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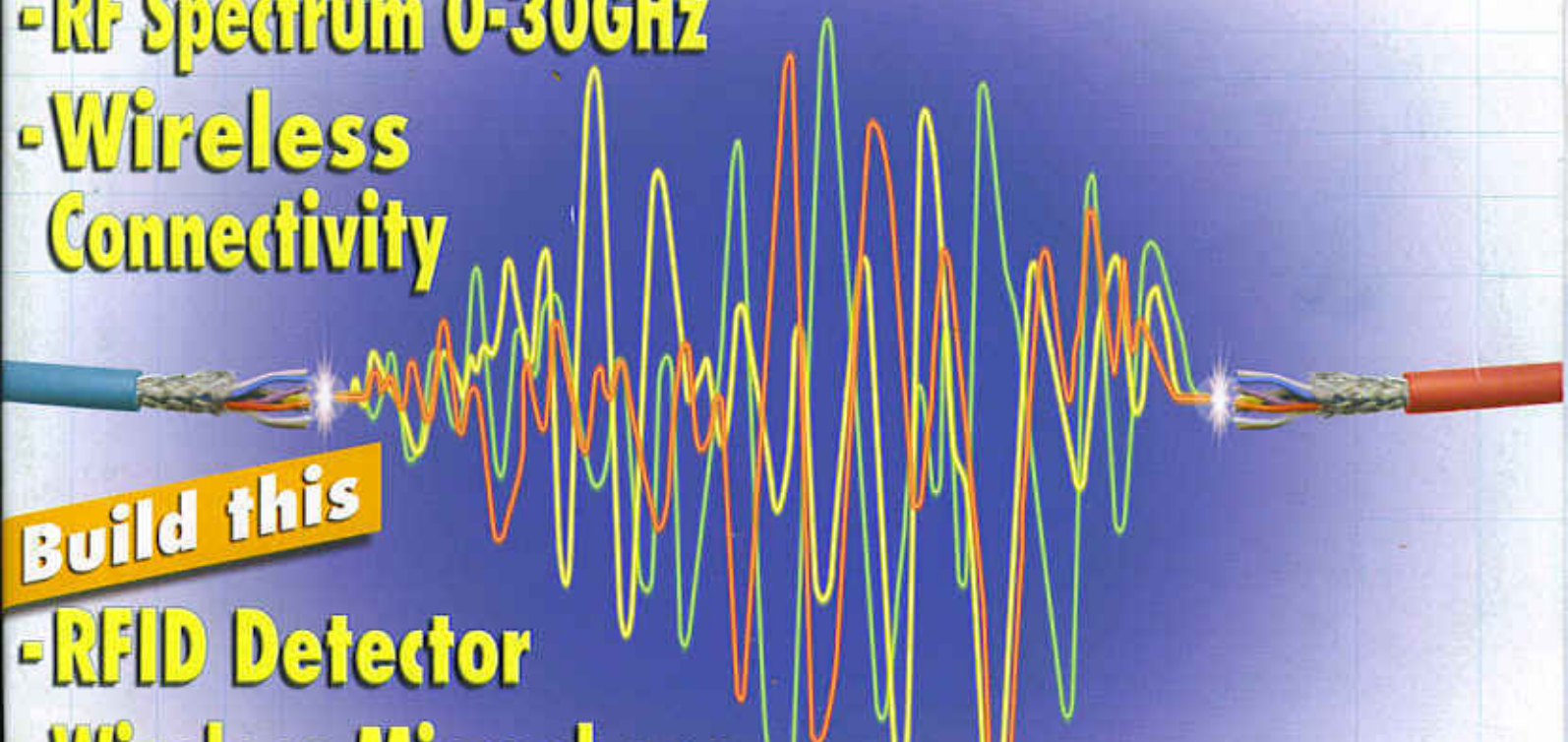
WIRELESS

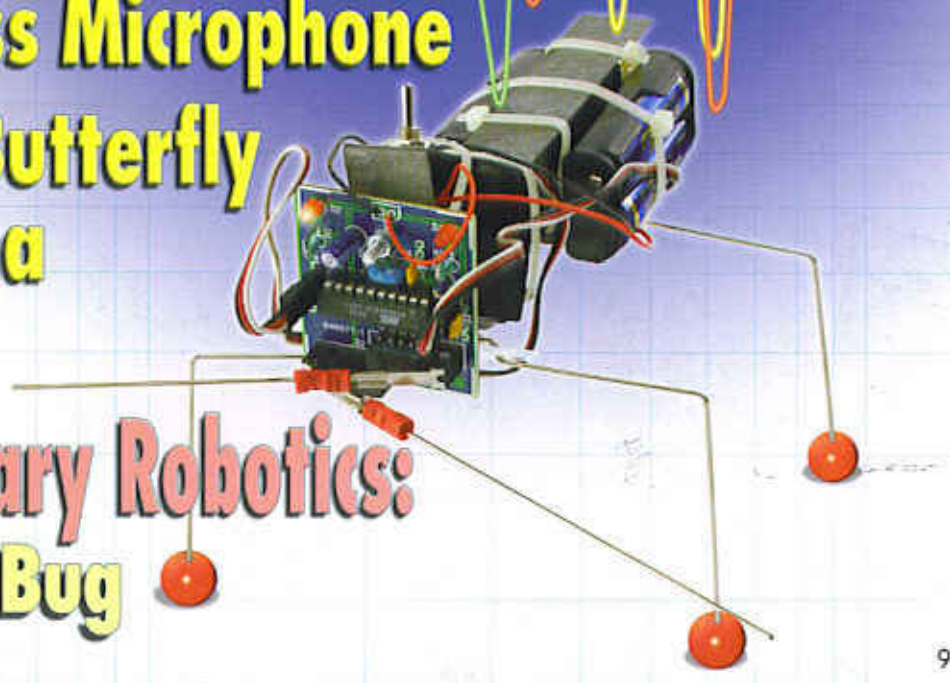
Overview

- RF Spectrum 0-30GHz
- Wireless Connectivity



Build this

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



Elementary Robotics: Walking Bug

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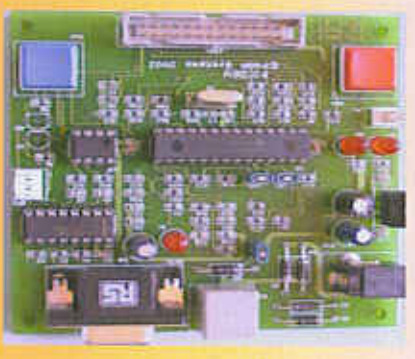

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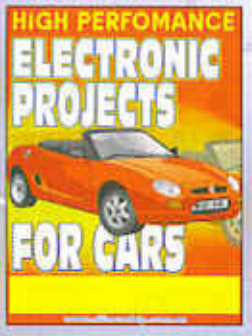

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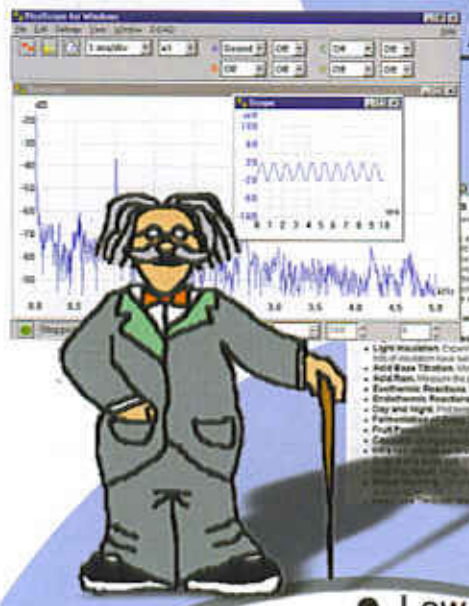

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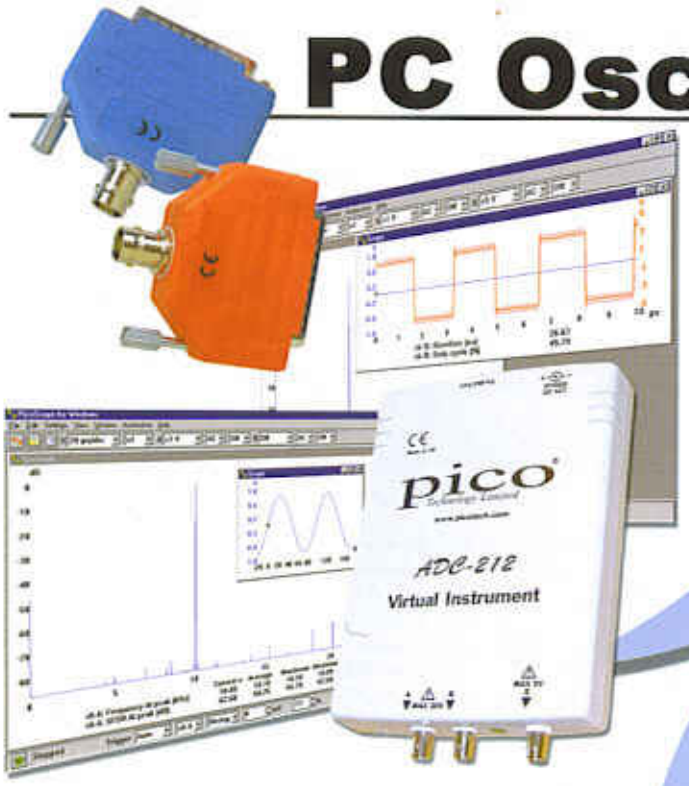

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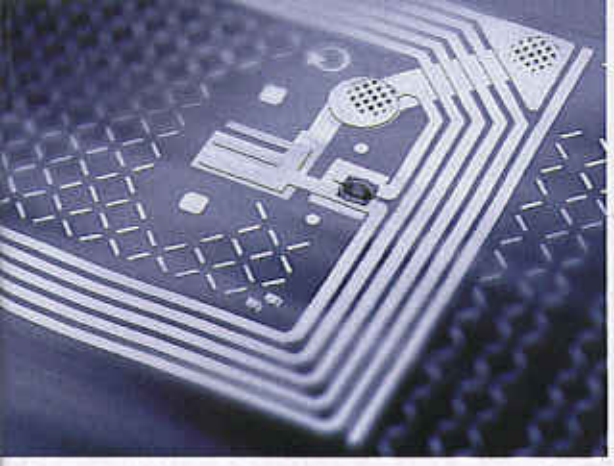

RFID frenzy

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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International Editor: Mat Heffels (m.heffels@segment.nl)

Editor: Jan Buiting (editor@elektor-electronics.co.uk)

International editorial staff: Harry Baggen, David Daamen, Rolf Gerstendorf, Ernst Krempelsauer, Guy Raedersdorf.

Design staff: Karel Walraven (head of design), Ton Giesberts, Paul Goossens, Luc Lemmens (techdept@segment.nl)

Editorial secretariat: Hedwig Hennekens (secretariaat@segment.nl)

Graphic design / DTP: Ton Gulikers, Giel Dols

Managing Director / Publisher: Paul Snakkers

Circulation Control: Margriet Debeij (m.debeij@segment.nl)

Subscriptions
Worldwide Subscription Service Ltd., Unit 4,
Gibbs Reed Farm, Pashley Road, Ticehurst TN5 7HE, England.
Telephone: (+44) (0)1580 200657, Fax: (+44) (0)1580 200616
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Head Office
Segment b.v., P.O. Box 75, NL-6190-AB Beek, The Netherlands
Telephone: (+31) 46 4389444, Fax: (+31) 46 4370161

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UK Advertising
Huson International Media, Cambridge House, Gogmore Lane,
Chertsey, Surrey KT16 9AP, England.
Telephone: +44 (0)1932 564999, Fax: +44 (0)1932 564998
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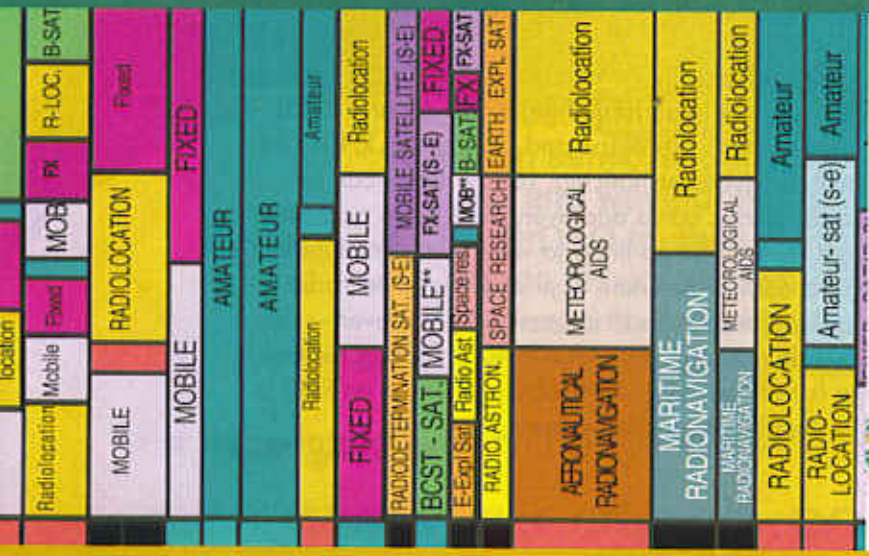

Wireless Connectivity

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'.

20

Wireless Microphone

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.

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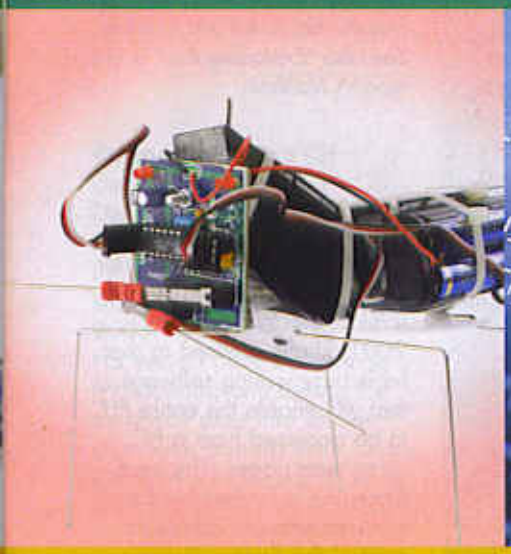
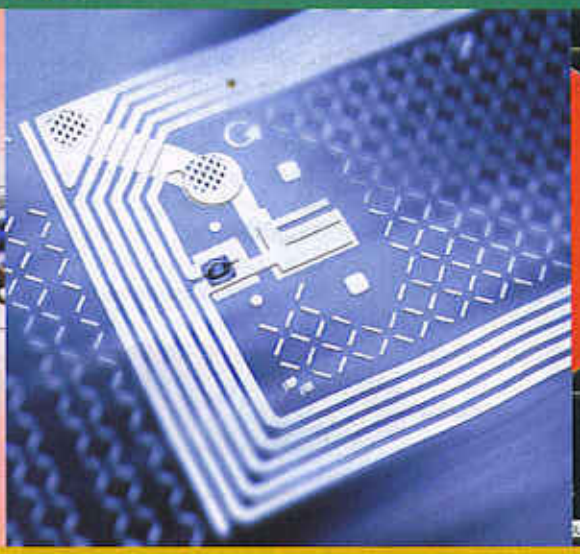


Walking Bug

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.

