLAN chip set. For each transfer (transmit and receive), the baseband controller checks which of the two paths provides the better result and selects it to be used for further processing. This technique is called ‘antenna diversity’.

**Spatial multiplexing**

Antenna diversity is aimed exclusively at improving results at the receiver end, and it can be used even if the transmitter end has only one antenna. However, if multiple antennas are used at both ends of the path, even more refined technical tricks can be used to improve the air interface.

It's clear that when radio waves in the centimetre-wave range are used for data communications inside a building, closely adjacent locations can have quite different data transfer characteristics. This knowledge can be used to cleverly transform the problem of multipath reception into a major benefit. If at least two antennas are used for both transmission and reception, it can be assumed that the two transmit–receive antenna pairs do not use the same path through the air, but instead two different paths. In theory, these two transmit–receive paths can actually be regarded as two separate channels, despite the fact that they use the same carrier frequency, so they can transfer different information and thus double the bandwidth (Figure 11). In practice, of course, the two paths do not behave exactly like two mutually isolated channels. Nevertheless, a significant increase in bandwidth can be obtained using this technique, which is called ‘spatial multiplexing’.

**Combination therapy**

There's a very good chance that MIMO will be included in the upcoming 802.11 WLAN standard, although the standard is unlikely to be approved before 2007. Nevertheless, manufacturers of WLAN chip sets, such as Atheros, are already anticipating the new standard with new generations of ICs incorporating ‘pre-802.11n’ features. For instance, the AR5005VA chip set has all the technical capabilities necessary to allow it to be made 802.11-compliant by simply updating the driver software after the standard has been firmly defined. The chip set has two RF front ends, so the MIMO tricks described above can be implemented using two antennas for the transmit and receive functions. A data rate of more than 100 Mbit/s can already be achieved using the AR5005VA, which is enough to allow even HDTV video to be transferred over a wireless network.
When the ISM frequency band was made available in Europe for audio applications, Circuit Design, a manufacturer of professional RF modules, decided to develop suitable high-quality transmitters and receivers with a wide dynamic range: these are ideal for use in wireless microphones.
The WA-TX-01 (transmitter) and WA-RX-01 (receiver) modules represent a novel concept in the wireless transmission of audio signals. Thanks to low power consumption, the technology lends itself to a wide range of audio applications. The transmitter and the receiver include components such as SAW filters, SAW resonators and noise reduction ICs. These key components allow the development of small high-quality audio modules in accordance with European radio regulations and with EMC and R&TTE guidelines. This means that a wireless link can be added to an audio device without having to worry about a complicated, expensive and time-consuming certification process. The frequency channel used by each module is fixed, but there are four separate channels available in the band from 863 MHz to 865 MHz, and so multiple systems can coexist in the same location.

**Dynamic transmission**

The maximum sound pressure level (SPL) which can be tolerated by humans is 140 dBSPL, which is measured relative to the minimum audible sound pressure level of 0 dBSPL = 20 μPa. In a quiet room the background noise level is about 20 dBSPL, and the sound pressure level of the human voice is around 120 dBSPL. It can therefore be seen that the dynamic range required for a normal wireless audio transmission system is around 100 dB.

If an audio frequency of 15 kHz is transmitted using analogue frequency modulation, the required bandwidth (BW) is given by:

\[
BW = 2 \times (\text{maximum frequency deviation} + \text{maximum modulation frequency}) \text{ [Hz]}
\]

Unfortunately any FM circuit must suffer from residual sideband noise originating in the PLL or crystal oscillator. As a rule of thumb, we can reckon with a residual noise, measured in terms of frequency shift, of around 50 Hz. For a dynamic range of 100 dB (i.e., a factor of 100 000), we therefore need an overall frequency deviation of 50 × 100 000 = 5 MHz. As you might expect, this means that the required bandwidth is much greater than that available in this application. For comparison, FM radio transmissions make do with a maximum deviation of 75 kHz in a bandwidth of 180 kHz (mono) or 264 kHz (stereo plus traffic data).

In order to solve this problem while keeping within the legal restrictions on frequency deviation, a compressor is built into the transmitter and an expander into the receiver. This technique is called a compander noise reduction system (Figure 1).

The Dolby noise reduction system varies the compression ratio with frequency. The compander noise reduction system used here, on the other hand, fixes the compression ratio at 2.1 over the entire frequency range, thus halving the dynamic range of the signal. In the expander, whose ratio is set to 1.2, the exact opposite occurs, and the dynamic range is doubled again. A dynamic range of 100 dB is thus reduced to 50 dB for transmission.

We can now recalculate the frequency deviation required. With a residual noise of 50 Hz we need a frequency deviation of 500 Hz for a 20 dB dynamic range, 5 kHz for 40 dB, and 20 kHz for 52 dB. A wireless system with a signal-to-noise ratio of 50 dB can carry sound signals with an original dynamic range of 100 dB.

Why, in this ‘digital age’, do we employ analogue transmission techniques for the wireless microphone rather than, for example, PCM? There are several reasons. Many countries have not allocated a dedicated frequency band for digital wireless microphones. Digital transmissions using PCM require a wide frequency band, which is not readily available below 1 GHz. Above 1 GHz ‘dead spots’ start to appear, meaning that these frequencies are not suitable for live use where the performer may move around between various positions on stage. Finally, conversion to digital requires much more power, making it less practical to run the device from small batteries.

If desired, the modules (both receiver and transmitter) can be operated from a 1.5 V battery via a low-noise DC-DC converter available from Circuit Design. In order to achieve the 100 dB dynamic range that is possible with the wireless microphone, the noise produced by the DC-DC converter must be less than –60 dBm. The WA-DC-01 DC-DC converter requires an input voltage of at least 0.9 V and can produce an output voltage of 3 V at the maximum load current of 50 mA.

**The transmitter**

Figure 2 shows the functional blocks of the WA-TX-01 transmitter. We will look at each in turn.

**Input buffer (BUF)**

This circuit is an input buffer for the microphone capsule or other sound signal source. The maximum input level is –15 dBV and the input impedance is 7.5 kΩ. If the maximum output level of the signal source is not sufficient, a low-noise amplifier must be connected before the buffer. If the signal source level is too high, an attenuator should be used.
Compressor
The audio signal from the buffer stage is compressed using a ratio of 2:1. The compressor consists of a reference generator, a full-wave rectifier and a summing amplifier. The reference generator provides a bias voltage and a constant current to the other parts of the circuit. The full-wave rectifier circuit rectifies the incoming signal with the aid of an external capacitor. The output current of the rectifier controls the gain cell amplifier. The time constant of the control loop is set, in part, using an external filter capacitor and an internal 10 kΩ resistor. The summing amplifier adds the incoming signal and the signal from the gain cell amplifier together. The summing amplifier used in the compressor needs different properties from the one used in the expander, and so different components are used in the transmitter and in the receiver.

Pre-emphasis
To reduce noise at the upper end of the audio frequency range, which is a particular problem when using frequency modulation, this circuit boosts higher frequencies using a time constant of 50 μs.

AF low-pass filter (AF LPF)
This circuit limits the bandwidth of the audio signal in order to ensure that interference to adjacent channels is kept within the permitted limits.

Oscillator and modulator
In order to operate directly in the 800 MHz band, a crystal-based SAW (surface acoustic wave) filter resonator with good temperature stability is used as the oscillating element. Frequency modulation is achieved using a varicap diode that forms part of the oscillator circuit.

RF power amplifier (PA)
This circuit steps the RF output of the oscillator up to the transmit power of about 5 mW.

RF low-pass filter (RF LPF)
This circuit attenuates the second and higher harmonics of the transmitted signal and provides antenna impedance matching.

Voltage regulator (AVR)
This circuit provides a stable 2.7 V supply for the whole circuit. It operates from a battery supply of between 3 V and 9 V.

The receiver
The block diagram of the WA-RX-01 receiver module shown in Figure 3 is practically the mirror image of the transmitter, using similar components.

RF band-pass filter (SAW)
The 800 MHz frequency band used in this wireless audio system is extracted using this filter. A high-selectivity SAW
filter is used to ensure that frequencies outside the band are eliminated.

Oscillator (OSC)
A quartz crystal oscillator is used to mix the incoming signal down to an intermediate frequency of 10.7 MHz.

RF amplifier (LNA)
A low-noise amplifier is used to amplify the 800 MHz frequency band by 10 dB.

Mixer (MIX)
This circuit creates an intermediate frequency of 10.7 MHz, produced by mixing the amplified received signal in the 800 MHz band with the output of the oscillator.

IF amplifier (IF1 to IF3)
These provide a total gain of 100 dB, the final stage acting as a limiter. Before and after the amplifier chain, 10.7 MHz ceramic filters are fitted to provide selectivity.

FM detector (DET)
This circuit demodulates the frequency-modulated IF signal.

RSSI detector (RSSI)
Signals from the middle of the IF amplifier chain are rectified producing a DC voltage proportional to the signal strength.

Muting comparator (COM)
The RSSI signal is compared to a preset voltage which can be adjusted using a potentiometer. If the level at the antenna input falls to 17 dB/\text{V} or less, the output signal is turned off.

De-emphasis
This compensates for the 50 \(\mu\text{s}\) pre-emphasis, making the overall frequency response of the system flat.

AF amplifier (AF)
This circuit amplifies the demodulated audio signal before it is passed to the expander.

Analogue switch (SW)
If the signal strength falls too far, the audio signal is muted using this switch. An LED indicates when this muting occurs.

Expander
The dynamic range of the audio signal is doubled by this circuit, which operates in much the same way as the compressor.

AF output amplifier (AF)
The output of the expander circuit is amplified again for output.

Voltage regulator (AVR)
This circuit provides the entire circuit with a stable 2.7 \text{V} supply from a battery voltage of between 3 \text{V} and 12 \text{V}.

Interface
Thanks to these complex modules that include almost all the necessary electronics, what remains is straightforward. Figure 4 shows the two parts of the circuit. In the transmitter we can either connect a microphone or any other desired audio source with a maximum output level of ~15 dBV. In most cases, however, an electret microphone will be used. There is a small offset voltage present at the AF input with P1 adjusted to maximum: in out prototype we measured about 0.15 \text{V}. If a dynamic microphone is to be connected, it is essential to add a coupling capacitor. Alternatively, omit R1 and connect the dynamic microphone in place of the electret microphone. P1 can be used to attenuate microphone signals that are too high, so that the radio module is not overdriven.

The receiver circuit is slightly less simple. The receiver module has two outputs, one for the signal itself and one which indicates whether the signal strength is adequate or whether the muting circuit has been triggered. Since we have plenty of power to spare at the receiver (battery operation here is not essential) we can afford an extra indicator in the form of LED D1. In order to amplify the output of the receiver module (which, at 10 \text{dBm}, is not exactly low impedance), we have added a buffer amplifier. This is a classical non-inverting AC amplifier built around a rail-to-rail opamp which can operate from a voltage of between 2.7 \text{V} and 12 \text{V}, almost the same range as for the module. We have shown a supply voltage of 5 \text{V}, although 3 \text{V} or 12 \text{V} would do just as well. If a different (non-rail-to-rail) opamp were used, a supply voltage of 5 \text{V} would be required. Many opamps will only operate correctly with a symmetric power supply of \pm5 \text{V} or

Figure 4: Interfaces for the radio modules.
Figure 5. Two circuit boards make one radio link.

COMPONENTS

LIST

Resistors:
- R1 = 2kΩ
- R2, R8 = 560kΩ
- R3, R4 = 22kΩ
- R5 = 4kΩ
- R6 = 47Ω
- R7 = 100kΩ
- P1, P2 = 10 kΩ preset

Capacitors:
- C1, C6 = 4μF 63V radial
- C2, C7 = 100μF
- C3, C5, C8 = 10μF 63V radial
- C4 = 470μF

Semiconductors:
- D1 = LED, 3mm, green, low current
- D2 = LED, 3mm, red, low current
- IC1 = WA-TX-01 (Circuit Design)
- IC2 = WA-RX-01A (Circuit Design)
- IC3 = T5921N (or equivalent rail-to-rail opamp)

Miscellaneous:
- JP1 = 2-way pinheader with jumper [angled if necessary]
- K1 = 3.5-mm jack socket, PCB mount (e.g. Conrad Electronics # 732893)
- T1 = battery holder for two 1.3V batteries
- Mic1 = electret microphone
- PCB, no. 040402-1, available from PCBShop

with an asymmetric 10 V supply. A further advantage of the TSS21 used here is its high output drive capability: it can directly drive headphones or even two 32 Ω headphone transducers wired in parallel, although in this case C6 should be replaced by a 100 μF 10 V type. The 47 Ω output resistor protects the opamp from the inductive load of a shielded cable and from short circuits. Trimmer potentiometer P2 allows the gain to be adjusted from unity (P2 at minimum resistance) to 10 dB (P2 at maximum resistance). C6 removes any DC component from the output and R7 ensures that there is always a load at the output. Since the opamp has asymmetrical supplies, a capacitor (C5) is also required in the feedback circuit. R3 and R4 set the operating point of the opamp at half the supply voltage. C7 and C8 provide extra power-supply decoupling. At higher supply voltages it is necessary to increase the current-limiting resistors for the low-current LEDs so that the current through them does not exceed about 2 mA.

We have designed a two-part printed circuit board to accommodate the radio modules and the few external components (Figure 5). The layout is designed for optimum audio performance. The components should be fitted to the board, observing that the transmitter module can only be fitted to the copper side. An ordinary 3.5 mm jack socket provides the audio output.

All that remains are the antennas. In principle a stiff piece of wire with length 1/4 λ (78 cm at 800 MHz) will do the job; more professional antennas can be found on the Circuit Design website at http://www.cdr21.com/.

[Figure 5]
Frequency: 863.125 MHz, 863.625 MHz; 864.500 MHz; 864.875 MHz
RF channels: one (fixed)
Emission code: F3E
Range: approx. 50 m line-of-sight
Signal-to-noise ratio: 90 dB (with IF A filter)
Audio frequency range: 50 Hz to 15 kHz ± 3.5 kHz (output level -50 dBV ± 3 dB)
THD: 2.5% (@ AF 1 kHz, deviation = 15 kHz or 7.5 kHz)
Pre-emphasis: 50 µs
Operating temperature: 0 °C to 50 °C

Transmitter
Oscillator: SAW oscillator, crystal-based
RF power: 2 mW
Frequency stability: ±10 kHz
Pre-emphasis: 50 µs
Noise reduction: Compressor
Spurious emission: 1 µW maximum
Deviation: 15 kHz (1 kHz, @ -25 dBV)
Audio input level: -11.5 dBV to -15 dBV (1 kHz)
Audio input impedance: 5 kΩ
Supply voltage: 3 V to 9 V
Maximum module current consumption: 25 mA
Measured current consumption: 17 mA @ 3 V

Receiver
Receiver type: Superheterodyne
Mixer oscillator: Crystal-controlled
Intermediate frequency: 10.7 MHz
Noise reduction: Expander
Sensitivity: 21 dBmV (@ THD 2%)
Squelch sensitivity: 17 dBmV ± 4 dB
Audio output level [at module]: -20 dBV (deviation = 15 kHz)
Audio output impedance [at module]: 10 kΩ
Supply voltage: 3 V to 12 V
Maximum module current consumption: 30 mA
Measured current consumption [D2 on, R2 = R3 = 560 Ω]:
- 32 mA @ 3 V
- 40 mA @ 5 V
- 52 mA @ 9 V

Note: 0 dBV = 0.775 V

Curve A shows the overall transfer characteristic of the entire radio link, measured at minimum gain (green) and maximum gain (red). The input signal to the transmitter was at -46 dBV (approximately 5 mV). The output signal at maximum gain was at -31 dBV. The output signal of the receiver is 5 dB above the input level to the transmitter. With a higher input signal level the response falls off somewhat at higher frequencies, but the amplitude at 5.5 kHz is up to 3 dB higher than that at 1 kHz.