38



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'.

50

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.

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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.

NiCd 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 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://home.scarlet.be/~dc11cd/dcieth.html

211 Elektors

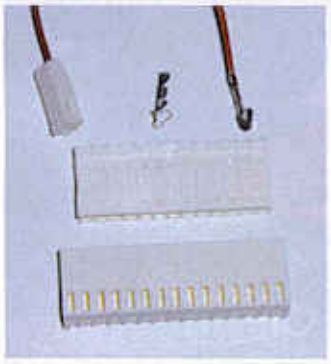
Dear Editor — I am clearing out my magazines. I have copies of *Elektor* magazine from issue 1 to 211. Are you or any of your readers interested in them? One condition is that if so they must be col-

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 having 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.



Don't solder them because this creates a sharp physical transition and the wire can be broken if it is flexed. This has been used successfully on commercial jobs that are still going till this day.

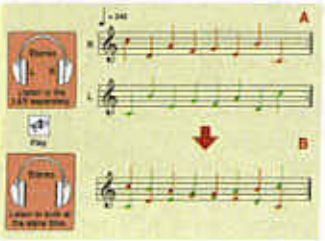
Farnell has Molex socket 77205, 26AWG, 16-way, P/N 148-623 @ 6.67 $NZ. Also from Farnell a crimp tool, P/N 147-124 @ 45.33 $NZ.
Alternatively, TYCO HE 14 system socket, single row, 12-way, Farnell P/N 429-648 @ 1.96 $NZ. Crimp terminals, Farnell P/N 429-703, etc.
These are numbers from the Australasian, i.e., New Zealand catalogue, sourced from Australia. I am sending some photos across.

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 Jan — 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 Ketley, 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 adapter 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.

MailBox Terms

– Publication of reader's correspondence is at the discretion of the Editor.
– Viewpoints expressed by correspondents are not necessarily those of the Editor or Publisher.
– Correspondence may be translated or edited for length, clarity and style.
– When replying to Mailbox correspondence, please quote issue number.
– Please send your MailBox correspondence to: editor@elektor-electronics.co.uk or Elektor Electronics, The Editor, P.O. Box 190, Tunbridge Wells TN5 7WY, England.

World's smallest microcontroller

Microchip has introduced revolutionary 6-pin Flash devices in an ultra-small form factor SOT-23 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™ (ICSP™) technology, power-on reset, power-saving 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® 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 free 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 SOT-23 packages.

Arizona Microchip Technology Ltd., Microchip House, 505 Eksdale Road, Winnersh Triangle, Wokingham RG41 5TU. Tel. (+44) (0)118 921 5858. Fax (+44) (0)118 921 5835. www.microchip.com.

(047147-2)

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

Providing PC and Mac® 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 (IEEE1394) and FireWire800 (IEEE1394b), OXFW970 high quality, multi-channel audio solutions avoid 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 AM824 audio format. Sampling 24-bit audio packets at 96 kHz, the chip provides four I²S 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™ 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 kbits 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.

Oxford Semiconductor Ltd., 25 Milton Park, Abingdon, Oxfordshire OX14 4SH. Tel. (+44) 1235 824-900. www.oxsemi.com

(047147-3)

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 MCP7386X 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 monitor 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 minimises 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 web site at www.microchip.com/mcp7386x

Microchip Ltd., Microchip House, 505 Eksdale Road, Winnersh Triangle, Wokingham RG41 5TU.
Tel. (+44) (0)118 921 5869.
Fax (+44) (0)118 921 5820.
Website: www.microchip.com.

(047199-4)

Battery Authentication and Safety

Following recent news of "exploding" mobile phones, due to the use of counterfeit batteries, Microchip today announced that its KEELOQ 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, KEELOQ, with its proprietary encryption and decryption algorithms, provides a high level of security without adding excessive complexity to the system.

For more information on the KEELOQ technology, visit the Microchip web site at www.microchip.com/keeloq, and for more information on Microchip's Powersmart battery fuel gauge devices, visit www.microchip.com/battery.

Microchip Ltd., Microchip House, 505 Eksdale Road, Winnersh Triangle, Wokingham RG41 5TU.
Tel. (+44) (0)118 921 5869.
Fax (+44) (0)118 921 5820.
Website: www.microchip.com.

(047199-6)

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 µWs 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 thrifty because each digital '0' is represented by the HF oscillator turning off completely. Careful design ensures that the oscillator is stable again within 1µs 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 1. Energy needs for each module function und mean power requirements of EnOcean radio modules in typical applications.

Application	Light Switch for use in buildings and industry	Room thermostat or smoke detector	In-tyre pressure and temperature sensor
Energy for measurement event (µWs)	0.5	4	1
Energy for sequence control, microprocessor (µWs)	1	6	2
Energy for RF transmission (µWs)	12	60	20
Total energy needs for measuring and transmitting	13.5	70	23
Transmissions per Minute	-	1	10
Power consumption	13.5 µWs per switching event	1.2 µW mean	3.8 µW mean

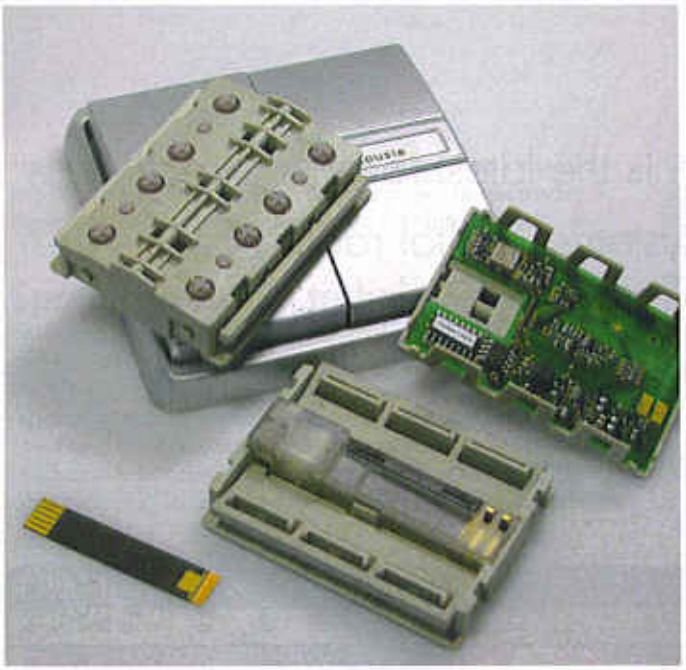


Figure 1. The battery-free piezo transmitter module PTM 100 (on the switch plate). Individual components are seen in the foreground: Piezo converter (left), mechanical energy converter and PCB with Antenna. (source: EnOcean GmbH)

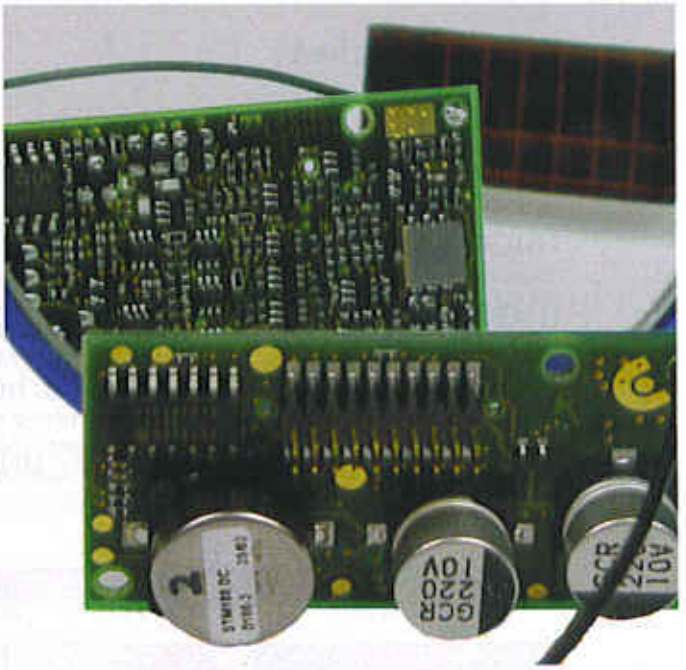


Figure 2. The STM 100 has three analogue and four digital inputs. Energy comes from a solar cell and is stored in a high value Goldcap capacitor.

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 (!). 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.

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Further information from:
www.enocean.com

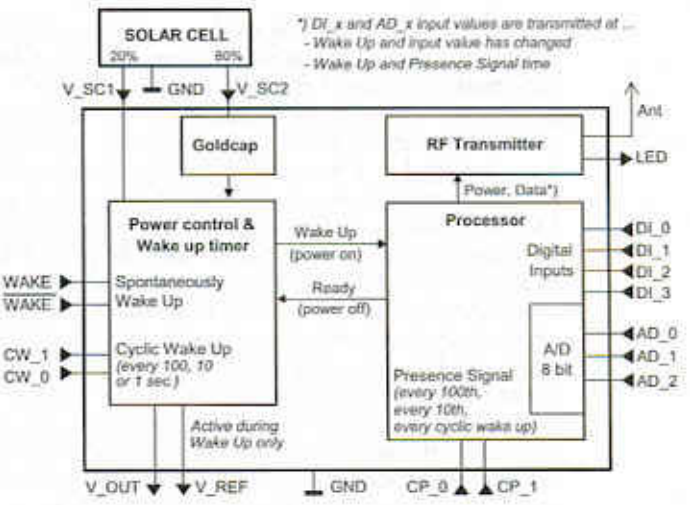

Figure 3. Block diagram of the STM 100.

WIRELESS CON

Stefan Tauschek

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'.

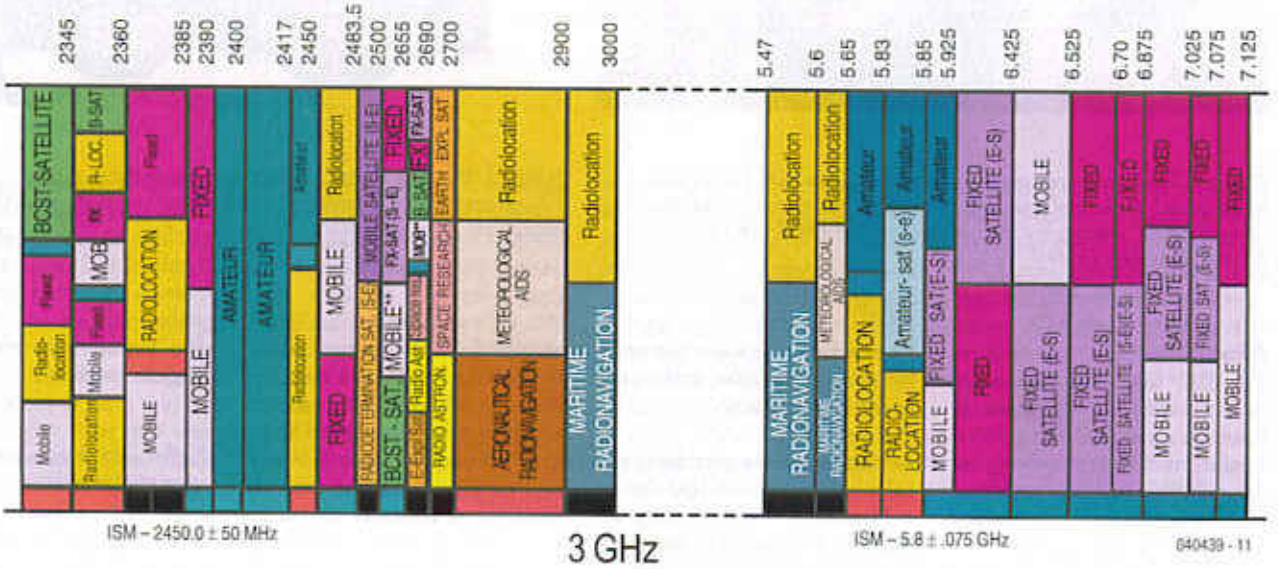

Figure 1. An excerpt from the international frequency allocation table.

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, HomeRF, 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. 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-

NECTIVITY ISM, WLAN, WMAN, Bluetooth et al.

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 metres 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 preconditioning or processing for data security. This is adequate for pumping data over the airwaves at up to 1500 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.

Table 1. Commonly used ISM bands

ISM Band	1	2	3	4	5 Bluetooth etc.	Others
Frequency range	26.957–27.283 MHz	40.660 – 40.700 MHz	433.050 – 434.790 MHz	868 – 870 MHz	2.4 – 2.483 GHz	5.8 GHz, 24.250 GHz 122.5 GHz
Bandwidth	326 kHz	40 kHz	1,74 MHz	2 MHz	83 MHz	> 150 MHz
Advantages	Low power consumption	No persistent interference sources, low power consumption	Relatively large bandwidth, good propagation, moderate price	Relative large bandwidth, low occupancy, duty cycle limited to 10% in most of the band	Very large bandwidth	Very large available bandwidth
Disadvantages	High noise level due to CB radios	Bandwidth too small, difficult to make antenna compact	High occupancy in certain areas (radio amateurs, radar)	More expensive than 434 MHz due to dual-superhet technology	Propagation problems (quasi-line-of-sight), interference from microwave ovens	Not yet economically viable

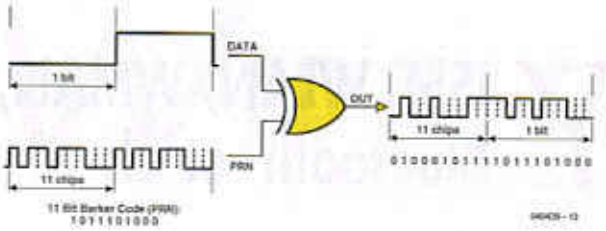

Figure 2. The DSSS technique buries the data in a noise signal.

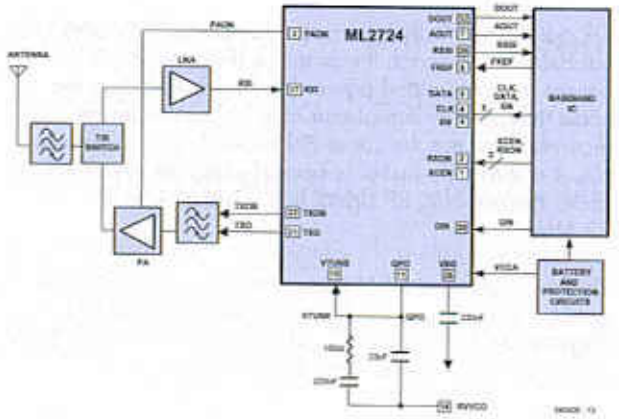

Figure 3. Typical DSSS transceiver architecture.

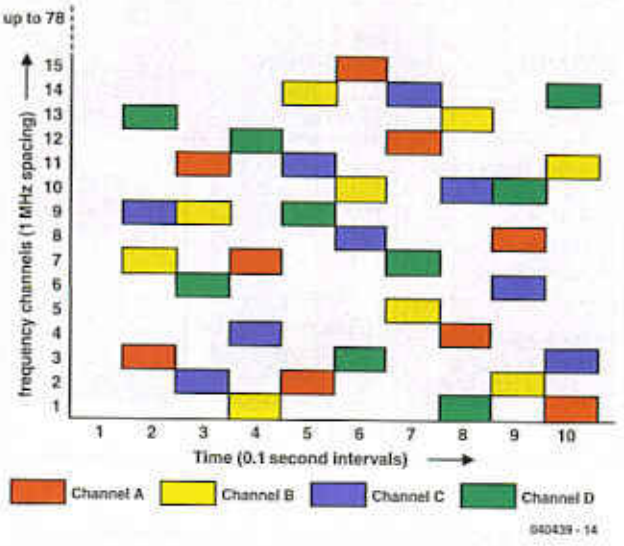

Figure 4. Frequency hopping allows each frequency to be used by several channels.

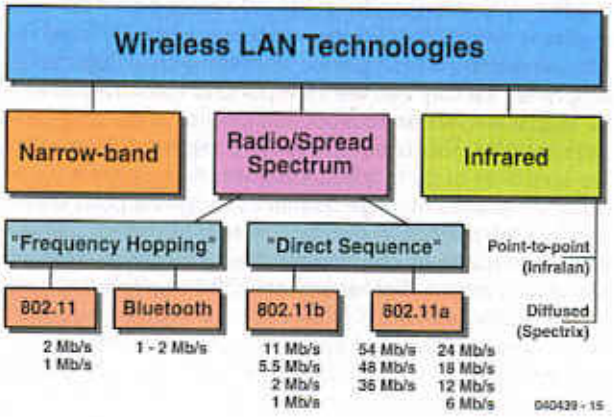

Figure 5. Summary of WLAN techniques.

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 ±75 kHz, and exact compliance with the scheme of hopping to a new frequency every 625 ns. Due to these technically 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 remote-action system (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 'cantenna', which is a combination of *can* 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.

Figure 6. Inexpensive and effective: the Contenna.

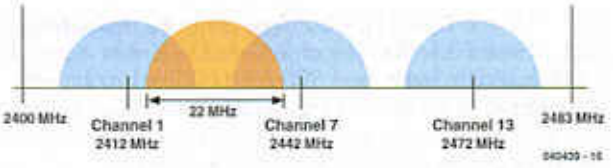

Figure 7. WLAN channel overlap.

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 5.8-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 2. Radio standards for WLAN and WMAN*

Standard	Frequency range	Maximum data rate (MBit/s)	Data throughput (MBit/s)	Range (m)
SWAP 1.x, 05/1998	2.4 GHz (ISM) licence free	1	1	50
SWAP 2.x, 07/2002	2.4 GHz (ISM) licence free	10		50
802.11, seit 1997	2.4 GHz (ISM) licence free	2	1	30 – 300
802.11a, 09/1999	2.4 GHz (U-NII) licence free	54	22	12 – 20
802.11a, 09/1999	5 GHz (U-NII) licence free	54	22	12 – 20
802.11b, 07/1999	2.4 GHz (ISM) licence free	11	6	30 – 300
802.11g, 06/2003	2.4 GHz (ISM) licence free	54	22	20 – 100
802.11h, 09/2003	5 GHz (U-NII) licence free	54	22	12 – 20
802.11n, (anticipated 2005)**			100 – 320	
802.16, 12/2001	10 – 66 GHz licence required	134	70	50 k
802.16a, 01/2003	2 – 11 GHz licence required	134	70	50 k
	2.4 GHz (ISM), licence free			
	5 – 6 GHz (U-NII/CEPT) licence free			
802.16e, 2004	2 – 6 GHz licence required		2	
802.20, 2004	10 – 66 GHz licence required	16	2/0.3	15 k
HiperLAN/1, 07/1998	5 GHz	23.5	20	10
HiperLAN/2, 04/2000	5 GHz	54	42	50
HiperACCESS	42 GHz	25	n/s	5 k
HiperMAN	2 – 11 GHz			

* '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 WiFi Alliance strived (and still strives) to achieve compatibility and interoperability for 802.11-based WLAN systems, the WiMax 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.

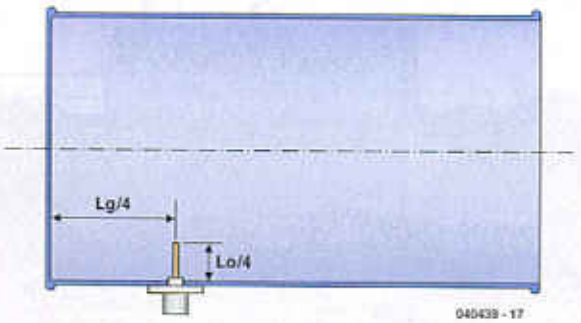

Figure 8. Cantenna construction plan.

802.11b and 802.11g – but they are to be replaced by 802.11n in the future. The objective is to further increase the data rate to more than 300 Mbit/s. This bit of magic is supposed to be achieved by using transmission protocols with greater efficiency, compression techniques, and receivers with improved dynamic characteristics (**Table 2**).

Smart antennas

The Cantenna shows that it's not that difficult to make antennas with good performance for centimetre-wave signals. Even so, it's still common practice to use rod antennas with omnidirectional characteristics, with the result 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 closed at one end, in which a standing wave is generated by suitable mechanical dimensioning. **Figure 8** shows the basic design of such a 'tin-can' antenna. Here L_g is the length of the standing wave in the antenna (with the maximum being located at $L_g/4$), and L_o 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 Cantenna like this and the calculation of L_g can be found on numerous Internet sites, such as http://www.turnpoint.net/wireless/cantennahowto.html and http://www.saunalahti.fi/elepal/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.

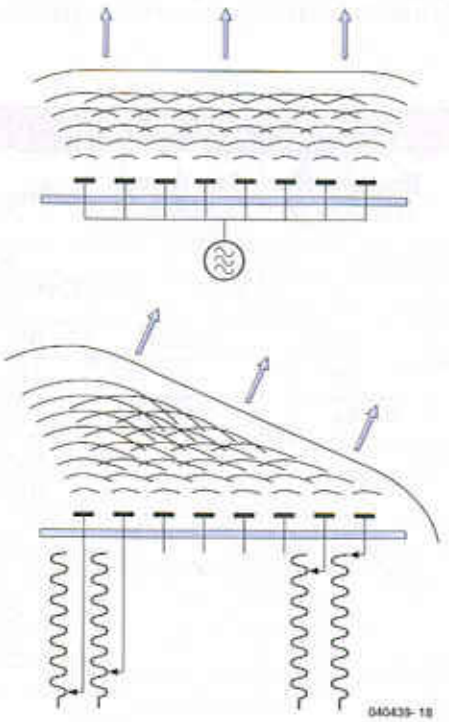

Figure 9. Beam forming can be used to steer the radio waves in various directions...

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 receiver antenna.

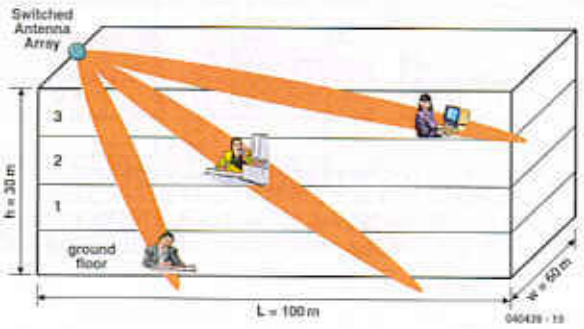

Figure 10. ...and selectively communicate with different areas in a building.

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, or course, the two

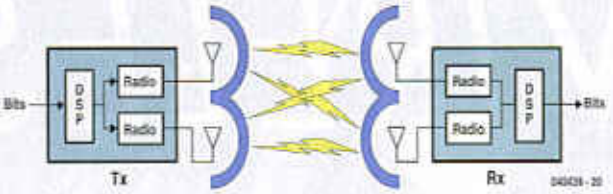

Figure 11. Multiple antennas at each end can considerably increase bandwidth.

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.

(040439-1)

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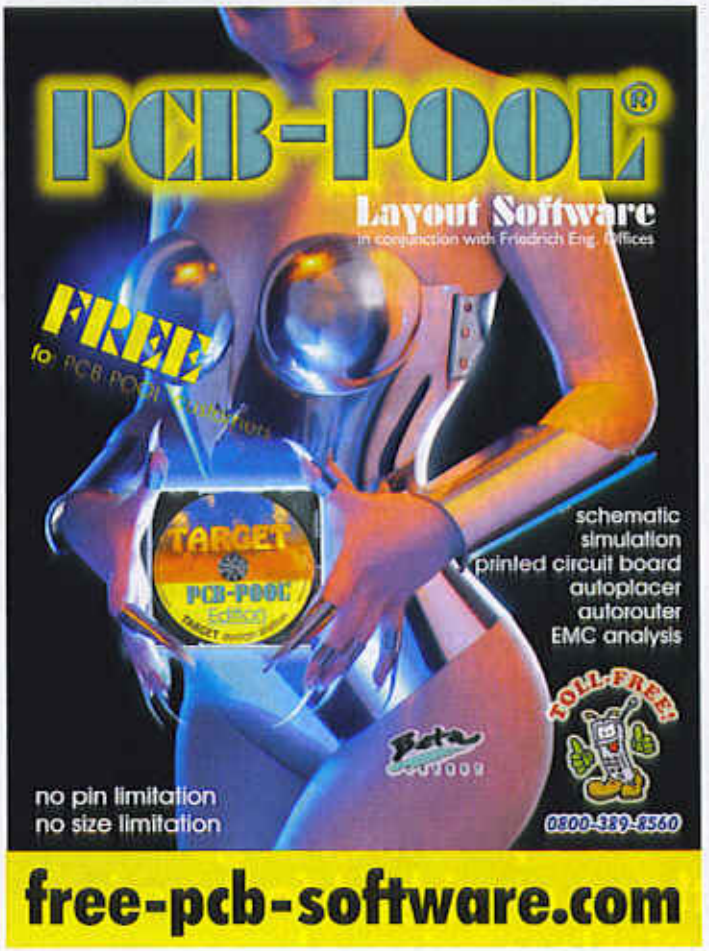
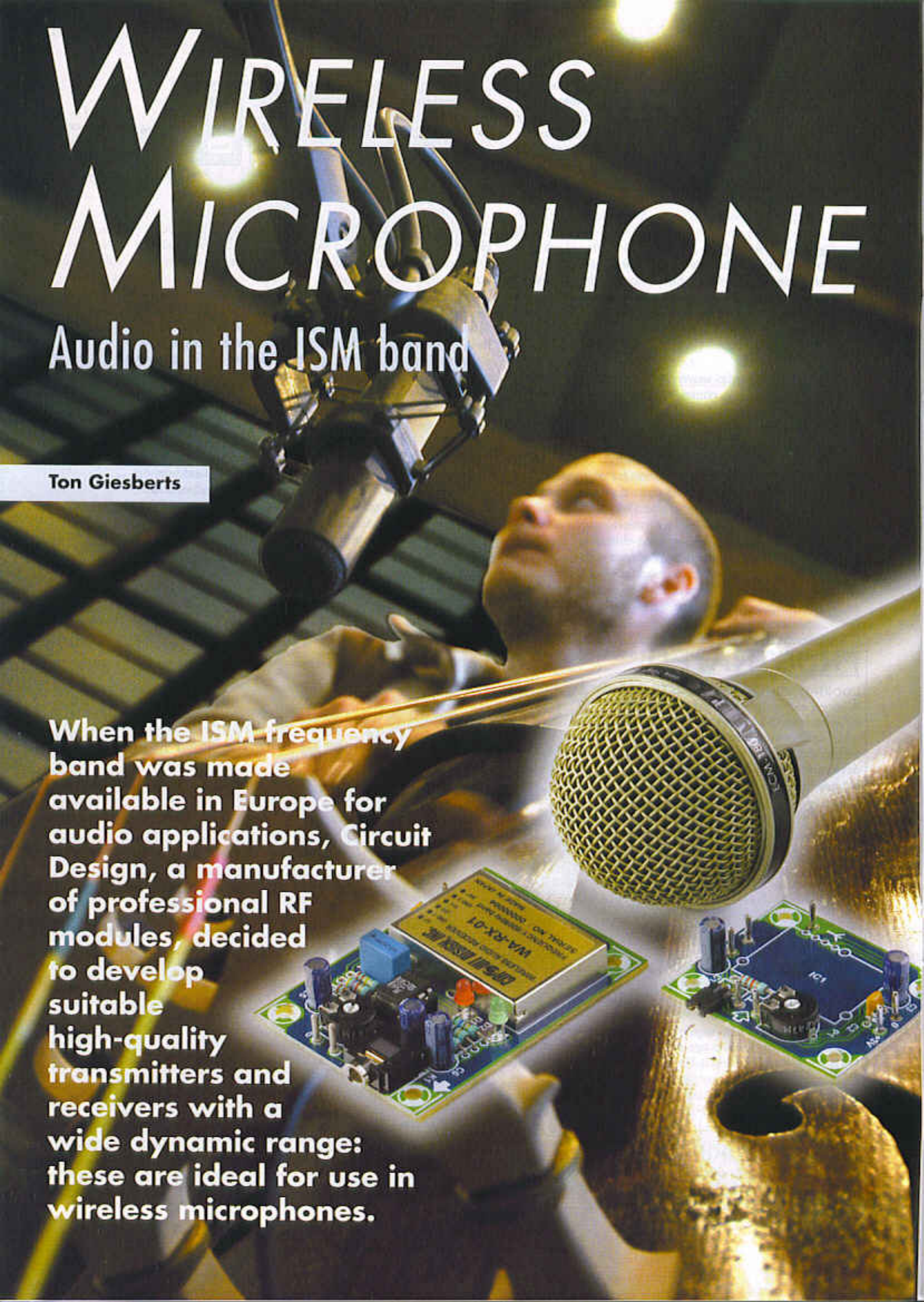


Wireless Microphone

Audio in the ISM band

Ton Giesberts



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.