Curve B shows the distortion (plus noise) at the output of the receiver against signal level, measured over the frequency range from 22 Hz to 22 kHz. The optimum value appears to occur with an input signal level at the transmitter of 5 mV. In this case the input signal is raised from -70 dBV to -15 dBV with the gain at the receiver is at a maximum. This is more than adequate for speech signals.

Curve C shows the frequency spectrum with an input signal level at the transmitter of 5 mV. Most of the distortion is at the second harmonic. In this case the THD+N figure is 0.85% (over the frequency range from 22 Hz to 22 kHz).
Life without wireless communications is almost unthinkable in the modern world. These days virtually everybody makes use of some type of transmitter or receiver: GSMs, broadcast radio and TV, WLAN, Bluetooth, and so on. And there is still a lot more happening in the radio spectrum. In this article we show what else can be found in 'the ether'.
Over the years, organisations throughout the world have allocated certain parts of the radio spectrum for specific applications. An overview of this allocation can be seen in the chart at the top of the page. The range that we're looking at here starts at about 300 Hz and goes up to an amazing 30 GHz.

The chart has been divided into eight parts, called frequency bands. This division has come about partially due to historical reasons and is also due to decisions made at international conventions. Roughly speaking, frequencies in a certain band seem to have similar physical properties. There will of course be some overlap of the properties at the transition of two bands.

**Low frequencies**

Radio signals with lower frequencies are hardly affected by obstacles such as buildings and trees, compared to signals with higher frequencies. The higher the frequency the more the signal will be attenuated by obstacles.

Another useful characteristic of signals with frequencies up to about 30 kHz is that they tend to follow the curvature of the Earth. Since the aerais are rarely much higher than the corresponding wavelength, the Earth plays an important role in the signal propagation. In this situation it is no longer necessary for the transmitting and receiving aerials to 'see' each other.

**Broadcasting**

One of the best known uses of radio communications must surely be broadcast radio. Until now the most common modulation types used for this have been AM and FM. Three parts of the spectrum are reserved for AM radio: the long wave (LW), medium wave (MW) and shortwave (SW) bands.

Of these, the shortwave (SW) is still used the most because depending on propagation this band is suitable for worldwide communications. Because of the higher frequencies (formally, between 1.6065 MHz and 30.00 MHz), groundwave propagation no longer plays an important role and these signals hardly follow the curvature of the Earth.

But it is still possible to receive world service stations on distant shores and to receive stations from the other side of the world in this country. This is made possible by a certain atmospheric layer, called the ionosphere. This layer reflects radio waves from the shortwave band. The radio station transmits a very powerful signal (1.5 to 120 kW) at an angle towards the ionosphere. This angle is chosen in such a way that the radio waves are reflected to the required area on the globe, where they can then be received.

The majority of people tend to associate LW/MW/WW with the past and instead listen to FM radio (87.5 to 108 MHz). The sound quality of these transmissions is much better than those on the 'AM' bands. FM transmitters often also provide extra services like RDS (radio data system). For example, a car radio can automatically switch to a different station (broadcasting the same programme) whenever the reception on the current station worsens. Another service automatically stops the CD or cassette player and switches to the radio whenever a traffic announcement is made.

A recent development in the broadcast world is the transmission of digital radio signals (DRM) in the shortwave bands. This allows data as well as audio to be included in a broadcast. It is therefore likely that various extra services will be introduced in shortwave broadcasts.

This is a subject that we've covered before in *Elektor Electronics*. In the March 2004 issue we published a design for a digital shortwave radio receiver (DRM receiver).

There are currently also digital radio transmissions (DAB, Digital Audio Broadcasting), which are an alternative to ordinary FM radio. The same development is taking place in television: the conventional analogue transmissions (which take up a fairly large part of the spectrum) will eventually be replaced by digital television (DVB-T, Terrestrial Digital Video Broadcasting). An improvement in quality is not the only advantage of the switch to digital technology. The available spectrum is utilised more efficiently because several channels can now be placed in the same section of the spectrum.

This development has already happened with satellite TV: apart from the original analogue TV satellites, you'll find that most modern satellite transmissions are now digital.

**Professional communications**

Apart from radio and television broadcasting, there are many more applications where radio is used for the exchange of information. Just think of the communications in aviation, shipping, the police, etc. These particular groups also have various parts of the spectrum reserved for them. It should be noted that the use of all bands mentioned so far require a licence.

One of the more remarkable bands for professional use is the one covering 0.3 to 3 kHz. This part of the spectrum is used primarily for submarine communications. The reason for this is that these extremely low frequencies (ELF) are not heavily attenuated by water. But since the bandwidth is very small it can only be used to send (morse) data, and not speech. Should a situation arise where speech communication is vital, the submarine will first receive a 'surface' command by ELF. It can then use the 'normal' higher frequencies (usually SW) for the transmissions.
Incidentally, licensed radio amateurs are also regarded as professional users. Various parts of the spectrum have been set aside for this group of users, whose transmissions are often of an experimental nature.

### ISM bands

The ISM bands (Industrial, Scientific and Medical) are special in that you don’t need a license to use them, unlike many other bands. There are many parts of the spectrum that may be used by anybody for various purposes, as long as type-approved equipment is used. The 433 MHz and 866 MHz bands are currently the best known of these (cordless phones and microphones). The 2.4 GHz band also comes into this category, which is where we find, among others, wireless LANs and Bluetooth. The microwave oven also has its place here.

27 MHz

The 27 MHz band, also known as CB (Citizens Band) or 11 metres, lies between 27.60 MHz and 27.99 MHz in the UK, and between 26.96 MHz and 27.41 MHz in the EU. In the UK a license is required to use CB, although in many other European countries this is no longer the case. Lorry drivers and cabbies are one group of people who are well known for their use of CB to keep in touch on the road. This band is also used (as well as parts of the 30, 35 and 40 MHz bands) for radio-controlled models, such as aeroplanes and remote controlled cars and boats.

A small part of the CB has been reserved for use as an ISM band.

### Time signals

Up to now we’ve concentrated mainly on communications between people. There are also a score of applications where radio communications are used to automate processes. One example of this is the transmission of time signals.

Extremely accurate time signals are sent from a number of VLF transmitters, spread around the globe. One of the best known in continental Europe is the DCF77 transmitter, which is near Frankfurt in Germany. This station operates at a frequency of 77.5 kHz and transmits a highly accurate time signal derived from an atomic clock. Watches, clock radios and other clocks that have a suitable receiver built in, automatically set their time to that from the DCF77 signal. Switching between summertime and wintertime also happens automatically! Since these types of transmitter use a relatively low frequency, their signals can be received at great distances (typically 1000-1500 kms). This means that one transmitter covers a very large area.

### Positioning systems

Another type of an automated application of radio waves is a positioning system. Although GPS is nowadays pretty much in the public domain, in commercial and military aviation a different type of navigation system is used, which has beacons on the ground, instead of satellites in the sky. Small bands have been reserved throughout the spectrum for the various types of positioning system. The aviation industry uses several systems side by side. In the IF part of the spectrum are the so-called NDBs (Non-Directional Beacons). These transmit, as the name implies, a signal in all directions. In aeroplanes that use NDB navigation, an arrow points in the direction of the transmitter. As long as this arrow points directly forwards you know you’re flying straight towards the transmitter.

Another system is the VOR system (VHF Omnidirectional Range). This navigation system tells you at what compass point the aeroplane is relative to the transmitter. Whereas the NDB system only works when you’re flying in the general direction of the beacon, the VOR system works regardless of the direction the aeroplane flies in. The ILS (Instrument Landing System) is probably the most widely known navigation system in aviation. This system assists pilots during the landing, so they can still make a safe landing when there is bad [or no] visibility. The ILS indicates whether the aeroplane is on the right course towards the runway and that it flies at the correct altitude.

A lot of effort is put into replacing these [old-fashioned] systems with GPS based ones, but at the moment GPS is not accurate enough to use it for landing aeroplanes.

### Galileo

A number of European countries are collaborating on a project to create a network similar to GPS. Just like GPS this network makes it possible to determine your position very accurately. This new system, christened Galileo, also uses a network of satellites in space. It is anticipated that this system will be even more accurate than the current GPS!

Three frequency bands have been reserved for this new system. One is for transmissions from Earth to the satellites to upload new information or course corrections. Another is for communications between the satellites and the last is for sending information to users in Earth.
The frequencies used for transmissions to users on Earth have been made intentionally high (max. 5.01 GHz), since these frequencies allow extremely accurate measurements to be made.

GSM

Mobile telephones are the application that has changed everyday life significantly in the last few years. Nowadays you can find somebody phoning or texting in almost every place imaginable. The telephone masts of base stations for the GSM network can also be seen wherever you go.

The first GSM networks made use of the GSM-900 system. This system operates, as the name implies, at frequencies near 900 MHz. This was later joined by the GSM-1800 network, which operates at frequencies near 1800 MHz. The frequencies for use by third-generation mobiles were auctioned off not long ago. The system used for this, UMTS, employs frequencies that are higher still.

The disadvantage of these high frequencies is that the range of the transmitters is reduced at the same power levels. This is not just due to the higher attenuation by the air, but is also caused by other obstacles such as walls, cars and trees. Any conducting objects (metal or containing water) contribute to the attenuation. This means that many more base stations will be required to cover the same area.

And finally...

If you want to find out more about the goings on in the ether you need look no further than the Internet. Websites such as the 'Dutch National Frequency Register' and the pages of the Radiocommunications Agency contain a vast amount of information about applications, allocations and licensing. A search for 'frequency allocation' on Google returns a large number of other interesting sites.

Links

UK RF spectrum [general]:
www.ofcom.org.uk/static/archive/ra/publication/ra_info/ ra235/ra235.htm

Formal Radiocommunications Agency:
www.ofcom.org.uk/static/archive/ra/publication/ra_info/ ra366.htm

US frequency allocations:
www.nra.doc.gov/osmhome/ allchart1.html

Does a microwave oven cause interference?

From the frequency chart you'll see that microwave ovens operate in the same band as Wi-Fi (Wireless LAN) and Bluetooth. There are often rumours around that microwave ovens interfere with wireless networks, but how true is this in practice?

Wireless LANs use a special modulation technique, which makes use of a fairly wide range of frequencies. This was done on purpose so that if there was interference in a small part of the spectrum it would only have a small effect on the connection. The Bluetooth system, which is also in the 2.4 GHz ISM band, also uses the so-called 'spread spectrum' modulation. Bluetooth transmissions rapidly change between different channels within the band, averaging out the effects of possible interference.

The interference may originate from a microwave oven. This machine is in fact just a powerful transmitter in a box with a door. This door is there for a very good reason, which is to stop the powerful RF energy from escaping. Microwave ovens are surrounded by metal and a metal mesh behind the window in the door. When the door is closed the whole functions as a Faraday cage and radio waves should not be able to leave the microwave oven. In practice the 'cage' always leaks slightly and some RF signal will escape. This is usually not a problem, but with older or defective microwave ovens it could be a significant amount of energy. If your WLAN receiver doesn't have a good input stage there is a possibility that the connection suffers when the microwave oven is turned on. In rare cases like this you'll notice that the data throughput of the wireless network reduces, but it is extremely unlikely that you'll lose the connection altogether.

Figure 1: RF signals can reach beyond the horizon using a layer of ionised gases in the atmosphere.
With the aid of a PC and intelligent temperature sensors it is very easy and quick to assemble a professional temperature data-logger. Using e-mail, up to four temperatures can be monitored from a distance. The sensors are simply connected to the PC parallel port.

In this article we describe a system that measures and records temperatures. The heart of the system is a Visual Basic program. This software reads the temperature sensors, which are part number DS1621 from Dallas Semiconductor. Up to four sensors can be connected. The measurement accuracy is 0.5°C and the interval between successive measurements is 2 seconds, 10 seconds or 1 minute. The program can display the measured values either as a graph or simply as text. A chart with the most recent 60 measurements is available and another chart showing the most recent week. The latter allows zooming in to a resolution of one hour. In addition it is possible to store the results in separate files for later manipulation in, for example, a spreadsheet.

A novelty of this program is the option of sending email warning messages via the network to which the PC is connected. This requires only an SMTP mailserver. The messages contain the date and time and the recipient can simply view them as any other email.

Up to three recipients can be entered. Furthermore, it is also possible to check remotely, or even when absent, whether a particular alarm has occurred and at what date and time. This could be used to monitor the temperature of an air-conditioning system, or for example, the temperature in a computer room or boiler house. The maximum period that can be recorded is one week. Each sensor has two alarms that can be set. They are triggered when a threshold has been exceeded. In this condition the program sends the warning message.
way the alarm can be raised whenever, for example, the temperature exceeds 25 and 30 °C. For each event a separate message can be sent. An upper- and lower-limit or two lower-limits are also possible. A hysteresis of 2 °C prevents (many) pointless messages when the temperature hovers around the alarm threshold. This circuit allows a cheap warning system to be built. An old PC with a 200 MHz or so processor and network card is easily sufficient.

**Circuits**

The sensors are connected using the familiar PC bus (Figure 1). The sensor boards themselves are effectively connected in series, where in each case the output from one sensor is connected to the input of the next one. The last sensor — which is, of course, the first one if only one sensor is used — is connected to the PC. In Figure 1 this is indicated with the symbol 'I'. Incidentally, the software also supports an internal ISA PC interface card. Figure 2 shows the schematic of a suitable interface for the parallel port of a PC. The design has been derived from an application note from Philips and actually consists of only a single IC. The 74L505, a hex inverter with open-collector outputs, is used as a buffer. In addition, a couple of pull-up resistors are required, a 25-way sub-D connector (male) and an RJ11 socket. That's all.

**Sensor connections**

The sensor used here, the DS1621, already contains practically all the necessary components. The IC also contains a built-in thermostat, but that functionality is not used in this project. The accuracy of the DS1621 is of the order of 0.5 °C without the need for any special calibration. The measuring range spans from –65 °C to +125 °C and the conversion time is 1 second. As well as the IC itself, three additional resistors are required, which are necessary for setting the address (Figure 3). In this way, conflicts on the PC bus are prevented. The sensors are identified using a 7-bit address, three of which are programmable by the user (typical for an I²C address) plus one mode bit. The address lies between 144 (A2/A1/A0 all logic zero) and 158 (A2/A1/A0 all logic one) in steps of 2 and is programmed using jumpers. The value that has been set needs to be entered into the Visual Basic program.

**Construction**

The circuits are not very involved and are easily built on a small piece of prototyping board. Of course, if you are familiar with a PCB layout package.

Figure 1. The sensors are connected via the I²C-bus.

![Figure 1. The sensors are connected via the I²C-bus.](image)

![Figure 2. One small IC and a few resistors make a complete interface.](image)
then it is also quite easy to design a PCB yourself. The final result is very compact. In the prototype, the pull-down resistors are SMD versions. They are very easy to solder directly to the PCB traces.

The sensors are connected to each other using cables fitted with RJ11 plugs. The maximum length of the bus that is allowed depends on the number of DS1821 circuits and is determined by the capacitive load on the I2C bus (400 pF maximum). In practice, the author, using two sensors, obtained a maximum length of 7 m. If necessary, this length can be increased using bus extenders like the 828715 from Philips.

Software

Now let’s take a close look at the software. When you start the program for the very first time it will initialize with the default configuration. You can subsequently modify the configuration by selecting the menu General Configuration from the main program window (Figure 4). The corresponding window will appear (Figure 5). In this window, all the parameters related to the temperature measurements can be adjusted. At I2C bus you select the type of I2C interface used. The option I2C.ini instructs the program to obtain the configuration information from an external file with the name I2C.ini. This file has to be in the Windows folder. In this file, under the section [I2C Card], you can enter the base address (hexadecimal) of the I2C interface card (default value is 0x300). Under the section [I2C Param] there should be the hexadecimal address of the parallel port (usually 0x376B for LPC1).

The parameters for the four sensors can also be entered in the screen of Figure 5. All the parameters for one sensor are next to each other. Underneath the decimal address of the sensor is a text field that can hold the name of the sensor. For example cooling1, cooling2.

By selecting Yes under Acquisition the actual measuring commences. If subsequently Yes under Record in file is selected, the measuring results are saved in a text file (file_opn1.txt through file_opn4.txt).

Activating the alarms is done in much the same manner. If Yes is selected under Alert high, the alarm is raised when the corresponding value is exceeded (otherwise when it drops below this value). You can enter in the remaining text box the message that needs to be sent via email.

Table 1. Addressing

<table>
<thead>
<tr>
<th>Bit 0</th>
<th>Bit 1</th>
<th>Bit 2</th>
<th>Bit 3</th>
<th>Bit 4</th>
<th>Bit 5</th>
<th>Bit 6</th>
<th>Bit 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>A2</td>
<td>A1</td>
<td>A0</td>
<td>R/W</td>
</tr>
</tbody>
</table>

Finally, you can enter at the bottom how often the temperature from the sensors needs to be polled (acquisition period).

Viewing the results

After you have entered the address and name of the sensor and activated the acquisition, click OK and you will return to the main window (Figure 4). This window is updated at the same rate as the acquisition period entered earlier. If the sensor has been detected, the corresponding name is shown on a flashing green background, with the temperature shown on its right. If the sensor does not reply or if the address entered is not correct, its name appears with a solid red background. In the same manner, the software indicates with a green colour whether communication on the I2C-bus is correct (IC OK).

Two graphs show the temperature variation(s). The first graph contains the most recent 60 measurements versus time. This display offers a quick

Figure 3. Jumpers select the address of the sensor.

Figure 4. The main program window gives a good overview of the temperature history.
view of the most recent information. Typically this is the last hour when the measuring interval is one minute. The second graph, using a zoom function and horizontal slider, allows all measurements to be examined over the period from 1 hour ago to 7 days and 8 hours. This enables you to view what happened a few days ago. The measurements in the graph are updated once a minute independent of the selected acquisition period.

**Alarm via e-mail**

To activate the alarm via email you require the following:

- an SMTP mailserver accessible via the network to which the measuring PC is connected. If no suitable server is available, but the Internet is, then you can install one yourself. There are numerous free mailservers available for all the common operating systems. One example is Mercury transport system, which is available for both Microsoft Windows as well as Novell Netware.
- An email account, configured for the name of the temperature station that will be sending the messages.
- Up to three email accounts to receive the messages.

Now go to Mail Parameters to enter all this information (Figure 6). In Mail server IP address enter the address of the SMTP server. In the boxes for Administrator, Secondary and Third email enter the addresses of those who will receive the alarm emails. Don’t forget to tick the corresponding Active box.

The email address of the temperature station is required because mail servers usually don’t accept incoming mail without a sender’s address. Enter the address that you configured earlier. Confirm by clicking OK. After completing all this you can send a test message to the server from the menu Preferences/Test. If everything goes well, the message will appear in the mailboxes of all the recipients.

**Finally**

Most of the boxes in this program have a brief help text that appears when hovering the mouse over the appropriate box. When installing the main program, the program TestFC is also installed at the same time. This utility allows the FC-bus to be checked for correct operation and can detect the sensors connected to the bus.

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**About the author**

Cyril Jouanjan is 38 years old and has qualifications in information engineering [specialty: system- and multimedia-networks]. He currently works in the south of France. Cyril has been a licensed radio amateur [F5NYV] since 1998 and as a consequence of this hobby he has been engrossed in the various techniques that are required for the realisation of certain subjects, such as mechanics and electronics.
Making a robot walk instead of drive around on wheels can be a daunting task. The author of this Walking Bug came up with a remarkably simple solution.
Although our robot does not stand upright on two legs, it can actually walk using just two servos and a minimum amount of electronics. The power of the design is, of course, found in the combination of these two elements. The servos make the natural movement needed here: just back and forth. As an advantage over other actuators, they can be directly driven by a microcontroller, which saves us a lot of driver and interfacing electronics, see Figure 1.

The mechanical construction of the Walking Bug is also relatively simple, the 'legs' being secured directly to the servo spindles.

### Servos

A servo is basically an electric motor with a gear assembly driven via an internal positional detection circuit. Besides the supply voltage, the servo needs a drive signal that serves to indicate the desired position. Consequently the servo monitors, changes and maintains its position all by itself. As long as the drive signal remains the same, the servo will not turn — the spindle will only turn if the drive signal changes.

The drive signal consists of squarewave pulses with a swing of 5 volts. The period of the pulses is constant, while their width determines the spindle position. The zero position of the servo spindle corresponds to a pulse width of about 1.5 ms.

Depending on the desired amount of rotation, the pulses are made shorter or longer, however a constant period of 20 ms has to be maintained.

### Software

Our purpose is to make the robot put one leg in front of the other so as to make the creature 'walk'. Considering how a servo needs to be driven, implementing this movement may look like a complex task for a microcontroller to handle. Fortunately, it could be done without too many problems thanks to the programming language used by the author. BASCOM AVR comprises a special routine for driving servos. It accepts a value, supplied in the form of a parameter, which directly determines the spindle position. This routine relieves us of the task of having to create the PWM pulse shape and timing required for servo driving.

All we need to do is program the actual 'walking' of the robot creature. This has been achieved as follows in the program. In the main loop, subroutine 'Step 1' is jumped to every 100 ms. In this routine, the micro counts from 1 to 12, the values corresponding to the 12 positions a servo spindle turns to when one 'real' step is made. Elsewhere in the program you'll find a table allowing the micro to look up a value to be read and copied to the servo subroutine at the current state of the step.

That concludes the operation of one servo. However, the other servo needs similar 'work' to enable the creature to actually move forwards and backwards. A co-ordinated walking movement has been achieved by making one leg precede the other by an angle of between 45 and 60 degrees. In the software, this has been implemented by adding a fixed amount to a current servo position, and reading the value for the result in the loop table. In this way, the servos follow each other's movement by a fixed difference.

### Backwards

You may have seen on the photographs that our Walking Bug has two 'antennae'. Two stiff wires are secured to microswitch levers, allowing the microcontroller to detect if the Bug has run into an obstacle.

If that is the case, the program branches out of the main loop into a subroutine 'Back' causing the robot to walk backwards for a while. The 'Back' subroutine simply calls 'Step' but this time with the variable 'Sense' set. With the 'Sense' flag set, the 12-position counter counts down causing the robot to walk backwards. The actual direction is determined by the microswitch that was first closed by the obstacle. At the start of the main loop, before the jump to 'Back', the variable 'Direction' is set; '1' meaning to the left and '2', to the right. Swing this variable an extra difference is created between the servo positions.

### Hardware

As you may have guessed from the software description, the hardware is 'modest' by all standards. An Atmel microcontroller type AT90S2313 is the 'brains' of the little robot, directly controlling the servo via port pins PD0 and PD6. PD1 and PD5 drive two LEDs that light alternately when the robot is walking straight on, or indicate it is walking backwards to the 'left' or 'right'.

S1 and S2 are microswitches secured to the two antennas — when actuated, the micro knows that an obstacle is in the way.

The bug is powered by four batteries or rechargeable cells — voltage stabilisation is not required.

### Construction

On the printed circuit board designed for the Walking Bug (Figure 2) you first mount the passive parts, that is, the resistors, capacitors, ceramic res-
onator, connectors and microswitches. Next, continue by fitting the LEDs and the microcontroller (preferably in an IC socket).

We recommend first checking the electronics for proper operation. This is simply done by connecting up the battery and the servos. If the servo discs move up and down and the movement changes when the microswitches are actuated you can safely assume that the circuitry works as it should, and you are ready to assemble the Walking Bug.

The backbone of the creature is formed by a strip of metal bent as illustrated in Figure 3 (example). The PCB is secured at the front using an M3 bolt and nut. Do not forget to insert a PCB spacer, else the copper tracks at the PCB underside are in danger of touching the metal strip. Immediately behind the first bend in the metal strip a hole is drilled to accommodate the on/of switch. This switch is inserted between the battery pack and the supply connector on the board.

Next, secure the 'legs' to the servo spindles. To prevent the robot sagging through its own weight, its legs should be cut from solid metal (steel) wire, for example, 2-mm thick spokes for bicycle wheels. Most servos have a disc with holes secured on to the spindle. These holes can be used for the legs, too, by bending the metal wire into a U shape, where the length of the lower side of the U equals the distance between the holes. This allows the wire to be passed down and up through two holes. Next, the end is bent back at the underside of the disc, clamping the wire in place. At some distance from the servo, again bend the two ends away from the servo at an angle of about 90 degrees. The correct position of the disc (with the legs secured on it) to the servo spindle may have to be established by trial and error.

The servo and battery holder may be secured using tie wraps, although this makes exchanging the batteries a bit difficult. Alternatively, glue the battery holders to the servos. A less permanent option is to use rubber bands or Velcro.

**Your own experiments**

This design is ideally suited to further experimentation, not just with the mechanical construction, but also with all parameters used in the software control. For example, if you decide to use different legs and adapt the values in the tables, or the difference values, the Walking Bug will continue to work, at least in principle, sometimes better, sometimes with a funny gait! Your aim should be to find the best interaction between software and hardware.

The PCB contains an ISP (in-system programming) connector, K2, which allows you to reprogram your robot using BASCOM-AVR (see link at the end of this article). The wiring of the ISP cable (including three resistors) is summarized in Table 1. In BASCOM AVR, select ‘sample electronics programmer’.

**Web link**

BASCOM-AVR: [www.msclelec.com](http://www.msclelec.com)

<table>
<thead>
<tr>
<th>Table 1. Programming cable details</th>
</tr>
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<tr>
<td><strong>printer port</strong></td>
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<tr>
<td>2 (via 330 Ω)</td>
</tr>
<tr>
<td>4 (via 330 Ω)</td>
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<tr>
<td>5 (via 330 Ω)</td>
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<tr>
<td>11</td>
</tr>
<tr>
<td>1B</td>
</tr>
</tbody>
</table>

Figure 2. The 'brains' of the Walking Bug.

Figure 3. Showing how the various parts are secured to the metal backbone.
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RFID Detector for

Spot RFID tag transmitters from a distance

As we all know, checkout gates in highstreet stores will faithfully sound an alarm if you walk out with an item not 'cleared' by checkout staff, i.e., paid for. This article describes a sensitive detector that will equally faithfully produce a sound in response to pulses picked up from an 13.56 MHz RFID tag transmitter, be it large or small, 'portal' or 'portable'. 
The system of passive RFID recognition has been in use for decades already mainly in large department and fashion stores like C&A. Traditionally, these systems work at frequencies designated for ISM (industrial, scientific, medical) use.

Many different frequencies have been adopted since the early 1980’s. The system is extremely simple and has proved quite effective in stopping shoplifters. All clothes and other items for sale in the shop are ‘tagged’ with a difficult to remove, mass-produced hence low-cost plastic ‘disc’ containing no more than a resonant circuit tuned to any one of many available EAS frequencies. These are generally in the bands 1.86-2.8 MHz, 7.44-8.70 MHz, 7.30-8.70 MHz but many other frequencies may be used depending on application, permission and country. Once your purchases have been paid for, checkout staff will remove the tag(s). Nothing will happen if you then carry your shopping bag through an RFID checkout gate. The AFS or glass gate contains a large antenna coupled to a quite powerful pulse transmitter working at an EAS frequency. If the passive tag is still present in your bag, it will resonate in response to the transmitter’s pulse and draw a tiny amount of energy from it, the coupling being mostly through the magnetic (H) rather than the electrical component (E). The pulse ringing, resonance, energy withdrawal or indeed any other disturbance of the magnetic field created by the TX power is faithfully detected and an alarm is sounded. Time to open your bag at the request of ‘Security’ or the shop manager.

Figure 1. At the heart of the circuit we see the NE615 monolithic receiver/detector IC.
From flaky to reliable

In the early days of passive RFID, the checkout gates and associated hardware produced more false than real alarms, to the extent of staff often no longer bothering about continuous alarms. Those were also the days when you could walk through an RFID gate with a common-or-garden grid dipper in your pocket tuned to an EAS frequency and trigger mayhem in the security department. In follow-up systems great improvements were achieved in respect of reliability by miniaturising and thinning RFID tags and on clothes and books. Instead of removing the tag, it was ‘disabled’ (we'd say grossly detuned) by a strong magnetic pulse at the checkout.

Today, much of the world’s fashion and clothes retail trade seems to have ‘tagged’ invisibly and transmitters have become unobtrusive to the extent of being handheld, much like a metal detector for use on persons. The basic principle, however, remains unchanged: a passive tag will either detune or ‘load’ a nearby RFID transmitter. Passive RFID cannot convey data unless that’s taken to mean “I’m here”. Also, goods (and even livestock) identification using unique numbers is securely in the realms of active RFID or barcode systems, never passive RFID.