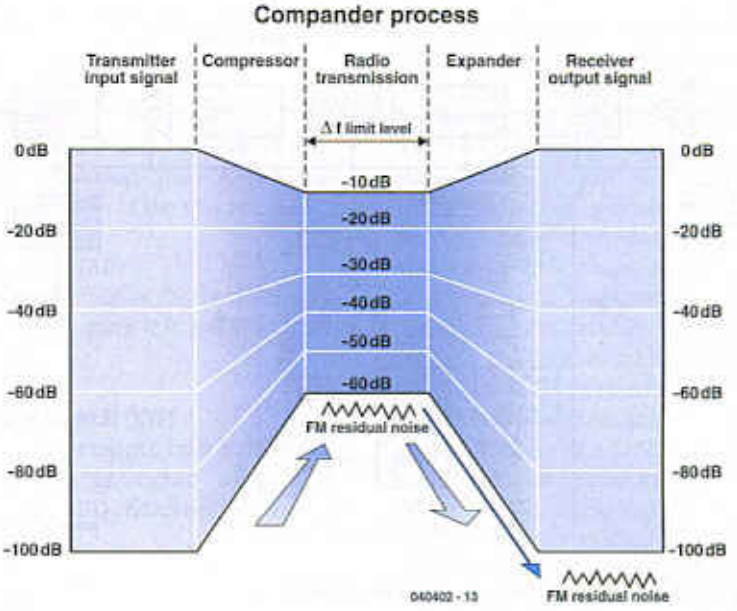


Figure 1. Use of a compander for noise reduction.

Dynamic transmission

The maximum sound pressure level (SPL) which can be tolerated by humans is 140 dB_{SPL}, which is measured relative to the minimum audible sound pressure level of 0 dB_{SPL} = 20 μPa. In a quiet room the background noise level is about 20 dB_{SPL}, and the sound pressure level of the human voice is around 120 dB_{SPL}. 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:

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

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 muct 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.

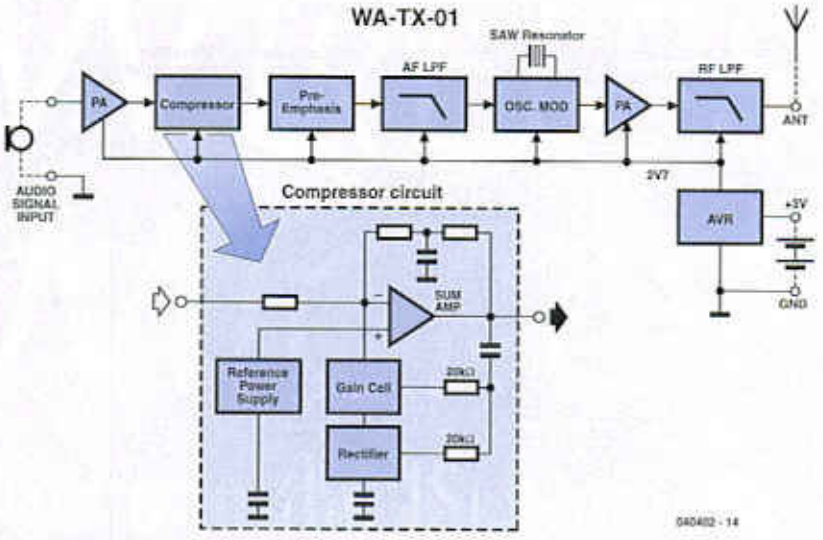


Figure 2. Block diagram of the transmitter module...

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

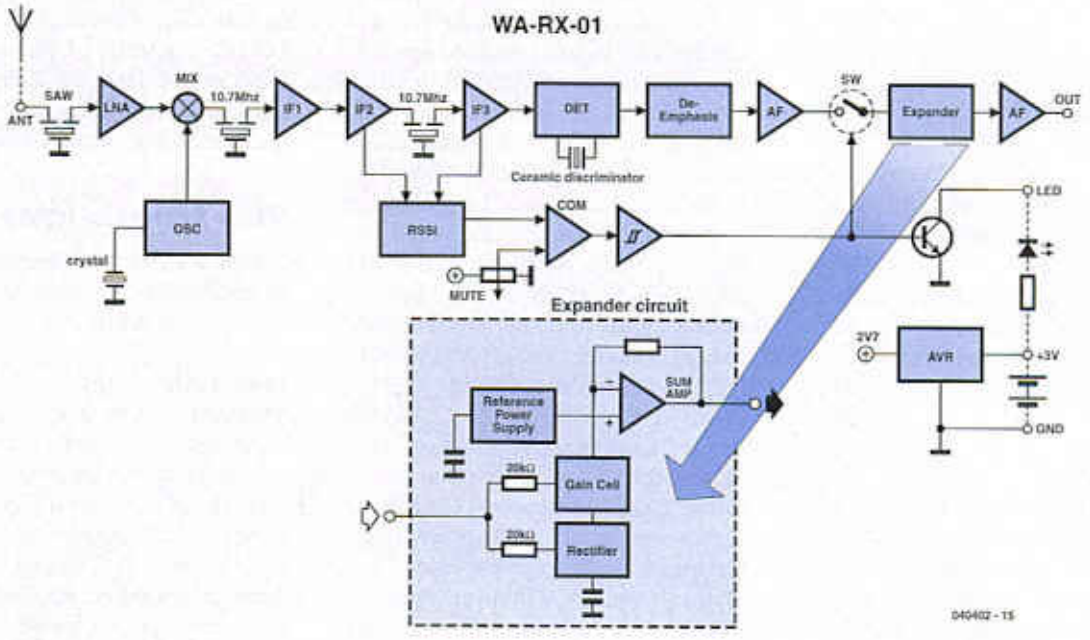


Figure 3. ... and of the receiver module.

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 dBµV or less, the output signal is turned off.

De-emphasis
This compensates for the 50 µs 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 V supply from a battery voltage of between 3 V and 12 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 our prototype we measured about 0.15 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 kΩ, 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 V and 12 V, almost the same range as for the module. We have shown a supply voltage of 5 V, although 3 V or 12 V would do just as well. If a different (non-rail-to-rail) opamp were used, a supply voltage of 5 V would be required. Many opamps will only operate correctly with a symmetric power supply of ±5 V or

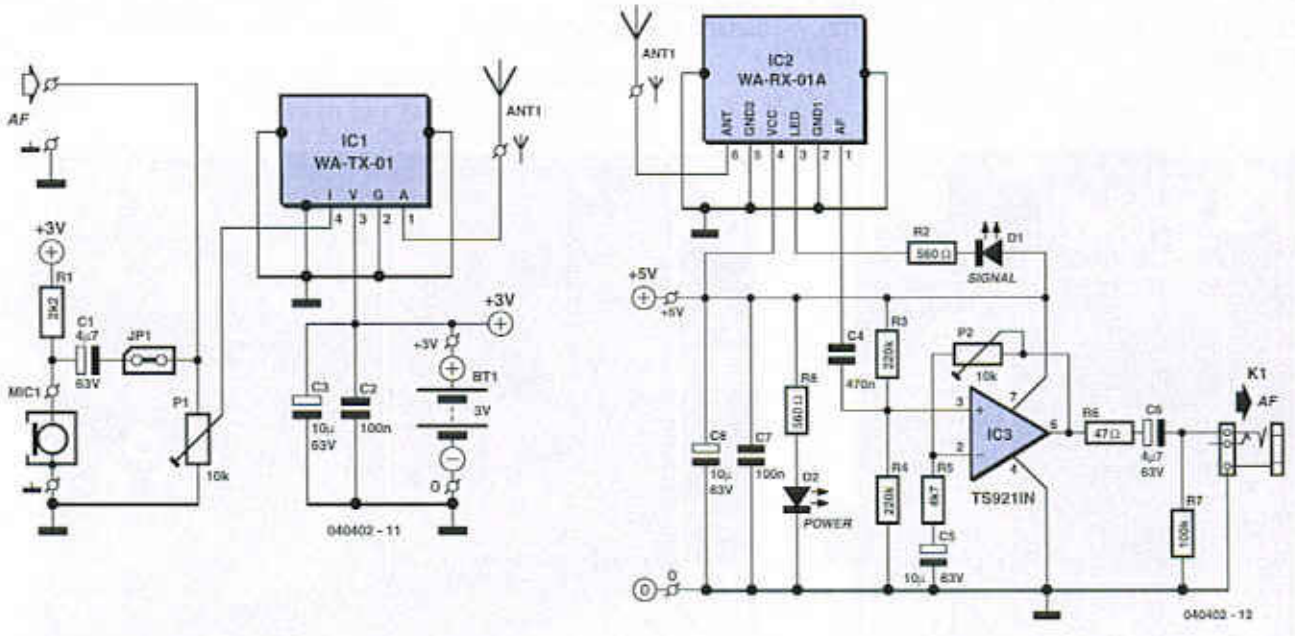


Figure 4. Interfaces for the radio modules.

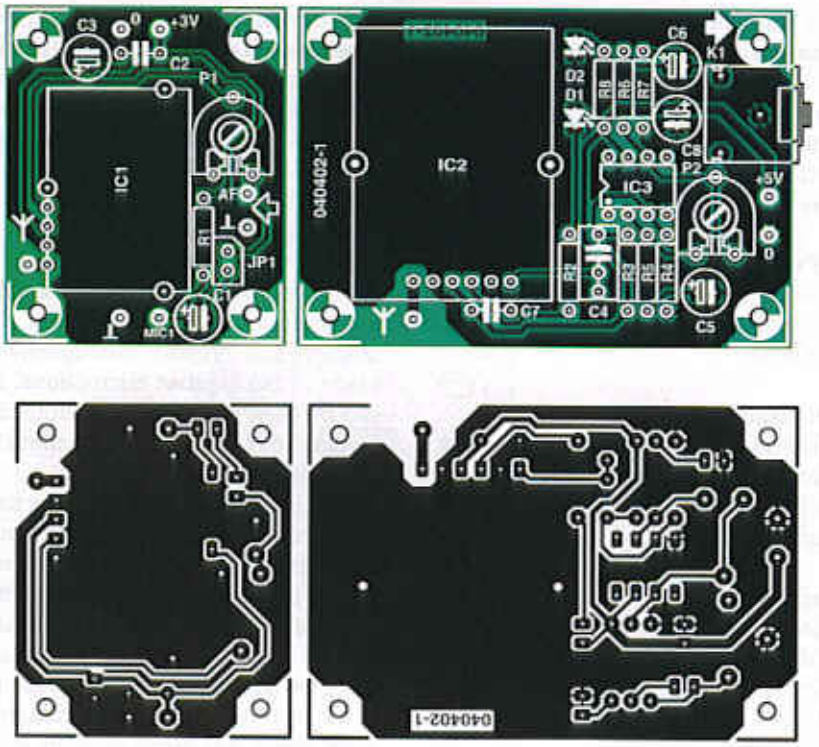


Figure 5. Two circuit boards make one radio link.

COMPONENTS LIST

Resistors:
R1 = 2kΩ2
R2,R8 = 560Ω*
R3,R4 = 220kΩ
R5 = 4kΩ7
R6 = 47Ω
R7 = 100kΩ
P1,P2 = 10 kΩ preset

Capacitors:
C1,C6 = 4µF7 63V radial
C2,C7 = 100nF
C3,C5,C8 = 10µF 63V radial
C4 = 470nF

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 = TS921IN (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)
BT1 = battery holder for two 1.5V batteries
MIC1 = electret microphone
PCB, no. 040402-1, available from The PCBShop

with an asymmetric 10 V supply. A further advantage of the TS921 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 mm at 860 MHz) will do the job; more professional antennas can be found on the Circuit Design website at http://www.cdt21.com/.

(040402-1)

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 IHF-A filter)
Audio frequency range	50 Hz to 15 kHz ± 3.5 dB (output level –50 dBV ± 3 dB)
THD	2 % (@ AF 1 kHz, deviation = 15 kHz or 7.5 kHz)
Pre-emphasis	50 µs
Operating temperature	0 °C to 50 °C

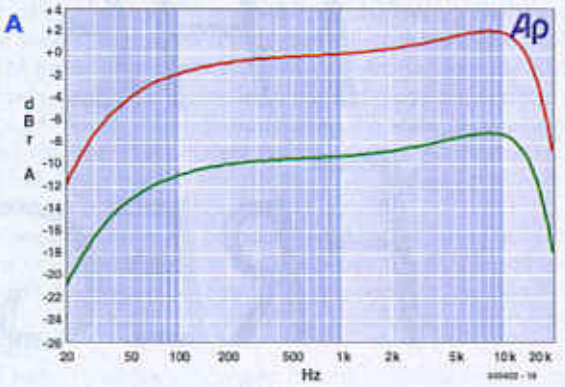
Transmitter

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	–115 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

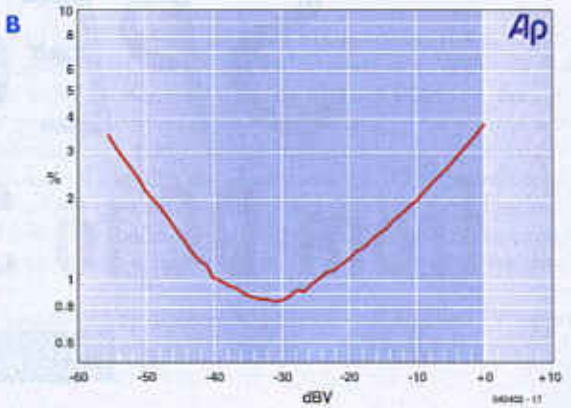
Receiver

Receiver type	Superheterodyne
Mixer oscillator	Crystal-controlled
Intermediate frequency	10.7 MHz
Noise reduction	Expander
Sensitivity	21 dBµV (@ THD 2 %)
Squelch sensitivity	17 dBµV ±4 dB
Audio output level (at module)	–20 dBV (deviation = 15 kHz) Maximum –10 dBV (deviation = 30 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

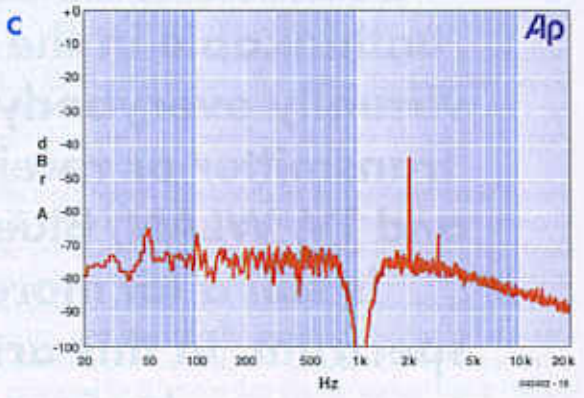
Note: 0 dBV = 0.775 V



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).