The ISM frequency 13.56 MHz on which our receiver is designed to work seems to be in use for active as well as passive (EAS) RFID tags.

A dedicated receiver

The detuning and resonance effects mentioned above take place at relatively small distances from the transmitter, say, two metres or less depending on TX power and antennas used. To be able to spot an active 13.56-MHz RFID transmitter from a greater distance we obviously need a sensitive receiver and a pickup antenna that’s as small as possible. Here, a superheterodyne receiver is used in combination with an etched microstrip antenna. Our design is not suitable for 134-kHz RFID systems.

The circuit diagram in Figure 1 is happily uncluttered and does not contain a microcontroller or any other blackbox element. The central part is an NE615 (or SA615) integrated circuit, IC1. Referring to the block diagram of the IC in Figure 2 we’ll explain the operation of the receiver. For convenience, the pinout of the 20-pin DIP ver-

COMPONENTS LIST

Resistors:
- R1 = 10kΩ
- R2 = 8kΩ
- R3 = 2kΩ
- R4 = 470Ω
- R5 = 1kΩ
- R6 = 1.5kΩ
- R7 = 4kΩ
- R8 = 100kΩ
- R9 = 560Ω
- P1 = 100kΩ preset

Capacitors:
- C1 = determine experimentally; start without it
- C2 = 470pF
- C3, C7, C10 = 100nF SMD case 0805
- C4 = 22μF 16V radial
- C5 = 3μF
- C6 = 56pF
- C11 = 4700μF
- C12 = 1μF 16V radial
- C13 = 47μF
- C14 = 2μF 16V radial

Semiconductors:
- D1 = LED, green, low current
- D2 = LED, red, low current
- T1 = BC547B
- T2, T3, T4 = BC557B
- IC1 = NE615 or SA615 (DIP20 case)
- IC2 = LP2951CN (DIP8 case)
- X1 = 8MHz quartz crystal
- BZ1 = 6V DC (active) buzzer

Miscellaneous:
- F1, F2 = SFE5.5 S ferrite bead
- S1 = on/off switch, 1 contact; alternatively a pushbutton
- Case: Hammond 1590B diecast
- 9V battery with clip-on leads
- PCB, ref: 040299-1 from The PCB Shop
The NE/SA605 and NE/SA615 are functionally identical but the '615 has improved specifications in some respects (see SA615 datasheet). The IF transmitter signal is picked up by a closed loop antenna made from PCB tracks. Together with tuning capacitors C1 and C2 we're looking at a miniature magnetic loop antenna. The balanced antenna signal is applied straight away to the mixer inside the NE/SA615. The oscillator input of the mixer (refer to Figure 2) receives an 8-MHz signal obtained from quartz crystal X1. The difference frequency obtained from the mixer is 13.56 - 8 = 5.56 MHz, which is taken through a 5.5 MHz ceramic filter (normally used for TV sound subcarrier systems). The filter's bandwidth of about 300 kHz is sufficient to receive signals between about 13.350 MHz and 13.650 MHz, which nicely covers our target frequency of 13.560 MHz. The output signal of the IF amplifier inside the NE/SA615 (pin 16) is applied to another 5.5 MHz ceramic filter, FL2, for additional suppression of unwanted mixer products. The limiter inside the SA/NE615 (input: pin 14) also amplifies the IF signal. Referring back to Figure 2, both filtered amplifier signals are applied to the RSSI circuit which serves to tell us the signal strength of the RFID transmitter.

The RSSI output (pin 7) supplies a current between 0 and 80 \( \mu A \) as a measure of the received signal strength. The relationship is logarithmic allowing large signals to be measured too. This allows us to equip our detector with two activity outputs: a LED, D1 and a buzzer for far away and nearby RFID transmitters respectively. The demodulator in the NE/SA615 is simply not required so we need not waste any words or even external parts on it.

The detector's trigger level can be set to personal requirements using preset P1. In practice, it should be set to maximum sensitivity, i.e., the LED should not come on when you're sure there isn't an active RFID TX for miles around. None the less, powerful SW stations or man-made noise around 13.5 MHz may cause the LED to light occasionally. The adjustable threshold also allows a lower battery voltage (after several hours of use) to be compensated.

The receiver has a simple power supply consisting mainly of a low-drop regulator LF2951 whose low-battery indicator signal is used to light an LED when the battery voltage drops below about 6 V.

The current consumption of the receiver in standby (non-activated) state is about 8 mA from the 9-volt PP3 battery.

### Construction

The receiver is built on the printed circuit board shown in Figure 3. The board is single-sided and no problems are expected in the construction department as only regular-size components are used at the 'top' side and a few SMD caps at the solder side. Also, there are no inductors to wind! The SMD capacitors at the solder side of the board have to be fitted first. The positive aspect of their small size is their extremely effective decoupling abilities while also allowing the board size to be kept to a minimum. The SMDs may be seen in the photo of the solder side of the board, Figure 4. The top side of the board with all the components fitted appears in Figure 5. Quite satisfied with the results obtained we plan to apply SMD caps...
Figure 6. A look inside our tested prototype of the RFID detector.

for decoupling at the solder side: more often in future Elektor projects, so it may be good idea to buy a small stock of 0805-size 100 nF capacitors. If you object to the use of SMDs altogether then solder on a couple of miniature ceramic C's instead.

The NE/SA615 is best soldered onto the board rather than inserted in a socket. The quartz crystal is preferably a low-profile type.

The photographs underline our strong advice to fit the receiver in a metal case, with the loop antenna of course protruding from a slot. A type 1590 diecast case from Hammond will also allow the battery to be secured internally with Velcro. Plenty of room, too, for the on-off switch or pushbutton.

**Test, use, customization**

Using a dip meter we were able to make the LED light at several metres distance from the detector. The buzzer started to sound when we approached the detector to about 10 cm. RFID transmitters with gate-type antennas can be relied upon to supply much stronger signals so you should be able to detect their presence and activity from quite a distance — a nice highstreet pastime while the museus does the shopping. The values of R2 and R3 are subject to experimentation if you want different LED/buzzer activation thresholds. The antenna may be carefully tuned to resonance at 13.56 MHz by tweaking the capacitance across it (C1/C2). This is conveniently done with the aid of a grid dipper or a squarewave generator and monitoring the voltage developed across P1 (RSSI output). If your function generator does not reach up to 13.6 MHz then set it to a frequency of which 13.56 MHz is an odd harmonic (like 2.712 MHz or 4.52 MHz). Terminate the generator output with its nominal impedance in series with a few turns of stiff insulated wire formed into a small loop. Hold this loop close to the detector's antenna and increase the generator output level until an RSSI indication is obtained. Now work on the capacitor(s) until the received level maximizes.

Finally, advanced users may want to try out a larger surface antenna to get even higher sensitivity. A window antenna with a size of 75 x 75 mm tuned with a capacitance of about 500 pF is a good starting point. A much simpler variant, two telescopic or whip aerials of about 1 metre in length may also give surprising results. Both variants are, of course, less suitable for covert operation.

**The road not taken**

Some of you may wonder why the receiver is not designed using a standard intermediate frequency of 455 kHz or 10.7 MHz. After all, the NE/SA615 can handle both and a wide choice of filters is available for these industry-standard IF frequencies.

It is possible to build a single conversion receiver for 13.56 MHz using the NE/SA615 and 455 kHz or 10.7 MHz IF. Let's assume we wish to use an IF of 455 kHz for which many dirt cheap ceramic filters are available. Consequently, the local oscillator (LO) frequency would have to be 13.56 MHz ± 0.455 MHz = 14.015 Hz or 13.105 MHz. Both are perfectly possible if you are willing to fork out 15-20 pounds for a custom-made quartz crystal and suffer a supply time of 4-6 weeks. The same horrors apply if an IF of 10.7 MHz is chosen. Impossible IR frequencies like 24.26 MHz or 2.86 MHz emerge from the calculations.

The alternative presented here, a cheap 8 MHz (microcontroller) crystal and two equally low cost ceramic filters beats any attempt at using non-standard quartz crystals for a DIY project.

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**Note**

The RFID receiver described in this article is intended for educational or scientific use only. It will sound an alarm if a nearby, active 13.56-MHz transmitter is detected, which may indicate the presence of a hidden RFID tag of the active or passive type.
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Together with a good directional antenna this high performance two-stage antenna amplifier for the VHF FM broadcast band will enable you to capture far removed (DX) stations. Alternatively, it will drastically improve reception of FM signals you’ve come to accept as marginal and noisy in your area.

FM broadcast transmitters are normally meant to have a useful range of 30-100 km. Fine, but if you are in a fringe area, all you may get is a very weak signal, possibly even blotted out by a powerful station around the corner. For various reasons, an increasing number of people are not satisfied with the quality of radio signals that can be received via cable systems. Unfortunately, cross-modulation, and other nasty effects created in the head end station are in stark contrast with the superb quality of high-end FM tuners that can be bought commercially. Not surprisingly, owners of such tuners will often prefer to have their own antenna on the roof. Add to that a high-performance FM antenna booster like the one described here and you can start DXing as well as enjoying high-quality stereo reception. The author employs the present amplifier in combination with a Sangean ATS-803 World band receiver, a Philips RR-571 tuner and a single-element cubical quad directional antenna at a height of just
**Booster**

New horizons in 3-metre band DXing

15 feet. Using this setup he is able to receive FM stations as far off as 500 km.

**Circuit description**

In the design we're about to describe you'll find the following important parameters coupled: low noise figure (approx. 1 dB); high gain (up to 40 dB) and low susceptibility to intermodulation products. Yet the amplifier is inexpensive and easy to build.

The circuit diagram in Figure 1 reveals the secret: dual-gate MOSFETs in positions T1 and T2. The first of these, T1, is configured mainly for low noise and antenna matching and the second, T2, for high gain. Unusually, the antenna signal is applied to T1 via its source (S) terminal, which is convenient because unlike one of the gates (G1 and G2) it already represents a fairly low impedance. None the less, for impedance matching with the 50 Ω coax cable a tap needs to be used on tuned filter L1/C2.

For VHF and UHF amplifiers, DG-MOSFETs represent a good alternative to cheap but noisy bipolar transistors and very expensive and difficult to get GaAs FETs.

The gain of the second DG-MOSFET in the circuit is adjustable using preset P1 which varies the bias voltage to T2's G2 terminal — this is the classic way of controlling the gain of a DG-MOSFET and it still works very well. Such a control is included in the design to allow you to get the exact amount of gain required for your particular application. For example, if you live near a powerful VHF FM or TV broadcast transmitter then you'll find that a lot of gain produces cross-modulation and other unwanted effects like coupled oscillation and 'birdies' within the FM band.

For stability the supply voltage is decoupled at several locations by electrolytic and ceramic capacitors for the low and high frequencies respectively. To enable it to be mounted as close as possible to the antenna, the amplifier is powered via the downlead coax cable, i.e., over coax connectors connected to K2 and K3. In the supply, the RF signal is taken off the coax core by capacitor C19.

The supply voltage is adjustable to some extent with pot P2, which will also allow a degree of gain control. The current through 'power on' LED D2 should be about 10 mA. If a low-current LED is used, then R8 has to be increased accordingly. With electrical safety in mind we strongly suggest the use of a mains adapter with 12 VDC output. Depending on the gain set and the DG-MOSFET used the circuit will consume about 50 mA so a 100-mA or slightly more powerful adapter will be fine in most cases.

**Construction**

The amplifier is built on the single-sided printed circuit board shown in Figure 2. The inductors in the design are all very simple to make, see the parts list for construction details. L1, L2 and L3, are wound on a 4.5-mm dia. drill or pencil. L1 then needs to be stretched to a length of about 10 mm. You'll find that a relatively large resistor is needed to wind choke L4 on — we used a 0.5-watt carbon-film resistor from the junkbox (metal film resistors seem to have taken over completely). The value 1 kΩ is uncritical, what we've after is 'a lot' of carbon for the case an 820 k or 1 MΩ will do just as well.

The DG-MOSFETs are not only sensitive to static discharges but also easy to fit the wrong way around. The non-SMD versions require 5-mm holes to be drilled in the PCB. Make absolutely sure you know each MOSFET's final orientation on the board before soldering it in place — check, think hard and
COMPONENTS

LIST

Semiconductors:
D1, D3 = 1N4007
D2 = LED
T1, T2 = BF965 or BF966S

Inductors:
FB1, FB2, FB3 = 5 turns 0.15 mm
(38SWG) enamelled copper wire on
ferro ferrite +
L1 = 7 turns 0.9 mm dia. (20SWG)
enamelled copper wire; internal dia.
5mm; length 10mm; top of 5 turns from
ground.
L2, L3 = 7 turns 0.9 mm dia. (20SWG),
internal dia. 3mm; close wound
L4 = 30 turns 0.15 mm dia (38SWG)
enamelled copper wire on a 1MΩ
capacitor.

Capacitors:
C1, C6 = 22pf ceramic
C2, C5, C14 = 22pf trimmer
C3, C7, C17, C18 = 1nF ceramic
C4, C9, C13, C15 = 100nF ceramic
C8, C10 = 10nF ceramic
C11, C16 = 100pF 25V radial
C12 = 3pF ceramic
C19 = 12pF ceramic

Resistors:
R1 = 10kΩ
R2 = 150kΩ
R3 = 1MΩ
R4 = 220Ω
R5 = 100kΩ
R6 = 30Ω
R7 = 1kΩ
R8 = 1kΩ
P1 = 47kΩ preset H
P2 = 10kΩ linear potentiometer

Miscellaneous:
K1-K4 = F socket, PCB mount
P1 = on/off switch, 1 contact
PC8, ref. 040145-1, available from The
PC8shop

<table>
<thead>
<tr>
<th>Type</th>
<th>Case</th>
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<th>Noise factor (dB)</th>
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<tr>
<td>BF998</td>
<td>SOT143 (SMD)</td>
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</table>

Figure 2. Copper track layout and component mounting plan of the PCB designed for the antenna booster.

Several VHF/UHF DG-MOSFETs may be used in this circuit — see Table 1. With some dexterity it is also possible to use SMD devices. In general, you should aim to use a BF99x with a low noise figure, although that may imply a slightly reduced overall gain. Remember, however, that the amplifier’s gain is secondary to the noise figure — in practice, any gain between 25 dB and 40 dB will be just fine.

The power supply parts are not accommodated on a PCB but may be connected up using flying lead construction in a small case. The finished PC should be cleaned with isopropyl alcohol to remove solder residue.

The amplifier must be housed in a metal case with proper coax connectors used for K1 and K2. The author used F-type sockets as customary with satellite TV rigs. They are cheap and easy to obtain. However, BNC sockets may be used equally well. The connections between the sockets and the amplifier input and output should be kept as short as possible using thin coax cable like RG174/U.

**Setting up**

Give the PCB a final, thorough inspection for bad soldering, wrong components, etc., and resolve all problems before proceeding.