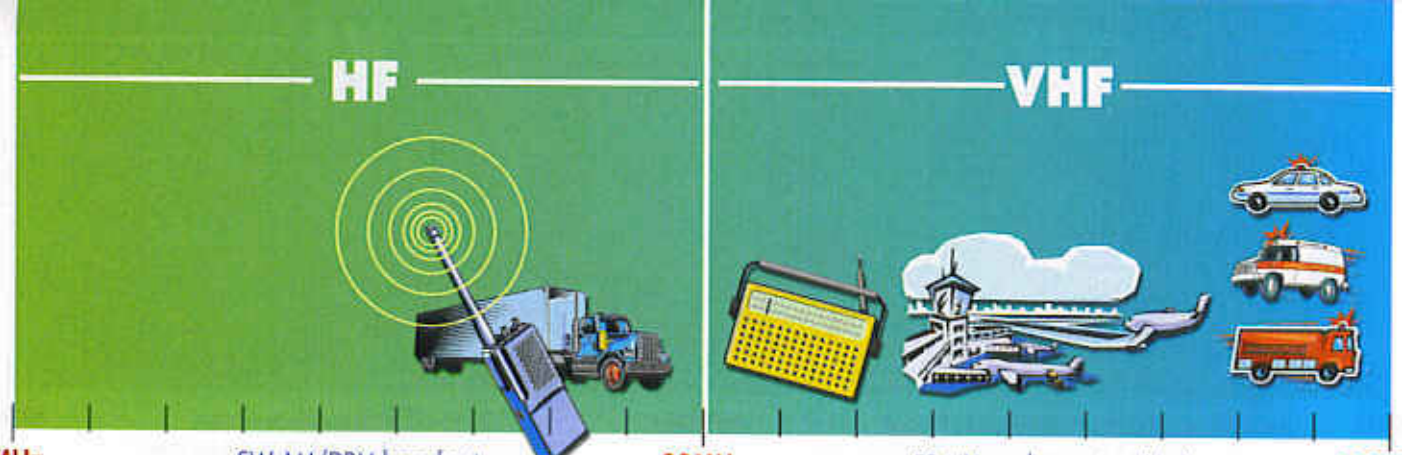
The Radio Frequency Spectrum

from DC to 30 GHz in 4 pages

Paul Goossens

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'.

LF
MF



SW AM/DRM broadcast,
Utility and Radio Amateur bands
(80/40/20/17/15/10m)
6.765 – 6.795 MHz ISM
13.553 – 13.567 MHz ISM
26.957 – 27.283 MHz ISM
26.96 – 27.41 MHz CB (EU) (11m)
27.60125 – 27.99125 MHz CB (UK) (11m)

50 MHz radio amateur (6m)
54 – 72 MHz MOD; VHF-television (phased out)
76 – 87.5 MHz PMR, MOD
87.5 – 108 MHz FM radio
108 – 117.975 MHz radionavigation (VOR)
137 MHz weather satellites (orbiting)
144 – 146 (148) MHz amateur radio (2m)
146 – 174 MHz PMR
174 – 216 MHz DAB; VHF Band 3 television

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

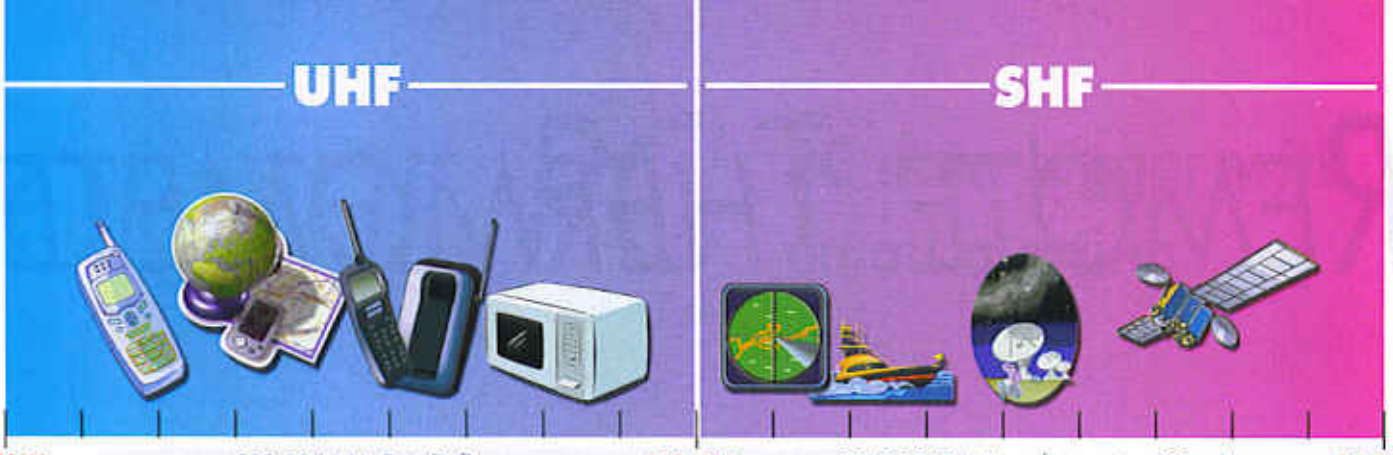
The 27 MHz band, also known as CB (Citizens Band) or 11 metres, lies between 27.60 MHz and 27.99 MHz in the UK, and between 26.96 MHz and 27.41 MHz in the EU. In the UK a license is required to use CB, although in

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 LF 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



300MHz

380-395 MHz Tetra(Pol)
400-430 MHz Trunking radio
430-440 MHz radio amateur (70cm); ship/shore radar
433 MHz ISM, SRD, LPD
446 MHz PMR-446 radio
440 – 470 MHz PMR, Tetra
470 – 806 MHz UHF (DVB-T) television
876.1 – 958.9 MHz GSM-900
1030 MHz/1090 MHz aeronautical transponder (IFF)

1.2 GHz

1240-1300 MHz radio amateur (23cm)
1650 MHz geostationary weather satellite
1710.1 – 1879.9 MHz GSM-1800
1880 – 1969.7 MHz DECT telephones
1899.9- 1934.9 MHz UMTS
2400 – 2500 MHz ISM (WLAN, WiFi, Bluetooth)
2446 – 2454 MHZ RFID
2450 MHz microwave ovens
10 GHz radio amateurs

30GHz

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

Does a microwave oven cause interference?

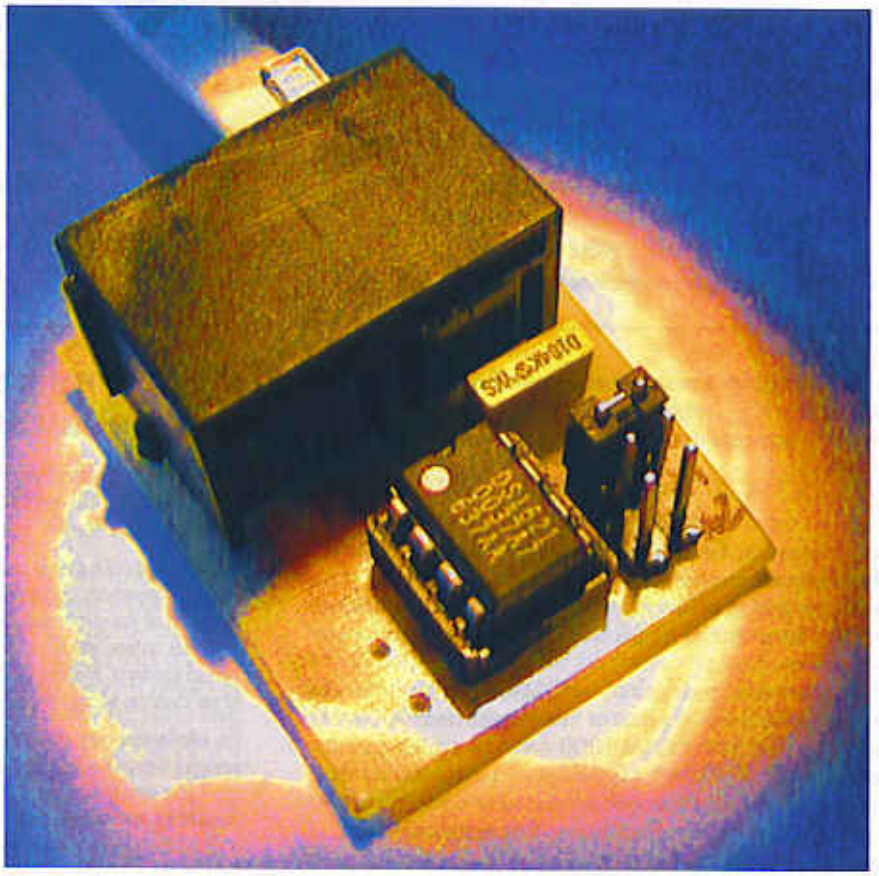
From the frequency chart you'll see that microwave ovens operate in the same band as WiFi (Wireless LAN) and Bluetooth. There are often rumours around that microwave ovens interfere with wireless networks, but how true is this in practice?

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

REMOTE THERMOMETER

Cyril Jouanjan



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

FOR THE PC

PC data logger with email alerting

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 I²C 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 '//'. Incidentally, the software also supports an internal ISA I²C 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 74LS05, 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 –55 °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 (refer **Figure 3**). In this way, conflicts on the I²C 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.

The DS1621 is connected to the I²C bus through the wires SDA, SCL and GND. The power supply is derived from the PC. The 100-nF capacitor provides decoupling of this power supply voltage.

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

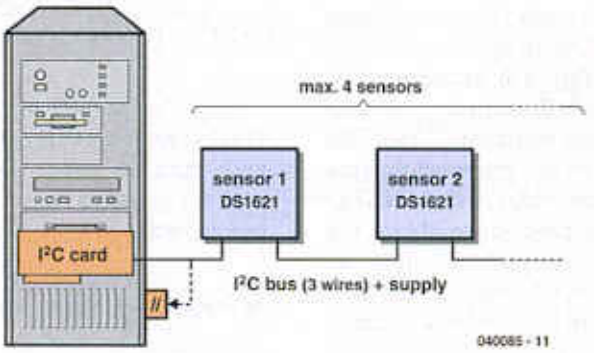


Figure 1. The sensors are connected via the I²C-bus.

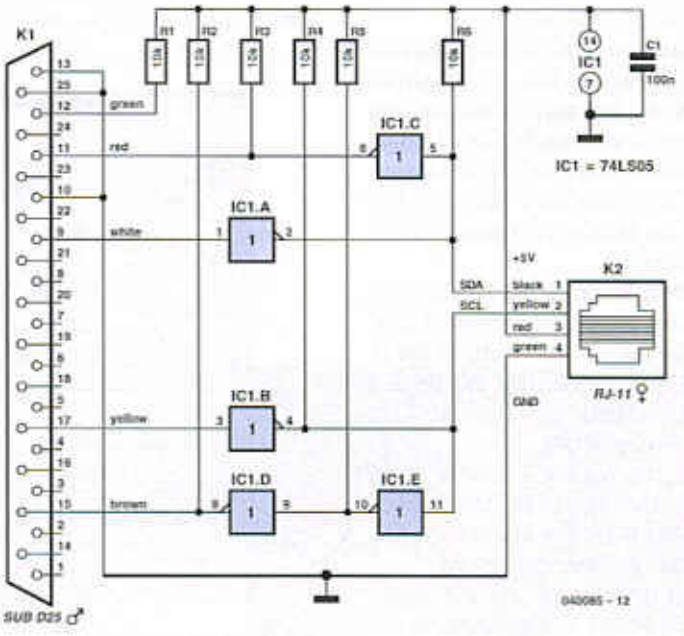


Figure 2. One small IC and a few resistors make a complete interface.

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 DS1621 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 82B715 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 initialise 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 PC 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 Para] there should be the hexadecimal address of the parallel port (usually 0x378 for LPT1).
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.

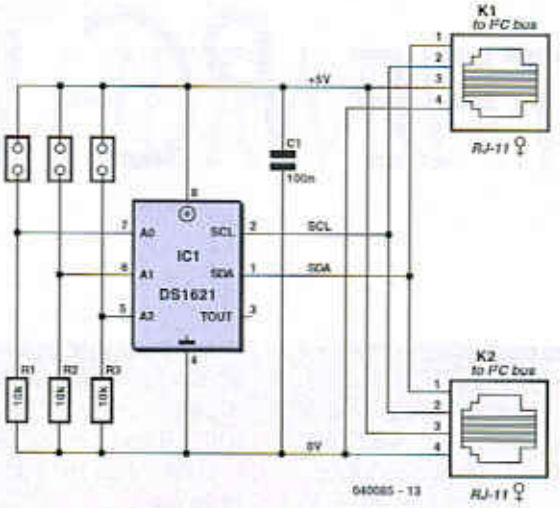


Figure 3. Jumpers select the address of the sensor.

Table 1. Addressing

Static part				Address 2	Address 1	Address 0	Read/ Write
1	0	0	1	A2	A1	A0	R/$\overline{W}$
Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0

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 (I²C OK).
Two graphs show the temperature variation(s). The first graph contains the most recent 60 measurements versus time. This display offers a quick

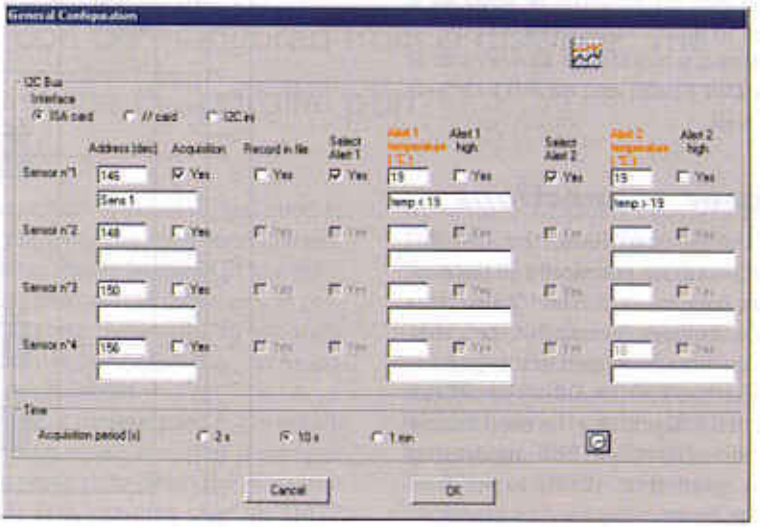


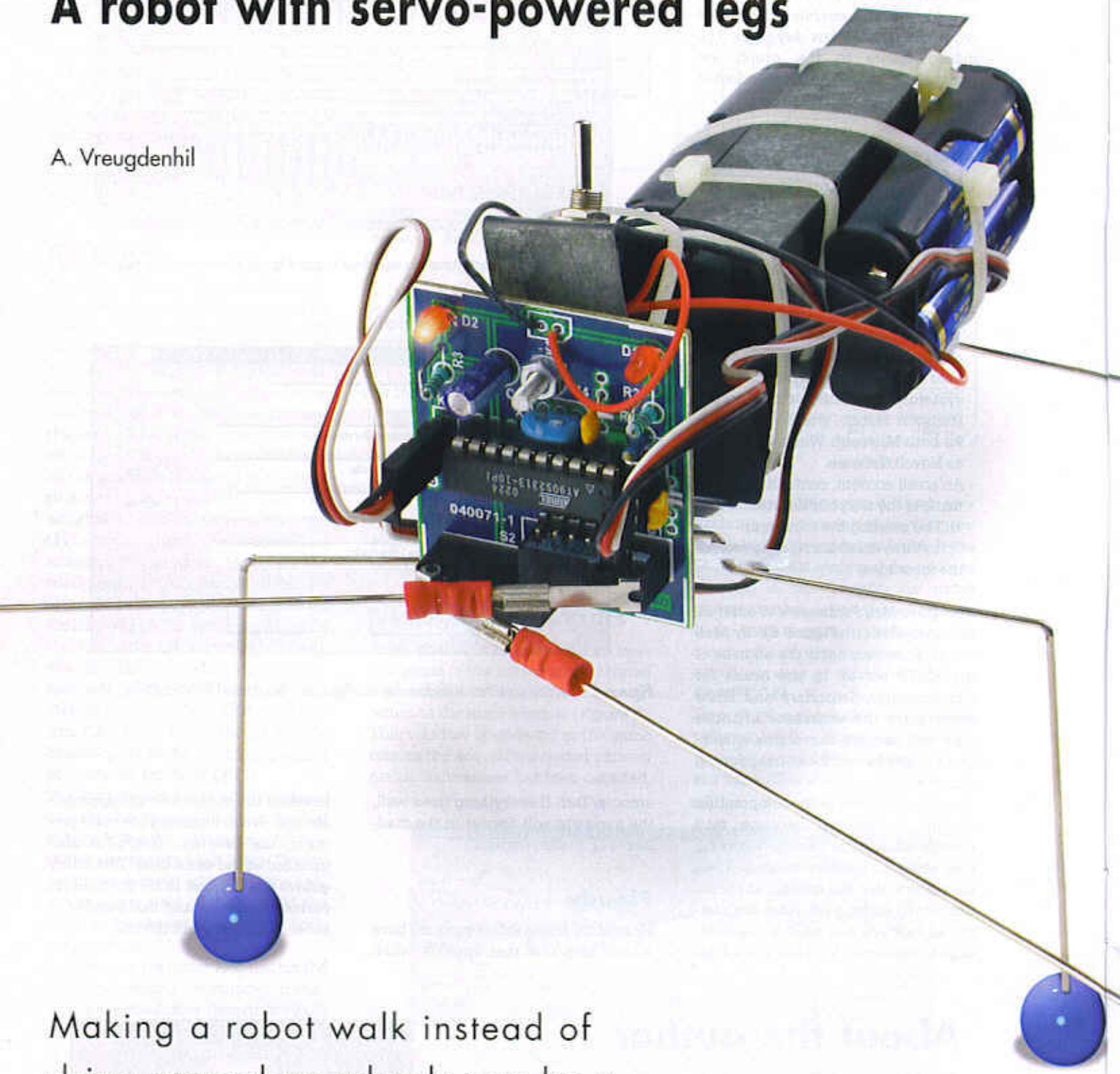
Figure 4. The main program window gives a good overview of the temperature history.

view of the most recent

WALKING BUG

A robot with servo-powered legs

A. Vreugdenhil



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.

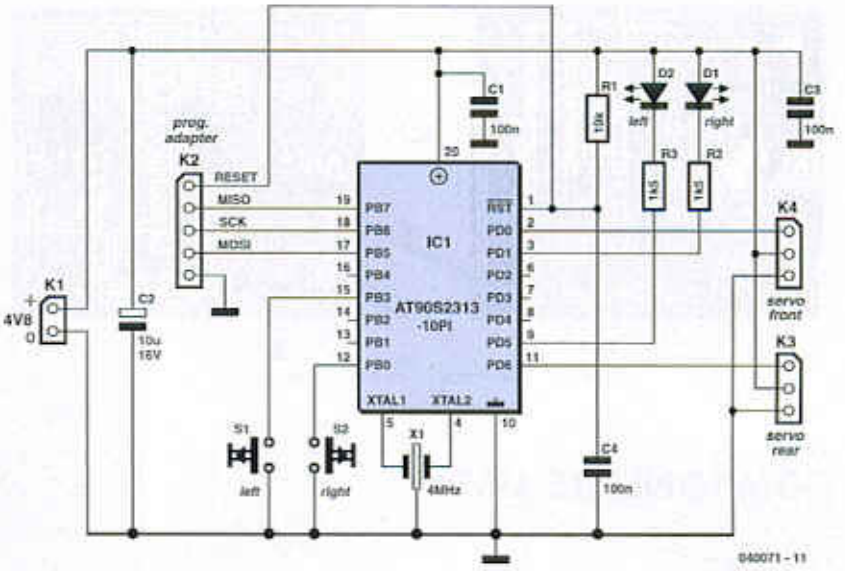


Figure 1. The microprocessor exercises direct control over the servos.

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 spindles position all by itself. As long as the drive signal remains the same, the servo spindle will not turn — the spindle will only turn if the drive signal changes.

The drive signal consists of square-wave 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 pulsewidth 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 to work 'in step' 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 lookup 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 'Step1' 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. Sing 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 antennae — 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-

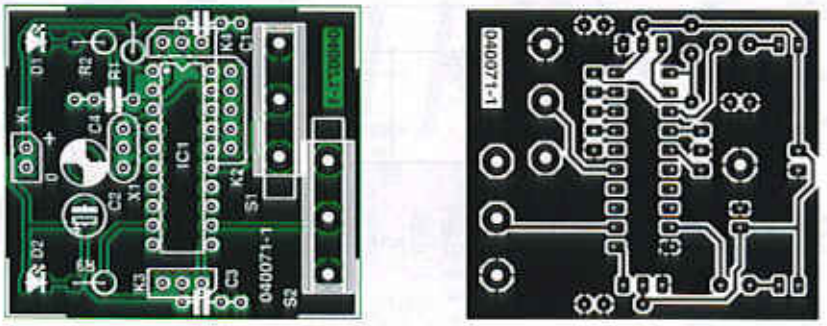


Figure 2. The 'brains' of the Walking Bug.

COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2,R3 = 1kΩ5

Capacitors:
C1,C3,C4 = 100nF
C2 = 10µF 16V radial

Semiconductors:
D1, D2 = LED, low-current, 3mm
IC1 = AT90S2313-10PI

Miscellaneous:
X1 = 4MHz ceramic resonator
K2 = 5-way SIL pinheader
K3,K4 = 3-way SIL pinheader
S1, S2 = miniature microswitch, (e.g., MBF5B, Conrad Electronics # 704571)
2 servos
2 battery holders for 2 AAA batteries
PCB, ref. 040071-1 from www.thepcbshop.com
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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.

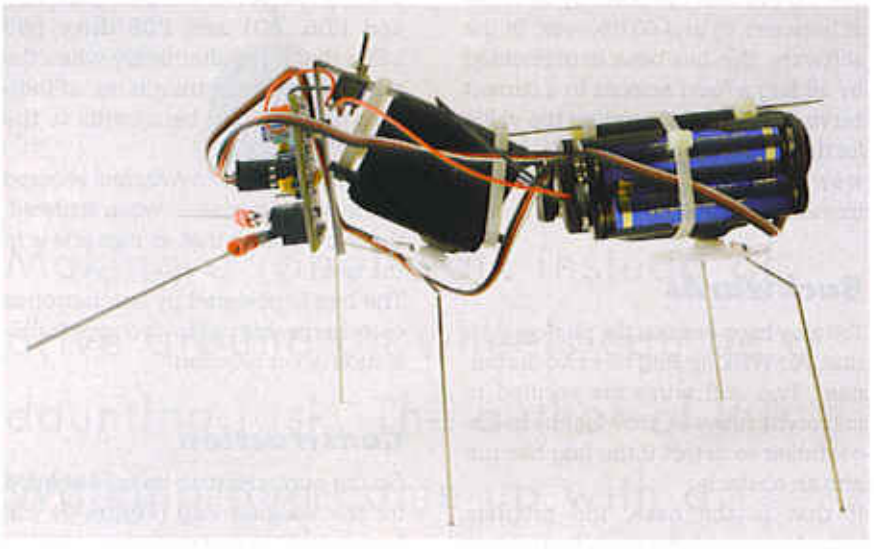

Figure 3. Showing how the various parts are secured to the metal backbone.

The servos 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'.

(040071-1)

Web link

BASCOM-AVR: www.mcselec.com

Table 1. Programming cable details

printer port	K2	function
2 (via 330 Ω)	4	MOSI
4 (via 330 Ω)	1	reset
5 (via 330 Ω)	3	SCK
11	2	MISO
18	5	GND

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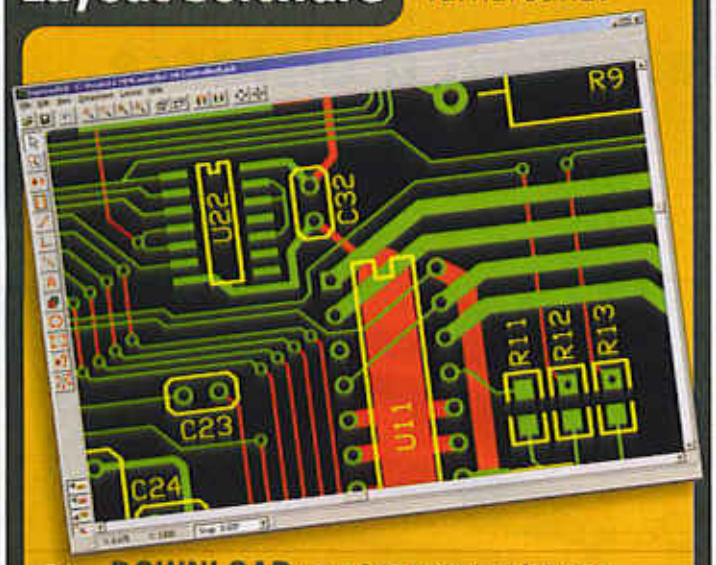

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RFID Detector for

Spot RFID tag transmitters from a distance

Gert Baars

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'.

13.56 MHz

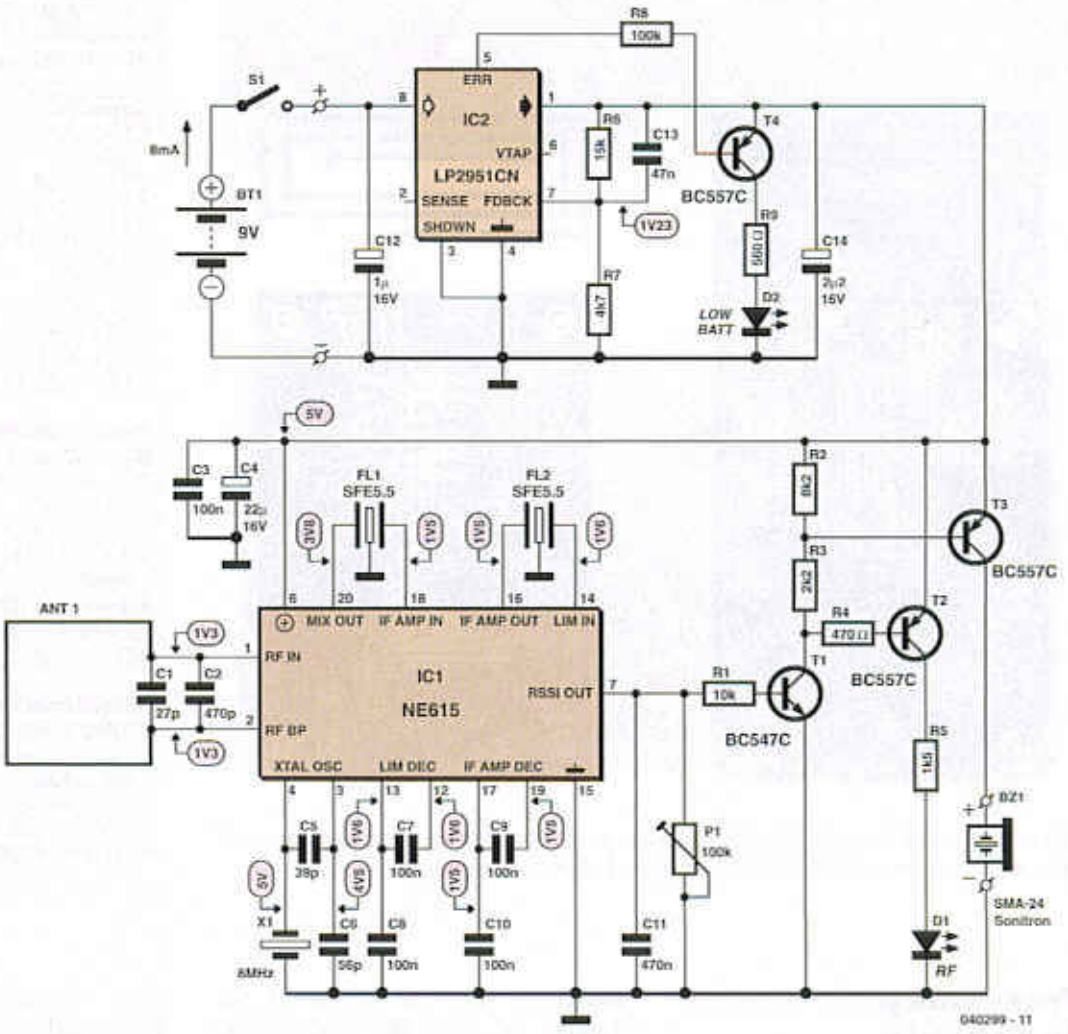


Figure 1. At the heart of the circuit we see the NE615 monolithic receiver/detector IC.

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 ABS 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.