Set all presets and trimmers to the centre of their travel. Apply power to the amplifier and check the various test voltages indicated in the circuit diagram. These voltages are typical and should not be taken to mean the ‘law’. Tune your VHF FM radio to a weak signal at around 96 MHz. Tune the amplifier back to front; that is, first C14, then C5 and then C2 for best reception — your ears and the tuner’s meter will tell you what’s happening. If necessary reduce or increase the gain using P1. A good way to simulate a weak signal is to turn the antenna away from the transmitter direction.

The amplifier’s 3-dB bandwidth will be about 10 MHz with all tuned elements at the centre frequency. By careful retuning of the three trimmer capacitors ("staggering"), this may be widened to 20-25 MHz at the cost of some gain. Fine tuning may also be
achieved by stretching or compressing the three air-space induced inductors. This method may be for specialists only, however.

**Other bands**

The amplifier may be modified for use at slightly higher frequencies like 120 MHz (VHF airband), 145 MHz (2-m radio amateur band or even 146-174 MHz (FM radio band). Some experience may be required in tweaking the inductors for resonance at their new frequency however. If you find that a particular trimmer no longer ‘peaks’ then the L/C combination is out of range. Lacking specialised test equipment like a grid dipper to see where it does resonate, go for trial and error by fitting an inductor with fewer turns and see what happens then. Whatever the frequency, the booster will not fail to give the kiss of life to a duff receiver.

---

**All change to SMD**

Although the BF966 DG-MOSFET is no longer produced, it is still around in electronics retail and surplus circuits. Broadly speaking, DG-MOSFETs from the BF9xx series in the 'traditional' SOT143 case are being superseded fast by their SMD (SOT163) counterparts. These are perfect electrical replacements but require short wires in order to be fitted on a board laid out for a SOT103 transistor. In many cases, the type number is that of the SOT103 parent device plus an offset. For example, a BF966S is electronically compatible with the BF991 and the same applies to the BF981 and it's successor the BF991.

A further interesting point to note is that the -R suffix in the type code of SOT143 DG-MOSFETs indicates a 'reflected' pinout.

The layout of the PCB designed for the antenna booster allows both SMD (SOT143) and 'leaded' (SOT103) DG-MOSFETs from the BF9xx series to be fitted, the latter being mounted recessed in a 3-mm hole allowing their terminals to be soldered flush with the PCB tracks. Unfortunately, the -R suffix SOT143 DG-MOSFETs cannot be used on this board.
Digital terrestrial television (DVB-T) is now available in many parts of the country. Of course, you need a DVB-T receiver and a (new) UHF TV antenna. If you don't have a suitable antenna, the small indoor DIY alternative described here is a simple and economical solution.
Terrestrial digital video broadcasting is now available in many parts of the country, and there are plans to eventually switch off existing PAL analogue broadcasts altogether; in some parts of Europe this is already happening. If you currently receive television by satellite or cable and, for reasons of cost, wish to switch over to DVB-T, a DVB-compatible antenna is required. Of course, this is not connected directly to the television, but rather via a DVB-T receiver, or so-called 'set-top box'.

Only a few of the DVB-T receivers have a simple indoor antenna available as an accessory. Figure 1 shows an example of a basic rod antenna. The main disadvantages of this type of antenna are its sometimes unsightly appearance and its narrow-band sensitivity compared to the width of the UHF band over which the digital channels are spread.

More appropriate for indoor DVB-T use is the patch antenna known as a 'butterfly dipole' after its striking shape. As well as demonstrating a better broad-band performance in field trials, this comparatively discreet antenna can easily be hidden, for example behind a modestly-sized picture frame.

**DVB-T**

Thanks to the data compression offered by MPEG-2 it is possible to transmit four digital channels in the same bandwidth as that occupied by a single analogue channel. This is particularly impressive when you consider that a modern television signal with 625 lines and a 50 Hz field frequency would give a raw digitized data rate of around 216 Mbit/s. The bandwidth required for that would be prohibitive for terrestrial or satellite transmissions. MPEG-2 is a significant advance on the MPEG-1 video compression standard. It can reduce the digital data rate to 13.27 Mbit/s, just 6% of its original value. Also, a sophisticated modulation scheme, known as COFDM (Coded Orthogonal Frequency Division Multiplex), ensures that the available bandwidth and transmit power are used optimally. Very early article on DVB-T may be found in [1].

**Butterfly dipole**

The real antenna impedance of a butterfly dipole is of the same order of magnitude as that of a full-wave dipole. For such a full-wave dipole system a typical impedance would be between 210 Ω and 300 Ω, and in practice probably nearer 300 Ω than 210 Ω. In any case, matching is required to the nominal 75 Ω input impedance of the antenna input of the receiver. For a matching transformer, used as shown in Figure 2, with a transmission ratio of N, we have:

\[ N = \frac{z_1}{z_2} = \frac{n_1}{n_2} \]

where \( z_1 \) and \( z_2 \) are respectively the input and output impedances of the system and \( n_1 \) and \( n_2 \) are the numbers of turns on each side of the transformer. For a transmission ratio \( N = 2 \) with \( n_1 = n_2 + n_3 \) and \( n_2 = n_3 \) we find that the numbers of turns \( n_1, n_2, \) and \( n_3 \) are all equal. This makes the practical construction of this transformer considerably simpler, because the same voltage appears across all the windings, and because we do not need the galvanic isolation between input and output that a full transformer would offer. We can use a single coil with a centre tap as shown in Figure 3.

Commercial low-loss air-cored versions of this transformer have a bifilar construction. Figure 4 shows the arrangement, where eight turns of two parallel 0.5 mm diameter enamelled copper wires (here shown in black and white for clarity) are wound on a 4-mm diameter cylindrical former, resulting in negligible coupling losses. Winding 3-4 of the air-cored transformer ends up being slightly larger than the others: this results in better matching to the actual antenna impedance encountered in practice.

As the circuit diagram of Figure 5 shows, the transformer matches the antenna to a 75 Ω impedance.
shows, a ceramic coupling capacitor C1 is fitted. This ensures that any DC level on the antenna input of the DVB-T receiver is not shorted to ground. Generally, receivers provide a 5-V supply for an optional active antenna or for a separate antenna amplifier.

**Construction**

The whole butterfly dipole antenna assembly, including transformer and coupling capacitor, is only the thickness of a ballpoint pen. It can be constructed on a single-sided piece of 1.5 mm thick epoxy-resin printed circuit board. The mounting plan is shown in Figure 6, and the layout, as always, is available for free downloading from www.elektron-elektrotechnik.co.uk. It would also be possible to construct the unit using thin sheets of zinc, copper or brass on an insulating substrate made of wood or Perspex. Figure 7 shows an example constructed on a thin curved piece of wood. The transformer and coupling capacitor are mounted on the back, along with the connections for the 75 Ω cable to the antenna connector.

Television transmitter antennas may be vertically or horizontally polarized, hence the dipole must be oriented accordingly. As always with indoor antennas, especially in the UHF range, some experimentation will be required to find the optimal position to minimize the effect of reflections. In general,
Comparison of indoor antennas

Of course, many manufacturers of television accessories have turned their attention to the DVB-T market. For example, Hama make an indoor antenna called the 'Butterfly' whose geometry is rather similar to that of the butterfly dipole. The proportions (Figure 8) are suggestive of the cross-section of a biconical antenna [2]. The patch design by Hama, on the other hand, is reminiscent of a strip dipole. Given its physical length of about 40 cm, it will have a resonance, and therefore be most sensitive, at around 350 MHz. This lies in neither the VHF nor the UHF band, but between the two.

Combined VHF and UHF indoor antennas are generally something of a compromise. Nevertheless, Thomson has chosen a different, but no less interesting, variation: the ANT200 (Figure 9) is a two-band antenna whose small internal dimensions are clearly designed for the middle of the UHF band; although too small for the VHF band, the circuitry is designed to compensate by electrically lengthening the dipole by a set amount. The geometrical dimensions of the dipole are more favourable for UHF DVB-T reception: overall, a sensible approach.

This principle also applies to the butterfly antenna described here with its near-equilateral triangle dipole geometry. The self-inductance of the transformer effectively lengthens the dipole halves at frequencies below the UHF band, which improves reception in the VHF band.

However, the antenna cannot make up for poor reception, for example on the ground floor of a building. Use of an antenna amplifier seems not to be recommended. Reports on Internet forums suggest that signals from other frequency bands of the electromagnetic spectrum, which may also be picked up and amplified by an active antenna, can cause problems. If noise spikes exceed the (rather low) input threshold level of the DVB-T receiver, then even the complex demodulation processing in the receiver will not be able to prevent distortion to picture or sound. This can also occur when an antenna amplifier is overdriven in an area of high signal strength. Since the butterfly antenna described here includes a 75 Ω transformer, any ordinary cheap commercially-available antenna booster can be used if signal amplification is really required, for example, if the set-top box or receiver is located at a relatively long distance from the antenna.


For theoretical foundations and a good source of references:

Part 1: PCB design basics
Karol Wulijvan

What do most electronics engineers enjoy a lot? Designing printed circuit boards, of course! In an irregular series of articles we would like to familiarise you with this subject. We start as simple as possible and it will become more difficult as we progress. Feedback and requests to cover certain topics are encouraged and welcomed!

When you’re just designing a small PCB, it often is not that important where the actual components are placed. However, there are a few rules of thumb that, when followed, quickly and easily result in a much better PCB. Better in this context means lower noise in the desired output signal and less interference with other equipment. The last sentence means, translated into practice: “your amplifier provides a better sound, makes no additional noises when the fridge turns on and does not interfere with your mobile phone”.

The following statement is perhaps surprising, but is actually true: “The optimum position of a component on a PCB is far more than 100% determined by its function in the schematic diagram.” That means you cannot avoid thinking about the function of each and every component in the circuit.

Example
We use an amplifier stage as an example. What are the different functionalities that can be distinguished?

In Figure 1, C5 is a decoupling capacitor, which decouples the power supply voltage. The current drawn by IC1 will charge during operation and C5 ensures that the peak current demand can be delivered.

C1 is a decoupling capacitor as well, but in this case it serves the purpose of preventing any hum and interference from the power supply from reaching the signal.

C3 is a decoupling capacitor too, but this time not for the power supply voltage, but for the signal instead. Its function is to ensure that the inverting input of IC1 is connected to ground, via R4, for AC voltages.

Rule 1: Decoupling components must be placed as close as is practicable to the nodes that need to be decoupled.

Long traces have a higher impedance (= resistance for high frequencies) and as a consequence the decoupling will not work as well. The higher the frequency, the more important it becomes to keep the traces short. Pay close attention! To clarify this a little more, take a look at Figure 2a. The traces towards and away always form a loop (also when one side of the component is connected to ground). In the figure we have shaded the area between the traces for clarity. We cannot overemphasise that it is very important to place the traces in such a way that the shaded area is as small as is possible. If you have to choose between long tracks with a smaller enclosed area or shorter traces with larger enclosed area, then choose the layout with the smallest area*. Why that is so we will explain at a later time. It is a little too advanced for the present discussion.

C12 and C4 are capacitors in the signal path. In this case it is also true that short traces and small area provide less opportunity to pick up trouble or cause trouble. We repeat the above once more because it is very important that you think about this.

How does a signal connection have an area? In Figure 3 you can see that the signal does not only go towards the capacitor, but also has a return path via ground! The ground trace has a certain length as well! Signal path and ground...
path together form a loop! This should not come as a surprise to you. Your very first acquaintance with electronics probably involved a small lamp and a battery. And when did the lamp light up? Just when the loop is closed... So, pay close attention to Rule 1.

We can make a few additional comments with regards to the signal path. The older you'll be among us, those who grew up with record players and volleys, will remember how easy it was to test an amplifier from days gone by. A finger in the vicinity of the input was enough to generate a loud hum from the speaker. This worked so well because the input to a valve amplifier is high impedance. High impedance connections pick up interference much easier. Always try to make an estimate of how high the impedance of a node is and pay extra attention to make sure that the connection is as short as possible and - if possible - run a parallel trace connected to ground as a shield (= keeping the area small).

**Rule 2** is therefore: Keep high-impedance connections shorter than low-impedance ones.

R6 ensures that the output of the circuit in the idle state is exactly zero. This prevents spurious noises from the loudspeaker when the amplifier is switched on or off.

R1 and R2 provide the correct DC bias of the non-inverting input of the opamp. This node is decoupled with capacitor C and is therefore not that critical. After all, the capacitor creates a low-impedance connection for interference signals, making the entire network less sensitive. The resistors may be placed a little further away from the opamp, provided the decoupling capacitor is placed as close to the opamp as possible.

R4 together with R5 determine the amplification. The input of the opamp is the node with the highest impedance, the output is much lower impedance and grounded is low impedance as well. The input, therefore, must have the shortest connection.

Get cracking

We’ll now get to work, keeping the above information in mind. A little bit of searching on the Internet will quickly produce a number of free demo versions of nice printed circuit board layout software. At the end of the article we have included a few links to get you started.

When designing a PCB layout you start with the fixed constraints. These are the components (or size of the PCB) that for one reason or another have to be in a fixed location. When a potentiometer has to protrude through a hole in the front panel, you could put it anywhere on the PCB, but in the end it still has to fit behind the front panel, so you may as well start with that. Otherwise, any other work would simply be a waste of time.

Follow this by temporarily placing all the other components on their most ideal location. It is all right to put them on top of each other, this is not yet the time to make compromises (Figure 4).

C2 and R3 are as close as possible to pin 3 of the IC, R4 and R5 as close to pin 2 as possible. You will now notice that you have to make choices. R3 can be placed close to pin 3 or close to C1. In this case, we always chose the shortest trace for the connection with the highest impedance. This is, after all, the most sensitive point for picking up interference! C1 is a relatively low impedance to ground, so that side of R3 is not that critical. The impedance on the other side of R3 is definitely higher. This connection is more sensitive and needs to be kept short. This is also true for R4 and R5 (R5 is connected on one side to the relatively low impedance of the opamp output). That is why it is better to make the signal path at the

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* Double-sided PCBs are ideal in this respect. When the traces are placed one above the other, one on each side, the area is minimised.
output a little longer so that the signal path at the input is as short as possible.

Power supply decoupling capacitor C5 is a little on its own in the schematic, but has to be placed as close as possible to pins 4 and 7. It is not important if it is closer to either 4 or 7, only the total length (area) of the path matters. If all of this is becoming too much, don’t panic! Remember three things:

- place decoupling components close to the load
- keep high impedance traces as short as possible
- make a star-point for ground connections**.

In general the following applies: keep the area of loops as small as is possible.

Wrapping up
Continue by placing the components in their final location (Figure 5). If you are short of space, check if the following tricks are of any help:

- Use SMD components. These are smaller (and therefore better at higher frequencies) than leaded components and can be placed on the bottom of the circuit board, so they do not occupy space on the component side. In Figure 2b you can see that with respect to the area an SMD decoupling capacitor is absolutely superior to an ‘ordinary’ decoupling (2a) capacitor.