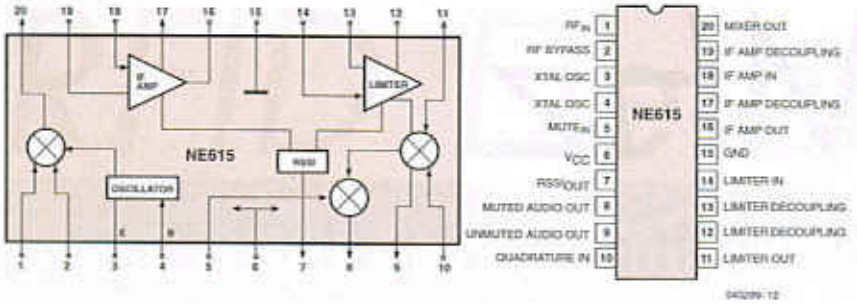
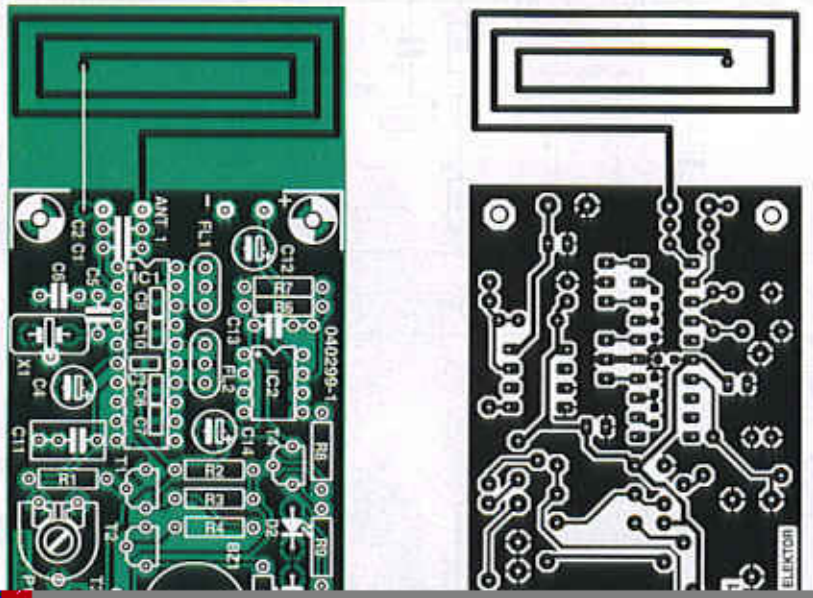


Figure 2. Block diagram of the NE/SA615 (courtesy Philips).



COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2 = 8kΩ2
R3 = 2kΩ2
R4 = 470Ω
R5 = 1kΩ5
R6 = 15kΩ
R7 = 4k7
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 = 39pF
C6 = 56pF
C11 =470nF
C12 = 1µF 16V radial
C13 = 47nF
C14 = 2µF2 16V radial

Semiconductors:
D1 = LED, green, low current
D2 = LED, red, low current
T1 = BC547B
T2,T3,T4 = BC557B
IC1 = NE615N or SA615N (DIP20 case)
IC2 = LP2951CN (DIP8 case)
X1 = 8MHz quartz crystal
BZ1 = 6V DC (active) buzzer

sion of the IC is also shown.
The SA615, says Philips, is a high performance monolithic low-power FM IF system incorporating a mixer/oscillator, two limiting intermediate frequency amplifiers, a quadrature detector, muting, logarithmic received signal strength indicator (RSSI) and voltage regulator. If the type code sounds vaguely familiar we bet that's due to the '615 combining the functions of the famous NE/SA602/612 double-balanced mixer and the NE/SA604 demodulator chip. As compared with the NE/SA605 the NE/SA615 features, among other plus points, a higher mixer input intercept point and higher IF bandwidth (25 MHz).
The NE/SA605 and NE/SA615 are functionally identical but the '615 has improved specifications in some respects (see SA615 datasheet).
The RFID 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 μA 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.

Figure 4. Some components need to be fitted at the solder side of the board, too.

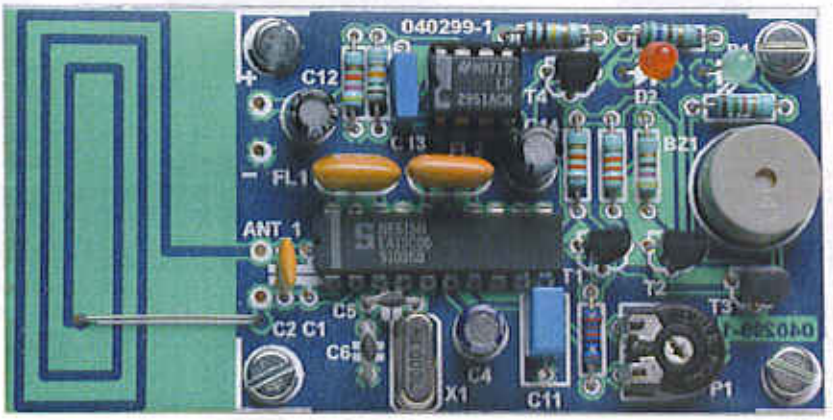


Figure 5. Top side of the board with all the parts fitted. Note the wire link connecting the stripline antenna to C2//C1.

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 just 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 LP2951 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*

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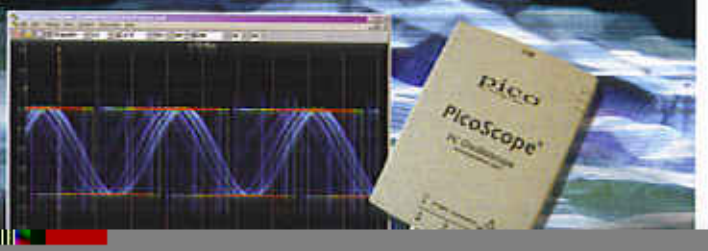

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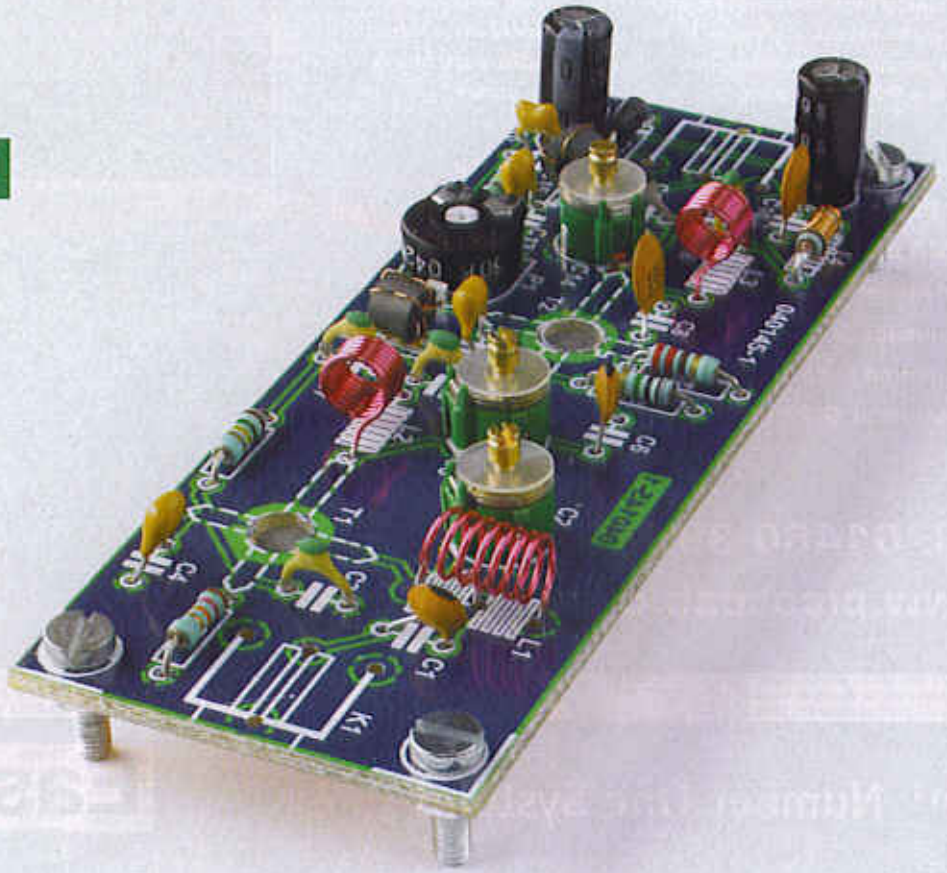
VHF FM Antenna

N. S. Hari Sankar VU3NSH



Together with a good directional antenna this high performance two-stage antenna amplifier for the VHF FM broadcast band will

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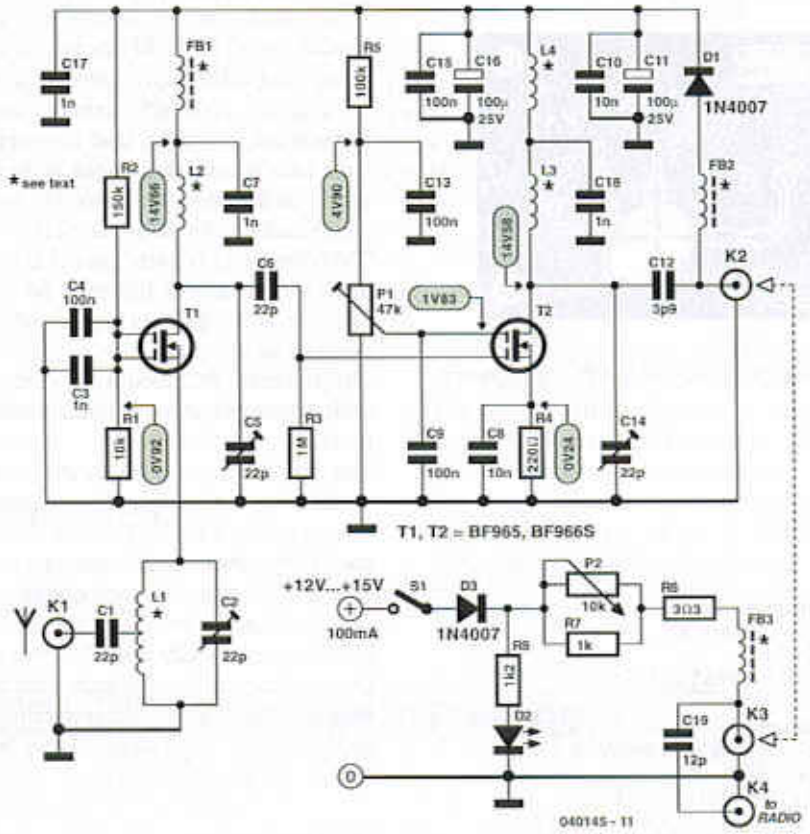


Figure 1. Circuit diagram of the two-stage preamplifier for VHF FM receivers.

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.

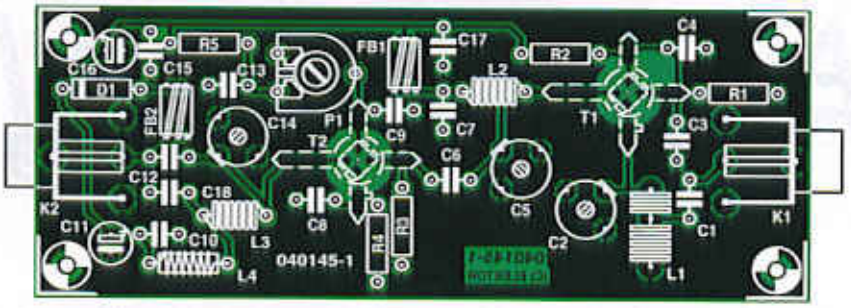
For stability the supply voltage is decoupled at several locations by electrolytic and ceramic capacitors for the low and high frequencies respectively. To enable it to be mounted as close as possible to the antenna, the amplifier is powered via the download coax cable, i.e., over coax connectors connected 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-MOSFETs 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 MΩ is uncritical, what we're after is 'a lot' of carbon for the core so 820 k or 1.2 M 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 t 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



refer to the component drawing shown in Figure 1. You may find that the legs are a bit too long for the PCB but don't use your cutters until the very last moment because without the stud marker (source terminal) you will be lost for device orientation.

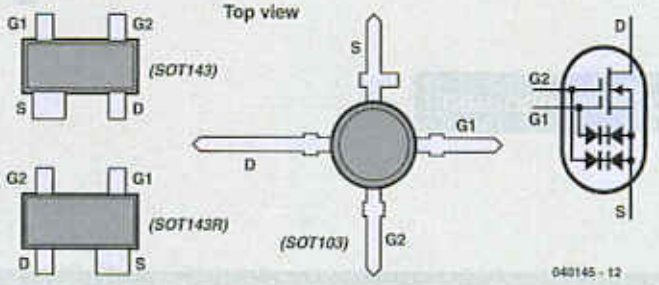
Several VHF/UHF DG-MOSFETs may be used in this circuit — see Table 1. With some dexterity it is also possible to use SMD devices. In general, you should aim to use a BF9xx with a low noise figure, although that may imply a slightly reduced overall gain. Remember however that the ampli-

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' SOT103 case are being superseded fast by their SMD (SOT143) counterparts. These are perfect electrical replacements but require short wires in order to be fitted on a board laid of 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 electrically compatible with the BF996S, and the same applies to the BF981 and its 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 5-mm hole allowing their terminals to be soldered flush with the PCB tracks. Unfortunately, '-R' suffix SOT143 DG-MOSFETs cannot be used on this board.



achieved by stretching or compressing the three air-spaced 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 (PMR 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.