- Split large capacitors into two smaller capacitors. You can quite safely place the decoupling capacitors with the larger value a little further away because it provides for the lower frequencies. Place a small (for example 10 to 100nF) capacitor close to the component to where the power supply track runs.

** In a future installment we will explore the confusing concept of ground a little further. We will also explain the principle of star-point grounds.

Tips
Finally another few tips. Don’t give interference an opportunity to skip past decoupling components. Figure 6 illustrates what we mean by this.

If you are designing a double-sided PCB, then it is usual to reserve one side as a ground plane. This makes the layout easier and works very well from an electrical perspective, because ground then becomes a real ground (= reference) as much as possible. When using leaded components each connection to ground is then made automatically. With SMDs you will have to make a manual connection with the aid of an additional via (a connection through the board from the top to the bottom side) which must be close to the ground pin of the SMD component. If you don’t do this the length of the ground trace could become too much!

PCB layout programs:
- www.cwbeurope.com/
- www.circuitsonline.net/download/cat/4
- www.mccad.com/
- www.franklin-industries.com/Eagle/starteagle.html
- www.orcad.com/downloads/orcadlite10/default.asp
- www.tech5.nl/products/eda/pclayout
- www.ibfriedrich.com/english/engl_vordownload.htm
- www.vego.nl/14/midden.htm
- http://tinycad.sourceforge.net/
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In the first instalment of this series, we introduced the Delphi programming environment and described several examples that illustrate how to program in Delphi. In this instalment, we take a more detailed look at the design of a somewhat more serious program. Our project here is to construct a simple pocket calculator in software. In next month's instalment, it will be expanded to include a keypad that can be connected to a serial port to allow the keystrokes to be read by the Delphi program.
This project consists of three components:
- The presentation layer, which shows the results on the monitor.
- The driver layer, which provides the interface with the hardware (the keypad). This layer will be described in the next installment.
- The processing layer, which is the software that simulates the operation of a pocket calculator.

As most of our readers are probably relatively unfamiliar with Delphi, in this installment we focus on the design of the program and the presentation layer. An attractive graphical user interface (GUI) forms an important part of the overall project. Ultimately, the success of a project depends heavily on the presentation. Nobody wants to have an ugly DIY amplifier in the living room, even if it has outstanding performance. The same holds true for software projects.

The end result shown in Figure 1 is obtained by placing various components sequentially onto the screen. In the following descriptions, we use Windows and Delphi terms and explain them as necessary.

**Presentation layer**

After Delphi has been started up, a Form object appears on the monitor. This grey window is where you will place various components from the tabs in the Component palette. Using the Object Inspector, which is also shown on the screen (usually at the lower left), you can change the properties of the window and all the components you have placed on the window. First, use Name to give the Form a unique name (such as FMain, as an abbreviation of Form-Main). Locate the properties Width and Height, and assign them values of 300 and 360 pixels.

Next, find the Color property. If you click on the small arrow to the right of the input field, a drop-down list will appear with a several Windows colours, and you can select one of them. If you double-click on the input field instead, a colour dialog will be opened to allow you to choose any possible colour. Choose a colour you find attractive.

Naturally, it's better to give the numeric display a different colour. To do this, you have to give part of the Form a different colour. This can be done by placing a Panel on the Form. You can find a panel object in the Component palette under the Standard tab. Select the panel object by clicking on it, and then click on the Form. You can use the mouse to adjust the position and size of the panel object by selecting it and dragging on the indicated points. As the position and size are properties, you can also adjust them using the Object Inspector. The panel object is not intended to be used to show numbers. It simply demarcates an area on the Form and serves as a 'container', on top of which you can place other components.

A line of digits (in the form of text) can be displayed using a Label. Place a label on the panel by clicking on the Label component on the Standard tab of the Component palette and then clicking on the panel. You will see that the label occupies only a small portion of the panel. That's not what you want, since the label should fill the entire panel. You can use the Align property to Achieve this. If you click on the small arrow to the right of the input field, several options will be shown. Select SClient. The label will then become just as large as the panel, which is exactly what you want. To right away get an idea of what it will look like, you can use the Caption property to type in several digits. This is also a good time to select a suitable font by clicking on the Font property and selecting a font, size and colour.

The final task is placing the buttons. Several different types are available on the Component toolbar. The nicest button for this application is the SpeedButton on the Additional tab (the third button from the left). Place 16 of them on the Form. Arrange them nicely in a group as shown in the figure. Each button has a caption with a font, which you can use to individually identify each button. By default, each button has a name with a number, such as SpeedButton1, SpeedButton2, etc. Use the Name property to give each button an individual name that allows you to recognize its function, such as 'CalculatorBin1'.

You can use the Tag property to allow the program to determine which button has been pressed. The tag is a property for programmers, who can use it as they see fit. In this case, you want the values of the digits assigned to the tags to be passed to the program. Buttons 0-9 should thus be assigned tag values 0-9. A similar approach is used for the operation buttons [+,-, * and /]. They are assigned the values 1-4. This completes the presentation component.

It's good practice to create a separate directory or subdirectory for every project set up. This avoids problems with old files that might have the same names as new ones. Delphi creates quite a few files while a program is being written, but many of them are not necessary afterwards. The files that must be saved have the extensions .DPR (Delphi Project Resource), .DFM (Delphi Form), and .PAS (Pascal Unit). They are necessary if you want to open the project again later on. When the program is compiled, an .EXE (executable) file is also created (for example, "Calculator.exe" if you named the project 'Calculator'). This file is the actual application.

**Processing layer**

Now you have to put the application to work. Every process in the calculator, such as adding two numbers, consists of four steps:

- entering the first number
- storing the operation
- entering the second number
- starting processing by pressing the = button
A number is formed by pressing the button for the first digit and storing that number. If a second digit is pressed, the previous number is multiplied by ten and the second digit is added to the result. This procedure is repeated until all digits have been entered.

Digits are entered by clicking on the appropriate buttons. Most components, such as buttons, can be used to initiate a procedure by clicking on them with the mouse. Such an action is called an Event. Select a button and then look at the Object Inspector. Select the Events tab at the top. If you double-click on one of the events, Delphi will automatically create a procedure. Double-click the box next to OnClick, and the procedure will be generated for you.

Now you need an auxiliary procedure to arrange the digits in a row. If you examine the code already generated by Delphi, you will see something like type TForm = class(TForm) at the top of the Form, followed by the references to the labels, panels, buttons and other objects you have placed on the Form. Below this you will see:

```var
FMmain: TForm;
```

This way of doing things requires a bit of explanation. Delphi is an object-oriented language. In ordinary English, this code means that a variable FMmain of a specific type ( TForm) has been created. Another way to describe this is to say that you first generate a definition of a calculator in the Type declaration type TForm, and then you use an example of this type (var FMmain). This way of doing things is characteristic of object-oriented programming languages such as Delphi, C++, DotNet, recent versions of Visual Basic, and various database programs.

The program now has the following structure:

```type
 TForm = class(TForm)
  Panel: TPanel;
  Label: TLabel;
  Btn1: TSpeedButton;
  Btn2: TSpeedButton;
  ...
  procedure Btn1Click(Sender: TObject);
  ...
private
  Accu1, Accu2: Integer;
  procedure AddAccu(x: Integer);
public
end;
```

You can also see that whenever a component is added to the Form, it is added to the Type definition of the Form. The same holds true for the procedures belonging to an event. The actual procedure is located further on in the program, under the heading 'Implementation'.

Borrowing a term from microprocessor hardware stacks (a stack is a specific type of list with its own particular manner of adding and removing data), we assign the names Accu1 and Accu2 to the variables that receive the two numbers to be processed. These variables belong to the properties of the calculator, which is why they are declared in that location. In this case they are included in the Private subsection, but that is not of any significance here. They are of the type 'integer', which is called 'Integer'.

The procedure used to place the digits in a row [AddAccu] is also declared here. Naturally, this procedure also has to be implemented. This occurs in the implementation section, under the heading 'Implementation'. The implementation appears as follows:

```procedure TForm1.AddAccu(x: Integer);
begin
  Accu1:=Accu1*10+x; // a statement is terminated with ;
  end; // comments are preceded by a double slash
```

If you press several digit buttons in succession, you want the digits to be placed in a row. This can be done by multiplying the previous number by ten and adding the current number to the result. Several operations are necessary to achieve this result. You have to store the first digit, read in the second digit, multiply the first number by ten and add the last number to the result, and so on. This can be done by introducing an auxiliary variable of type Boolean. Just as in digital electronics, this variable can take on the value TRUE or FALSE.

Declare a variable EntryPsy : Boolean with an initial value of FALSE (see Listing 1). The first digit is read in, the content of Accu1 is copied to Accu2, and the digit is placed in Accu1. After this, the value of EntryPsy is set to TRUE. When the next digit is read in, the procedure sees that the value of EntryPsy is TRUE, so the above steps are not executed. Instead, the value of Accu1 is multiplied by ten and the new digit is added to the result.

The complete procedure appears as follows:

```procedure TForm1.AddAccu(x: Integer);
begin
  if EntryPsy = FALSE then
  begin
    Accu2:=Accu1;
    Accu1:=x;
    EntryPsy:= TRUE;
  end
  else
  begin
    Accu1:= Accu1*10+Accu2+x;
  end;
```

(No that all keywords are shown in boldface. A keyword is a reserved word or symbol that is recognized by Delphi as part of the programming language.)

Now you can process the result of pressing a button as follows: select a button (such as BTN1), go to Object Inspector / Events, and double-click on the input field next to OnClick. The following procedure will be generated automatically:

```procedure TForm1.Btn1Click(Sender: TObject);
begin
end;
```

You also have to ensure that the variable X is assigned a value before the procedure is called. The procedure has already been generated by clicking on the OnClick event of button. One possibility would be to include the following statement between the Begin and End keywords of the procedure:

```AddAccu([BTN1].Tag); // use the tag number of the button
```

This would have to be repeated for each digit button, which would yield ten nearly identical procedures. However, there's a shorter solution. As you can see, the procedure includes a parameter named Sender. This parameter
receives the properties of the component that calls the procedure. You can thus assign AddAccu a suitable value, since you have already assigned the tag property a number in the range 0–9:

    AddAccu(Sender as TComponent, Tag);

Now you want to have all the digit buttons point to this procedure. For each digit button in turn, go to the OnClick event and click on the button next to the input field. Then select the proper procedure (BtnTClk). After this, you still need some means to show the assembled number on the display (see Figure 2). As this has to be done several times in various situations, you can generate a separate procedure for this purpose. Include the procedure ScreenRefresh in the definition and place it in the implementation section:

    procedure TFMain.ScreenRefresh;
    begin
      Label1.Caption := IntToStr(Accul);
    end;

The function IntToStr ("integer to string") converts a number into a line of text (text string), and this text string is assigned to Label1.Caption. This causes the result to be placed on the screen.

Processing the operation buttons requires a small trick. If an operation button [+,-, *, or /] is pressed, processing the operation must not be executed immediately. Instead, it must wait until the = button is pressed. This means you have to remember which operation button was pressed. To do so, declare an integer variable:

    Processing: Integer;

The +, −, *, and / buttons have tag values of 1–4, and the = button has a tag value of 0. Generate a new procedure that uses these two numbers:

    procedure TFMain.ProcessNumbers(proc: Integer);
    begin
      case proc of
        1: Accul := Accul + Accu2;
        2: Accul := Accul − Accu2;
        3: Accul := Accul * Accu2;
        4: Accul := round(Accul / Accu2);
      end;
      Processing := proc;
      EntryBtn := False;
    end;

The variable EntryBtn is set to TRUE to enable the calculator to again accept a new number. This procedure is called using a procedure that is linked to an event. Now double-click on the OnClick event for the 'add' button.

Up to now, no value has been assigned to Accu2. The simplest approach is to include a line in the AddAccu procedure to copy Accu1 to Accu2:

    Accu2 := Accu1;

Figure 2. Settings in the Object Inspector. The colour selection for the calculator is show at the left, and the setting of the Align property for the label is shown at the right.

Generate a new procedure that calls the procedure listed above:

    procedure TFMain.BtnAddClick(Sender: TObject);
    begin
      ProcessNumbers(Sender as TComponent, Tag);
      ScreenRefresh;
    end;

Now select this procedure (BtnAddClick) in the OnClick event for each of the three other operation buttons and the = button, in the same manner as described above. When a program is started, all of the variables are set to zero (Processing = 0). When the + button is first pressed, the value of Processing is initially 0, and in the ProcessNumbers procedure it is assigned the value for addition (1). When this procedure is executed the second time, the addition is actually executed and the result is shown on the display.

You're almost done now; only the Clear button still has to be assigned a function. By now, you should be familiar with how to do this, so it shouldn't be difficult to fill in this procedure. Simply double-click on the OnClick event of the Clear button and select the BtnClrClick procedure:

    procedure TFMain.BtnClrClick(Sender: TObject);
    begin
      ClearAccu;
      ScreenRefresh;
    end;

Figure 3. The SpeedButton icon is located on the Additional tab of the Design palette.
This procedure calls ClearAccu to set Accu1 and Accu2 to zero and set EntryBusy to FALSE.

```
procedure TForm1.ClearAccu;
begin
  Accu1 := 0;
  Accu2 := 0;
  EntryBusy := FALSE;
end;
```

Listing 1 shows the complete program, including all the components that have been added manually.

Now that the program is complete, you can run it and test whether the calculator works the way it should. If it doesn’t work properly the first time, you should first check the settings of the 16 Speed Buttons. Verify that the name, tag and OnClick event values are entered correctly for each button. It should be noted that the calculator is still rather primitive in its present form, since it can only handle whole numbers (no decimal places). However, you shouldn’t let that spoil your programming pleasure, since it’s just a start.

In this instalment, we have devoted considerable attention to the design of the program in order to familiarise you with all the commands and procedures. With all that out of the way, in the next instalment we can carry on with connecting a keypad to the serial port of the PC. Exchanging data between the PC and the keypad is an important aspect of this next step.
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REPLACEMENT FOR HV

Prof. Martin Ohsmann

Valve circuits and radios in particular are graced by vast crowds of enthusiasts. If you want to keep your prize vintage radio as authentic as possible while actually using it from time to time you need a HV (high voltage) battery or its electronic equivalent.

One of the most popular types of vintage radio running off a high voltage (HV) battery is the valved, portable, medium-wave or long-wave receiver. If you decide to use a switching step-up converter for the 90-volts plate supply then a design using the usual 30-50 kHz switching frequency will soon be found problematic when it comes to preventing harmonics from leaking into the receiver’s RF circuitry. In many cases, the problems are insurmountable.

This article describes a circuit that prevents exactly this kind of trouble by using a very low switching frequency indeed: 50 Hz (or 60 Hz)! This approach not only ensures that harmonics at, say, 200 kHz remain at a negligible level, but also that an off the shelf mains transformer may be used, eliminating the need for constructors to wind their own transformers or inductors.

Also, at 50 Hz even standard CMOS logic will be able to reverse the gate charge on a MOSFET at a sufficiently fast rate. Neither do we require fast high-voltage diodes, the ubiquitous 1N4007 handling the job with ease. With the above concept in mind a circuit diagram is quickly drawn (Figure 1).

Logic gates inside a 74HC04 IC are configured as an oscillator with a complementary driver for two small power MOSFETs. The MOSFETs power the 2
A 90-volts inverter for vintage radios

Figure 1. Circuit diagram of the 50-Hz switching step-up converter with +90-V output.

Figure 2. Copper track layout and...
COMPONENTS LIST

**Resistors:**
- R1 = 1MΩ
- R2 = 100kΩ
- R3, R4, R5, R6 = 100Ω
- R6 = 15kΩ
- R7 = 10kΩ
- R8 = 680kΩ

**Capacitors:**
- C1, C2 = 100nF
- C3 = 680nF
- C4, C5 = 3300µF 16V radial (dia. 13mm, 5mm lead pitch)
- C6, C7 = 470µF 200V radial (dia. 25mm, ‘snap-in’; Farnell # 443-7913)

**Semiconductors:**
- D1 = zener diode 6.2V 0.4W
- D2-D7 = 1N4007
- T1, T2 = IRID120 (International Rectifier; Farnell # 362-1056)
- IC1 = 74HC04

**Miscellaneous:**
- TR1 = 2x9V 3VA mains transformer.
- PCB, available from The PCBShop, ref. #040207-1

Figure 3. Finished prototype of the converter.

The converter's output voltage is dependent on the load connected. Some test values obtained at a supply voltage of 6 V are listed in Table 1.

**Construction**

Both the construction and the component choice are uncritical. The MOS-FETs are housed in 'haxidip' cases. The drain connections are the interconnected pins. The two radial electrolytics C4 and C5 are mounted horizontally to save space. Do not forget to fit the wire link between the transformer and T2.

If you want to keep hum levels to a minimum, it is recommended to screen the entire circuit using tin sheet metal which will also reduce the risk of magnetic coupling. The finished circuit board is shown in Figure 3.

Different output voltages and powers may be created by using appropriate mains transformers.

**Warning.** The circuit generates dangerous voltages. No part must be touched when the circuit is in operation and all relevant electrical safety precautions should be observed.

---

**Table 1. Measured values**

(6 V supply voltage)

<table>
<thead>
<tr>
<th></th>
<th>No load</th>
<th>12-V output loaded</th>
<th>90-V output loaded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current consumption</td>
<td>48 mA</td>
<td>207 mA</td>
<td>101 mA</td>
</tr>
<tr>
<td>12-V output</td>
<td>11.6 V</td>
<td>9.54 V</td>
<td>11.2 - 11.4 V</td>
</tr>
<tr>
<td>90-V output</td>
<td>115 V</td>
<td></td>
<td>100 V</td>
</tr>
<tr>
<td>(not loaded)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Picture source**

Kit Radio Company, Westhamp (introductory photograph and Figure 4).

**Web pointer**

http://homestown.gol.co.uk/~ht_g/idralisco/uk.htm

Radio kits (including HV battery replacement KRC-A-2), components and free construction guides.

---
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Free Internet does not exist

David Daamen

Of course, there's no such thing as free Internet, but surely that does not mean you have to pay the bill? Today, with a little ingenuity and some experimentation it is often possible to tap into a neighbour's wireless network, if it is not, or not sufficiently, protected. Many people use WLAN and WiFi equipment out of the box and totally forget about installing or even enabling encryption. The result: lots of 'free' Internet access points!

Sheer negligence and 'Dilbert's Boss thinking' are not the only reasons for the occasional hubbub in the press about (corporate) networks being easily accessible by any WiFi user within radio range. The phenomenon is not just caused by weak encryption technologies, but also by many private computer users and professional system operators being sloppy in their dealing with encryption keys and passwords.
In many cases, no encryption key is set up at all, resulting in a system that’s about as open as it gets and consequently allowing free Internet access by any non-authorized user within radio range.

**Hacking**

In practice, however, totally open systems are a rarity. Using software like ‘Airpeek’ [1] you can get a quick overview of what’s on the air in your area, and which networks are protected. The three most popular encryption standards are listed in the table, together with the lesser than respectful nicknames given to them by hackers — clearly, WEP is the least powerful standard. Unfortunately (or should we say luckily), WEP is currently the widest used standard — and highly vulnerable it is, see [2] and [3].

Putting aside the question whether breaking into a protected wireless network is immoral or even illegal, it is a fact that free Internet access is perfectly possible.

**Countermeasures**

Of course, you do not want unauthorized users appearing on your wireless network. Now that you are aware that the greatest imperfection is in the standard(s) used to protect the system, it is fairly easy to come up with effective countermeasures.

The obvious choice would be an access point employing WPA (WiFi protected access) based on the 802.11i standard. However, if you already have a router having just WEP, check if it is possible to employ ‘authentication’. Using the 802.1x standard that’s common for these systems, a new connection/session key is assigned to a user any time he/she logs onto the network. This does, however, require an authentication server [RADIUS; remote authentication dial-in user service] but there are also access points on the market that have such a server as an integrated facility. This setup no longer allows eavesdropping on the traffic carried by the access point using a previously ‘hacked’ or stolen key. Moreover, the key is invalidated when the session is over. For continued protection, a recommended procedure is to log out and on again from time to time.

Besides RADIUS there are other measures that can help to increase system security. A step-by-step guide to commissioning a wireless network may be found at [4] where security gets a lot of attention.

**Legal**

Finally, we would like to mention a few links to so-called ‘hotspot directories’ [5, 6, 7 and 8]. These are guides on the Internet listing locations of publicly accessible wireless networks. However, most access points found in these directories are not actually ‘free’ and access has to be paid for. Paid-up service or not — here, too, poorly protected networks are an open invitation to hackers.

---

**Internet addresses**

(1) Airpeek WLAN analyzer: www.wildpackets.com/products/airpeek
(2) AirSnort key recovery: airsnort.shmos.com
(3) WEPCrack: wwwcrack.sourceforge.net
(4) Designing your WiFi network: www.wi-fi.org/OpenSection/design.asp
(5) WiFi Freespot Directory: www.wififreespot.com
(6) Jiwire Guide to WiFi: www.jiwire.com
(7) WiFi ZoneFinder: www.wi-fizone.org/zoneFinder.asp
(8) HotSpot Haven: www.hotspothaven.com

<table>
<thead>
<tr>
<th>WEP</th>
<th>WPA</th>
<th>WPA2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wired Equivalent Privacy</td>
<td>WiFi Protected Access</td>
<td>WiFi Protected Access Version 2 (802.11i)</td>
</tr>
<tr>
<td>WPA1 Even Protect</td>
<td>WPA Protect Alright</td>
<td>WPA prove alright</td>
</tr>
<tr>
<td>Weak, static keys</td>
<td>Improved security by rotating keys</td>
<td>Strong encryption and authentication options</td>
</tr>
</tbody>
</table>
Step-up Converter for White LEDs

Dirk Gehrke

White LEDs are increasingly used for lighting applications in battery-powered equipment. To cope with the effects of a fluctuating supply voltage, a constant-current source is a must.

There are now countless applications where white LEDs (light emitting diodes) are used as (background) light sources. As examples we could mention LCD or keyboard backlighting. Alternatively, white LEDs have advantages in bicycle lights and energy-friendly pocket flashlights.

The circuit shown here allows two variants to be built:

- up to four series-connected white LEDs powered from two series-connected NiMH, NiCd or alkaline cells;
- up to six series-connected white LEDs powered from three series-connected NiMH, NiCd or alkaline cells, or from a single lithium-ion cell.

For the first option it is sufficient to have an input voltage range of 1.8 V to 6.0 V; for the second, a range of 2.5 V to 6.5 V.

The TPS61042 from Texas Instruments is a PWM (pulsewidth modulation) step-up converter configured as a constant-current source. This setup allows a constant current flow to be set up through a number of series-connected white LEDs. The value of resistor R1 between the FB and RS pins of the chip and ground fixes the LED current at 19 mA. An on-chip OVP circuit protects against damage from overvoltage. The circuit deactivates the switching transistor at an output voltage greater than 30 volts.

A further useful function is the ability to switch the chip on and off via the CTRL pin. The switch mode converter is activated when the CTRL pin is taken to the input voltage level. When CTRL is pulled to ground potential, the TPS61042 goes into ‘sleep’ mode, reducing its current consumption to a mere 0.1 µA.

Figure 1. Step-up converter TPS61042 for operation with up to six white LEDs.

QFN — a troublesome case

The IC used in the proposed circuit is only available in an SMD case without leads. Although it is hard to deny that the Quad Flat No-Lead (QFN) case (a.k.a. Small Outline No-Lead or ‘SOW’), saves cost and board space, it is far from ideal for manual soldering using just a solder iron. Undoubtedly the best way to fit the IC on a board is to use infra-red heating. For an experimental construction, a QFN IC may be connected up by turning it over and (quickly) soldering a wire to the connection pads. Unfortunately that is not so simple with the TPS61042 because it has a metal area at the underside (power pad) that assists in transferring chip heat to the PCB surface. A suggestion for experimental use of the chip would be to solder a thin copper strip and a miniature heatsink to the power pad. This requires dexterity, thought.

Once you’ve successfully fitted the IC with its pretinned pads onto the board, a larger hole may be made under the power pad and filled with solder to establish a thermal contact with the PCB.
DIY Through-Plating

For a double-sided printed circuit board to be produced successfully with minimal tools, it is first necessary to have perfectly aligned films of the solder and component sides of the board. Another important aspect is the through-plating of holes in the board that establish a contact between tracks on pads at the component and solder side. A common error made by beginners is to have IC sockets being neatly aligned and soldered at the solder side and then discovering that it is impossible to reach the pads at the component side that also need soldering. Without through-plated holes, component leads with a pad contact at both sides of the board need to be soldered at the component as well as the solder side.

A method often applied in the Elektor labs when stuffing prototypes of boards that will be mass-produced 'through-plated' is to run a very thin wire (copper litz) along with the component lead and soldering it onto a copper track. The wire is easily obtained by pulling it from a multi-strand cable. In this way, contact is established between the board sides without having a real through-plated hole available. There are, however, alternative ways. Using the 'Copperset' system from Multicore it is possible to produce a perfect electrical contact with a professional look in no time at all.

Holes that need to be through-plated are first filled with tubes (bail bars) snapped off from a large bar. The tubes contain a solder core (1). Using the mini anvil and the centre punch tools (2) the tube is fixed in the hole (3) and then soldered (4). Applying the usual desoldering methods, the tube is then opened (5) allowing the component lead to be inserted and soldered (6). If the hole only serves as a 'via' then steps (5) and (6) are not required. The Multicore Copperset kit contains the special tools and three bars of 500 tubes with diameters of 0.8 mm, 1.0 mm and 1.2 mm. The kit is not cheap (Farrell) but fortunately the bail bar tubes are also sold separately and what's more they are easy to handle with just common garden tools. The system is suitable for boards with a thickness of up to 1.6 mm.

Simple Mains Failure Alarm

Jacob Gestman Geradts

A 'Mains Failure Alarm' was published on page 70 of the July/August 2004 issue of Elektor Electronics. Although that circuit is full of ingenuity, it may be a bit over the top given the purpose, which boils down to making a noise when the mains voltage disappears. The author thought the same could be achieved with considerably fewer parts.

If you compare the two schematics, you will agree that although a lot of parts have been omitted, a back-up energy supply remains a central and indispensable part. In the version proposed here, an array of NiCd cells is used. The author salvaged them from an old cordless drill that was banned because of a dust battery pack. As in many other cases, just two cells turned out to be beyond hope, the others working just fine.

With mains voltage normally present on the power outlet, the cells are charged with a small current to keep them topped up. The charge current is supplied via the mains adapter, D1 and R1. The latter is dimensioned such that a trickle charge current of a just a few mA is obtained.

When a power cut occurs, the transistor in the circuit will conduct and DC buzzer Bz1 will produce some noise. Once the circuit has done its job — alerting you that the mains voltage has vanished — you or your housemates will soon want to silence the buzzer. This is done by pressing S1, which takes the transistor's base to ground.

Supplier: www.farrellinone.com

[Diagram of circuit]
RF Detection

David Daamen

WiFi detectors are small gadgets that claim to detect wireless access points for computer networks. The effectiveness of these devices is already covered in many Internet articles, but here you will find out exactly how they work.

To begin with, we opened the first device we had to hand; see Figure 1 (Kensington 'WiFi Finder'). It was immediately apparent that it used a fairly large number of components: Apart from a large section of passive components (resistors, capacitors and inductors) we counted five transistors and three ICs. All components, apart from three LEDs, were surface mounted. On the other side of the double-sided PCB were two watch batteries.

Principle

It soon became clear that the heart of the circuit was an RF detector IC made by Maxim, the MAX4003. This logarithmic amplifier is preceded by an input stage consisting of an array of transistors and a filter. The MAX4003 converts the RF signal into a DC voltage with an amplitude that corresponds logarithmically to the amplitude of the RF signal. The DC output signal is amplified further by an opamp (MC33202, ON Semiconductor) and then fed to an A/D converter input of a microcontroller (MSP430F1101A, Texas Instruments).

Microcontroller

The primary function of the controller is to periodically measure and evaluate the signal strength of the input. Three LEDs are used for the display: a bi-colour LED indicates when a measurement takes place (a short red flash) and together with two green LEDs it forms a mini bar graph meter, which shows the signal strength as one of three levels.

It is clear that the controller doesn't look at the contents of the received signal; there is nothing left of the digital information after the detector IC; just the RF energy is measured. This became even more evident by the fact that the detector also reacted to a Bluetooth signal (very near by). In practice you'll hardly notice this when searching for wireless networks, since Bluetooth signals are much weaker than WiFi signals.

Selectivity

The only selectivity offered by this circuit when it has to differentiate between wireless networks and other RF signals is achieved by the filters in the input stage. These are tuned to the band used by 802.11b and g wireless networks (2412 MHz to 2482 MHz). It is clear that such a passive filter is not perfect. When a GSM phone (900 or 1800 MHz) is nearby, this also causes a few LEDs to light up.

RF detection

You may well wonder if there isn't an easier way. If you only need to measure the RF energy there should be some simpler alternatives. Although this is the case, there are still very good reasons for using a logarithmic amplifier. There are two other methods for measuring high frequency power, but both of these have significant disadvantages. We've put the three methods in a table along with six
The output voltage of a log amp is a logarithmic function of the RF input power.

**Figure 2.** The output voltage of a log amp is a logarithmic function of the RF input power.

Important design aspects to show you how they compare.

**Thermal detector**

The thermal detector is the most conventional. The RF power is determined from the rise in temperature of a resistor that is fed with the RF signal. From the table you can see that this option scores badly on all fronts, apart from cost. The main disadvantage is that the thermal detector is too slow for use as a WiFi detector.

**Diode detector**

Although the diode detector may appear to be a better alternative at first sight, the advantages it offers over the log amp are not important in this application. You may argue about the power consumption, but a good temperature stability is definitely not important in this case.

At about the same cost, the solution provided by the WiFi detector that we opened offers the smallest PCB with the best dynamic range and a fast reaction time. Furthermore, the microcontroller is used to perform multiple functions. Not only does it take care of the actual measurement, but it also drives the LEDs and implements an auto power-off function.

<table>
<thead>
<tr>
<th>Detection principle</th>
<th>Thermal</th>
<th>Diode</th>
<th>Log amp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of PCB</td>
<td>large</td>
<td>medium</td>
<td>small</td>
</tr>
<tr>
<td>Power consumption</td>
<td>high</td>
<td>low</td>
<td>medium</td>
</tr>
<tr>
<td>Thermal stability</td>
<td>bad</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td>Reaction time</td>
<td>milliseconds</td>
<td>microseconds</td>
<td>&lt; 10 µs</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>20 dB</td>
<td>20 dB</td>
<td>20-100 dB</td>
</tr>
<tr>
<td>Cost</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
</tr>
</tbody>
</table>
If you are not lucky enough to have access to expensive test gear then lamp circuits using LEDs offer a good chance of success and allow a little bit of electronic experimentation.

One of our readers has come up with this simple but useful addition to the bedside table. The lamp is activated either by pressing a push button or automatically when the in-built microphone detects a noise. Once lit the LED remains on for a predetermined time. The circuit has quite modest power requirements and four rechargeable NiMH cells (BT1) will be sufficient to power the circuit for a couple of months of intermittent use before they need to be topped up. The complete circuit takes around 400 µA in standby and 24 mA with the LED burning. The microphone requires a connection to the positive supply via R1 and the circuit diagram (Figure 1) shows it AC coupled to IC1.C. The microphone sensitivity is to some extent governed by the value of R1.
A value of 15 kΩ is recommended but it may need to be changed to suit the sensitivity of your particular microphone capsule. At maximum sensitivity the LED was triggered by pressure on the microphone diaphragm from a draft of air produced when the bedroom door was opened! Capacitor C1 is used to remove the DC component of the microphone signal while R2 ensures the resultant AC signal is referenced to earth potential. Resistors R3 and R4 form a potential divider to provide the voltage threshold at the negative input of comparator IC1.C. Whenever the signal level produced by the noise exceeds this threshold value the output will go high and switch on T1. Capacitor C2 will then be charged and the voltage level on the positive input of IC1.B will rise exponentially. Pressing pushbutton S1 will have the same effect because it is wired in parallel with T1. The charging path of C2 has no series resistor so even a very short duration sound will be sufficient for C2 to fully charge. IC1.B is configured as a comparator with resistors R7/R8 forming a potential divider defining the threshold voltage of 20% of the supply voltage (about 1 V) at the inverting input. When C2 is fully charged it takes around 1.5 min for the voltage to fall to this level while discharging through resistor R6. The last opamp IC1.A is configured as an amplifier together with transistor T2. The LED current (and hence brightness) can be altered by changing the value of R11 (ILED = 0.44 VR11). The voltage developed across R11 is used by IC1.A to control the conduction of T2 in a classic feedback configuration. This ensures that the light intensity of D1 remains constant even when the battery output voltage sinks to the sharp ‘knee’ in its characteristic. Connector K1 allows an external charger to recharge the cells. The PCB component placement (including a socket for IC1) is shown in Figure 2. It is not necessary to fit any wire links and apart from the semiconductors there is only one polarised component (C2). It may be tempting fate but there is hardly any opportunity to fit any component incorrectly! The LED is soldered in place once the PCB is fitted into its enclosure and the LED

**Turn off delay calculations**

The LED turn-off delay time is relatively simple to calculate or change if required. The output of comparator IC1.B remains high as long as the signal on the non-inverting input (pin 5) is above the voltage on the inverting input (pin 6). The voltage level at pin 6 is given by:

\[
U_{PIN_6} = U_{BST1} \times R8 / (R7+R8)
\]

The voltage across C2 discharges according to the natural logarithm function:

\[
U_{C2} = U_{BST1} \times e^{-t/RC2}
\]

Rearranging the equation for t:

\[
U_{C2} / U_{BST1} = e^{-t/RC2}
\]

\[
\ln (U_{C2} / U_{BST1}) = -t / RC2
\]

\[
t = -RC2 \times \ln (U_{C2} / U_{BST1})
\]

\[
U_{C2} \text{ and } U_{PIN_6} \text{ should be equal so substituting:}
\]

\[
t = -RC2 \times \ln (U_{BST1} \times R8 / (R7+R8)) / U_{BST1}
\]

The battery voltage can be cancelled from the equation so that the turn off delay time is only dependent on the resistor and capacitor values:

\[
t = -RC2 \times \ln (R8 / (R7+R8))
\]

Substituting actual component values we get:

\[
t = -106 \times 47 \times 10^{-6} \times \ln (10^2 / 4.9 \times 10^2) = 7.5 \text{ s}
\]
positioned through an opening. A reflector can be fitted to help concentrate the LED light.

Wire connections to the PCB can be made via solder pins. It may be possible to connect the charging socket and pushbutton directly to the relevant pins without the need for wire but this will depend on the type of enclosure that you use. The microphone capsule can be mounted inside the case but don’t forget to provide an opening to allow sound waves to reach the microphone.

Figure 2.

COMPONENTS LIST

- **Resistors:**
  - R1 = 15kΩ
  - R2, R8, R9 = 100kΩ
  - R3 = 22kΩ
  - R4 = 5kΩ
  - R5 = 6kΩ
  - R6 = 1MΩ

- **Capacitors:**
  - C1 = 22nF
  - C2 = 47µF 16V radial

- **Semiconductors:**
  - D1 = LED, white, e.g., Conrad Electronics # 153867

- **ICs:**
  - IC1 = TLC274
  - T1, T2 = BC547B

**Miscellaneous:**
- B1 = battery holder for 4 NiMH cells
- K1 = charge socket for batteries
- MIC1 = electret microphone capsule
- S1 = pushbutton, 1 make contact
- PCB, ref. 030122-1 from The PCBShop

---

**ELEKTOR AUDIO BOOKS** 3 *must-haves for all audio-enthusiasts!*

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To many people, the thermionic valve or electron tube is history. However, whether it is nostalgia, interest in the technical parameters, the appeal of a gleaming amplifier chassis with softly glowing valves or perhaps the firm conviction that the sound of a valve cannot be bettered, it is a fact that the valve is making a come-back. This book contains, apart from construction projects for preamplifiers, power amplifiers, and amplifiers for musical instruments, information on the operation of electron tubes, while the first chapter gives a short history of the valve.

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76
Marconi TF1152 RF Wattmeter

Jan Buizing

In line with this month's focus on all things wireless, I am covering a vintage instrument that has given me many years of excellent service and peace of mind at a very small investment indeed. If you like to work with transmitters, large or small, the most important thing to have on the test equipment shelf is not a hefty power supply, not a spectrum analyser, not helical trimmer tools or any new-fangled bit of LCD multimeter. Forget about these — invest in a proper dummy load as it will give you a feeling of utter confidence that the expensive transmitter is always properly loaded and prevented from radiating away. Much to the amusement of some of my more DC-inclined friends, if unknown equipment lands on my benchtop I invariably hook up the wattmeter before anything else and then carefully inspect the coax lead and adapters if applicable. I bought my Marconi TF1152A/1 "Absorption Wattmeter" about 10 years ago for just under 20 pounds from an electronics surplus store. I guess it was built in the early 1970's. From the available stock in the crammed store I was careful to pick a TF1152 with a not too clean face but clearly marked '50 Ohm' above the N-type input socket. These meters also came in 75 ohm guise which I believe is mostly for use in professional systems employing 75-ohm coax cables. Yes, N connectors also exist in a 75-ohm variety and only experts can see the difference with 50-ohm counterparts. For years I dreamt of owning a Bird 'fermaline' (no typo) wattmeter with a box of those beautiful plug-ins for various bands and power levels. To cut a long story short: too expensive for me.

The TF1152 combines the functions of a wideband dummy load and accurate RF power meter in a single lightweight case painted a dull 'tech-nogrey'. Mine has a 13-digit number engraved on the front panel which I suspect is a NATO stock number (n.s.n.). The instrument has two switch-selectable power ranges with matching meter scales: 0-10W and 0-25W. Its frequency range is 0 to 500 MHz.

The size of the instrument and its sturdy carrying handle belies its weight — in a positive way because the TF1152 is very easy to carry around. I have used my TF1152 to test and adjust more PMR equipment than I care to remember, also on windswept hills and towers and in radio amateur shack covered in thick cigar smoke. The meter needle will faithfully indicate 200 mW or less of RF power even on 70 cm. The needle response enables you to do TX PA trimmings adjustments quickly and with confidence as you can observe the power output 'trend' — try that on a modern instrument with digital readout. I must admit I never bothered to look inside the instrument until I started to write this article. The wattmeter being of the 'absorption' type, it contains a thermistor bolometer element in a glass encapsulation. This element is electrically incorporated in a bridge circuit together with several calibration and (thermal) compensation elements: A small bead inside the thermistor consists of a component of metallic oxides possessing a negative temperature coefficient of resistance. Such a thermistor element is very hard if not impossible to obtain as a one-off and certainly outside the reach of the average hobbyist.

The 50-Ohm RF load inside the TF1152 looks like a tapered tube running almost the length of the meter's case (see photograph). Near the end, I was only able to see what looked like a ceramic insert. The VSWR of the mysterious load was found to be less than 1.10 across the band. The accuracy of an RF wattmeter is not terribly important, as on VHF and UHF it makes no difference at all whether you're feeding 15.0 watts or, say, 16.1 watts into your antenna system. Despite the presence of two hefty and clearly labelled pots inside the instruments I never felt the need to recalibrate my TF1152 against, dare I mention it, a Bird. I'm sure the guys who designed and built the TF1152 knew what they were doing.

Retronics is a monthly column covering vintage electronics including predatory Elektor designs. Contributions, suggestions and requests are welcomed; please send an email to editor@elektor-electronics.co.uk, subject: Retronics EC.
Lamp intensity

This time consider the circuit in Figure 1. Lamps L1 and L2 each have a nominal power $P = 1$ watt. Lamp L1 has an internal resistance of $R_1 = 100 \, \Omega$ while for lamp L2, $R_2 = 200 \, \Omega$. Both resistance values are applicable at the nominal lamp power. The alternating voltage source now supplies a voltage $U = 22.63 \, V$ at a frequency of 50 Hz. The value of capacitor C is such that the component also represents a reactance of $200 \, \Omega$ at 50 Hz, in other words, $C$ has a value of 15.915 µF. Initially, switch $S$ is opened (as shown in the diagram) and the voltage source supplies a voltage $U$ causing lamp L1 to be supplied with current and the lamp to light at a certain intensity.

Next, switch $S$ is closed, which leads us to the question:

**After closing the switch, will the intensity of lamp L1 increase, decrease or remain the same?**

Followed by a second question:

**After closing the switch, which of the two lamps L1 and L2 lights brighter?**

Send in the best answer to this month’s Quizz’away question and win a

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All answers are processed by Martin Ohsmann in co-operation with Elektor editorial staff. Results are not open to discussion or correspondence and a lucky winner is drawn in case of several correct answers.

Please send your answer to this month’s Quizz’away problem, by email, fax or letter to: Quizz’away, Elektor Electronics, PO Box 190, Tunbridge Wells TN1 7WY, England. Fax (+44) (0)1892 65216. Email: editor@elektor-electronics.co.uk, subject: ‘quizaway 2-05’.

The closing date is 25 February 2005
(solution published in March 2005 issue). The outcome of the quiz is final. The quiz is not open to employees of Segment B.V., its business partners and/or associated publishing houses.
As of the September 2004 issue Quizz’away is a regular feature in Elektor Electronics. The problems to solve are supplied by Professor Martin Ohsmann of Aachen Technical University.

Solution to the December 2004 problem

(p. 78; Wond’rous Light Chain)

Surprisingly few correct answers were received so the light chain must have been ‘wondrous’ indeed to many of you. However, a few attentive readers were able to discover, by ‘reverse reasoning’ that the voltage source used was not an ordinary transformer connected to the mains but one producing an RF signal at about 13.56 MHz and supplying a nominal output voltage of 36 volts into 360 Ω. At 13.56 MHz (an ISM frequency often used for RFID), the wavelength in vacuum, λ₀, equals c/f or 22.11 m. Consequently the cable length is not small relative to the wavelength, forcing us to describe the operation of the circuit in terms of transmission line theory. The impedance of an unshielded twisted-pair Ethernet cable (i.e. two wires) is about z₀ = 120 Ω, which equals the internal resistance of the lamps at 12 V / 0.1 A = 120 Ω. In other words, the lamps are ‘impedance-matched’ to the lines. Since the propagation speed of waves on the twisted-pair lines is about 0.81 times the speed of light, a cable with a length L of 4.5 m as used in our Christmas tree represents exactly a quarter wave (L = λ₀/4)! This should start some bells ringing in the RF engineering department because the wires to the lamps act as quarter-wave transformers.

Figure 2 illustrates what happens. The impedance seen at the powered point ‘S’, depends on the resistance R used to terminate the transmission line. If, in the case of the correct lamp connected up, R = z₀ then the line is perfectly matched and an impedance R = z₀ will also be seen at the feed point ‘S’. Now, if R becomes infinite, as in the case of a defective lamp, the current at the end of the line must be zero, while it is at maximum at the feed point (lower drawing). The voltage has the opposite behaviour, reaching zero at the feed point and maximizing at the (open) end of the line. In this way, a quarter-wave transmission line transforms an ‘open circuit’ at the end into a ‘short circuit’ at the feed point. The line itself then carries a so-called ‘standing wave’, not conveying energy into a direction but causing energy to be exchanged between the electrical and magnetic field components — just as with a resonant circuit.

The above effect allows us to explain the operation of the Wond’rous Light Chain in a simple and straightforward way. We are looking at three lamps connected to an RF source via wire pairs acting as quarter-wave transmission lines. Close to the voltage source, the three feed points are connected in series. With all three lamps intact, the circuit will function just as any primitive set of Christmas tree lights. However, if a lamp fails, the open-circuit condition at the line-end is transformed into a short-circuit at the local feed point. Consequently the source voltage will distribute across the remaining network of two lamps, which will light brighter.
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<td>Remote Light Control with Dimmer</td>
<td>DE0095-2</td>
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<td>AVR TV Tuning</td>
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<td>Four LCDs Controller</td>
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<td>High-Level Display Control</td>
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<td>Temperature Indicator for the PC</td>
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