(040145-1)

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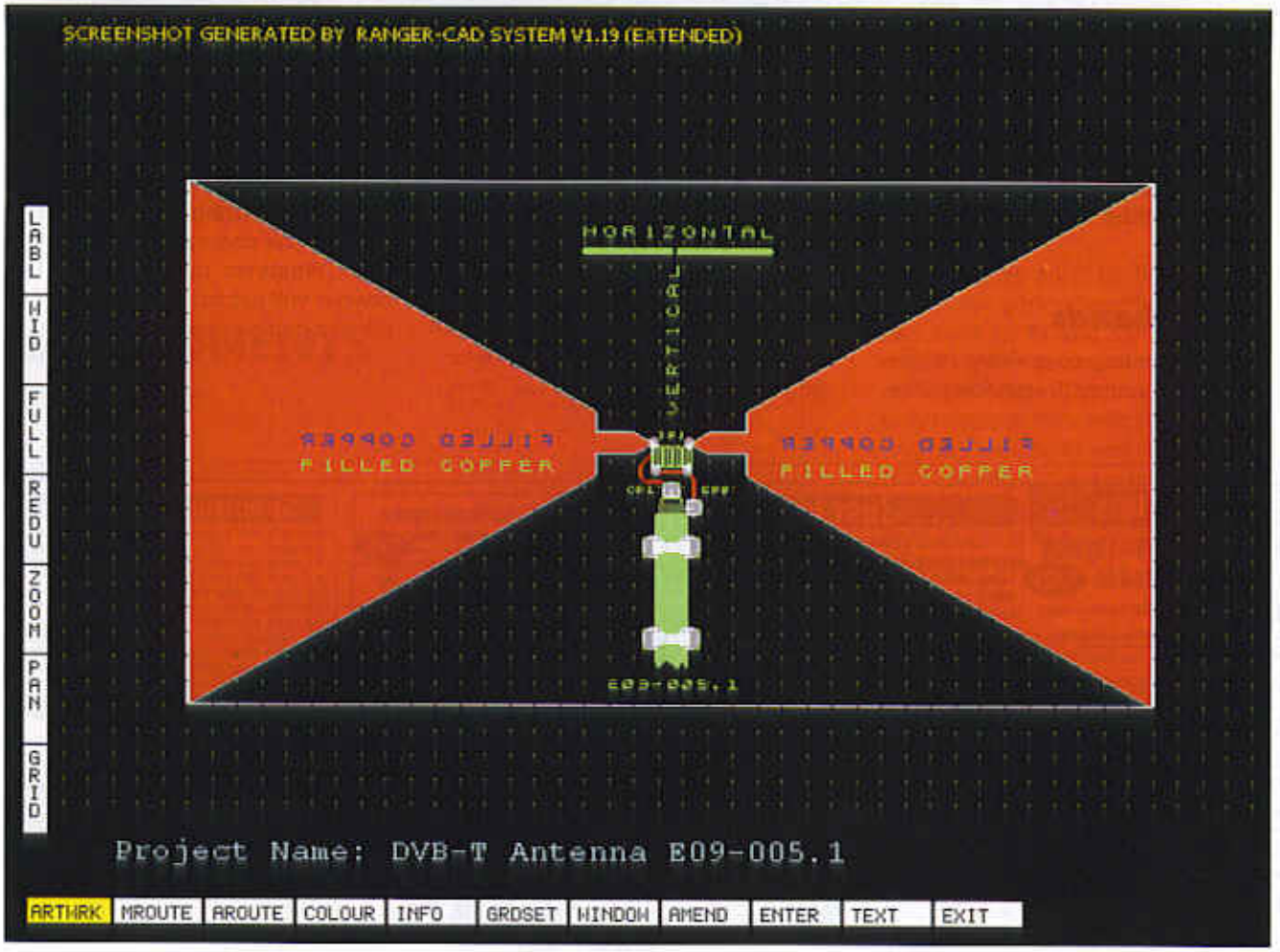
Butterfly Dipole

Rolf Badenhausen



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.

for DVB-T

Simple and economical
DIY indoor

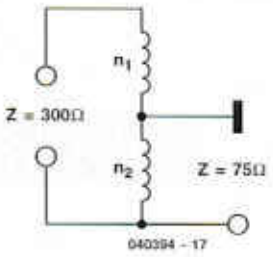


Figure 3. Matching using a transformer with a single winding.

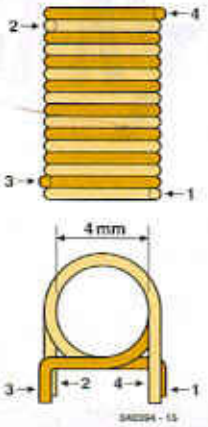


Figure 4. Practical construction using a bifilar air-cored coil.

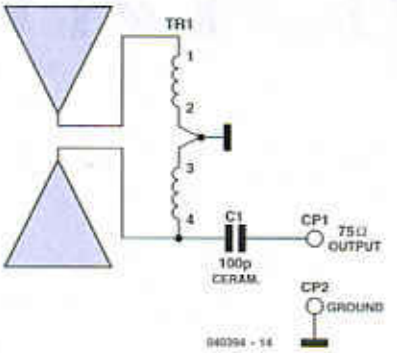


Figure 5. Antenna with transformer and coupling capacitor.

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.elektor-electronics.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 polarised, 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 minimise the effect of reflections. In general,

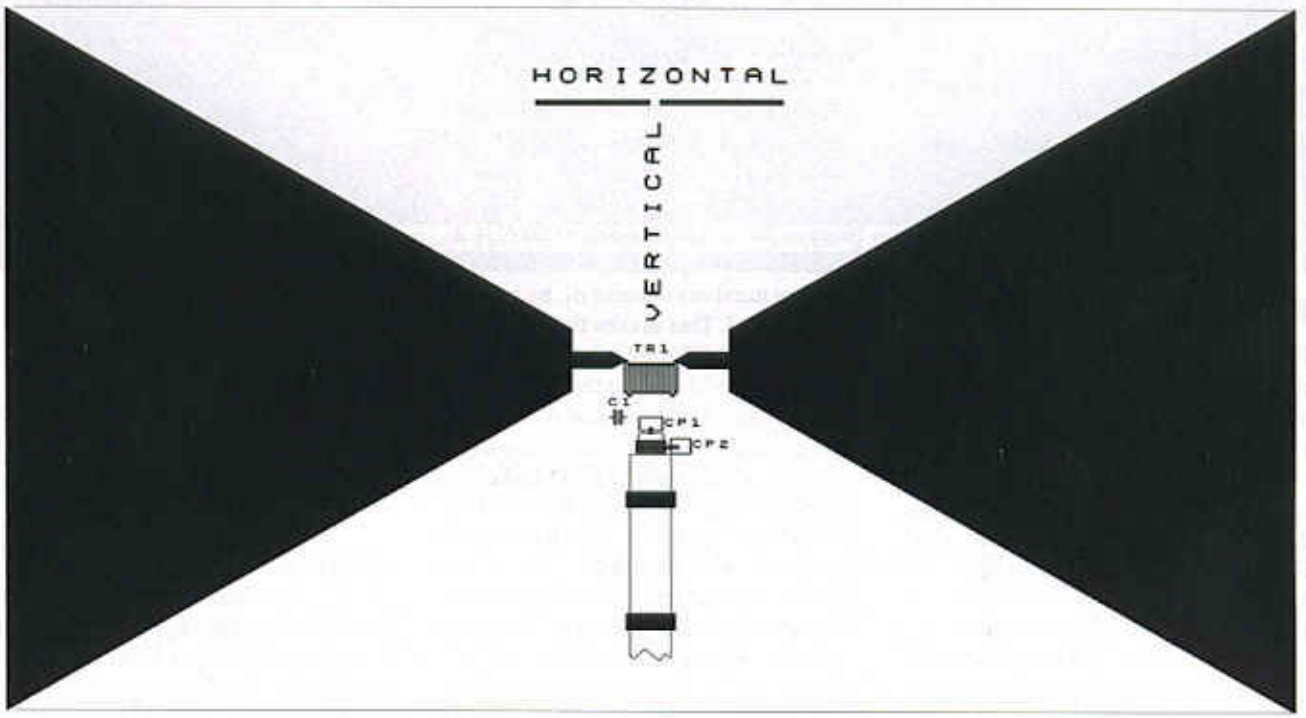


Figure 6. Component side of the printed circuit board (reduced). Copper track layout available for download from our website.

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.

(040094-1)

[1] **Digital Television**;
Elektor Electronics, September 1995.

For theoretical foundations and a good source of references:

Kraus, John D.
Antennas
McGraw-Hill Book Company, 1950.

Figure 7. The author's prototype antenna.

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.

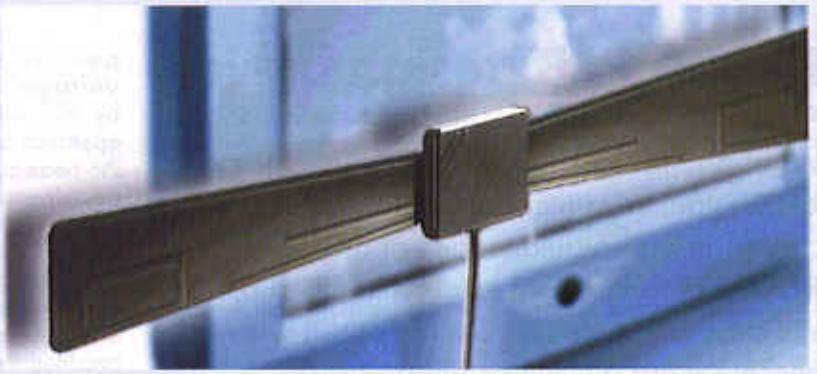


Figure 8. Hama butterfly antenna (source: Hama).

Combined VHF and UHF indoor antennas are generally something of a compromise. Nevertheless, Thomson has chosen a different, but no less interesting, variation: the ANTD200 (**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 VHF band 3.

Figure 9. Thomson ANTD200 patch antenna with 18 dB gain (source: Thomson).

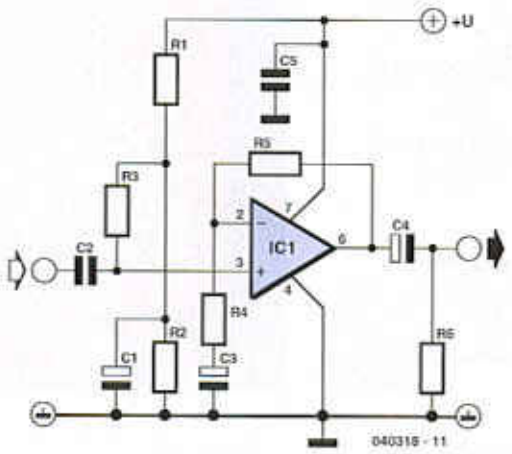


Figure 1. Schematic of a simple amplifier stage.

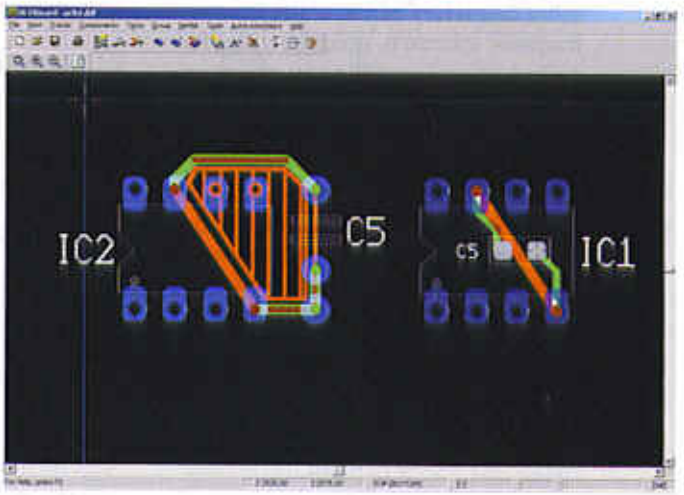


Figure 2. Make short connections that occupy the smallest possible area. This is done the easiest with SMD (b) components.

Part 1: PCB design basics

Karel Walraven

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 for nearly 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 change 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

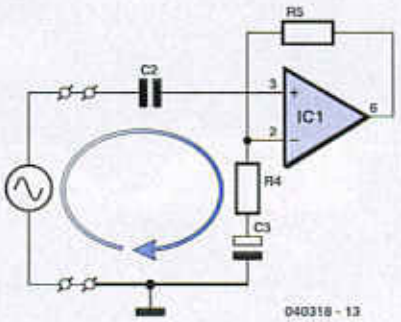


Figure 3. The area of the signal connection is formed by the signal path towards and away from the component.

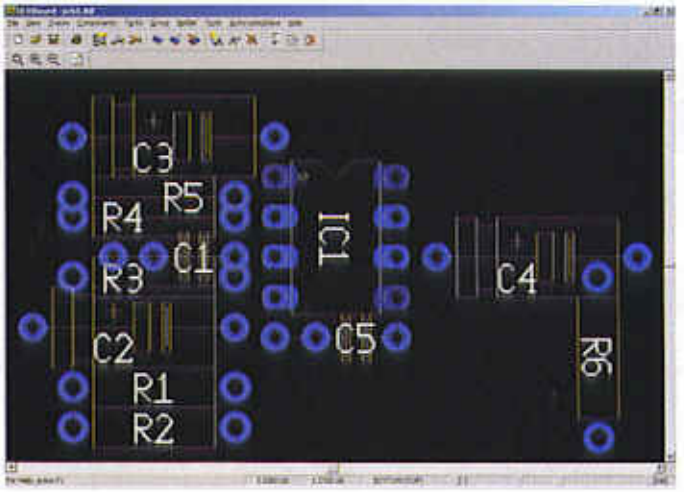


Figure 4. The components are first placed in an arbitrary location.

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 youths among us, those who grew up with record players and valves, 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 for 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 ground 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

* *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.*

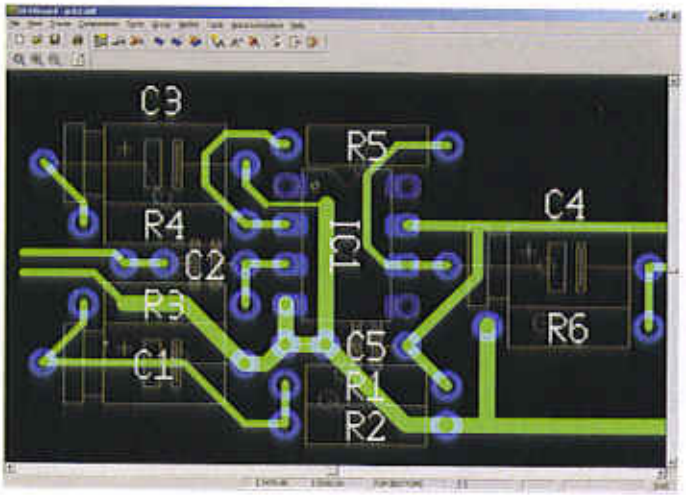


Figure 5. Optimal location after applying all the rules.

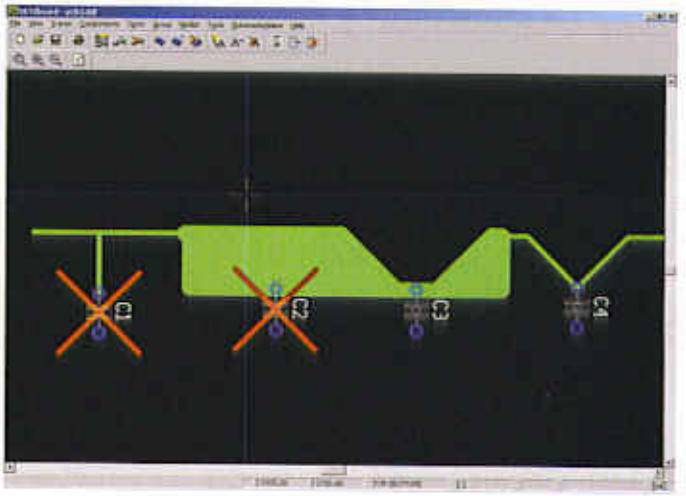


Figure 6. Don't give interference an opportunity to slip past decoupling components.

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 capacitor 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 instalment 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 slip 'past' the 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!

(040218-1)

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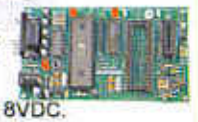

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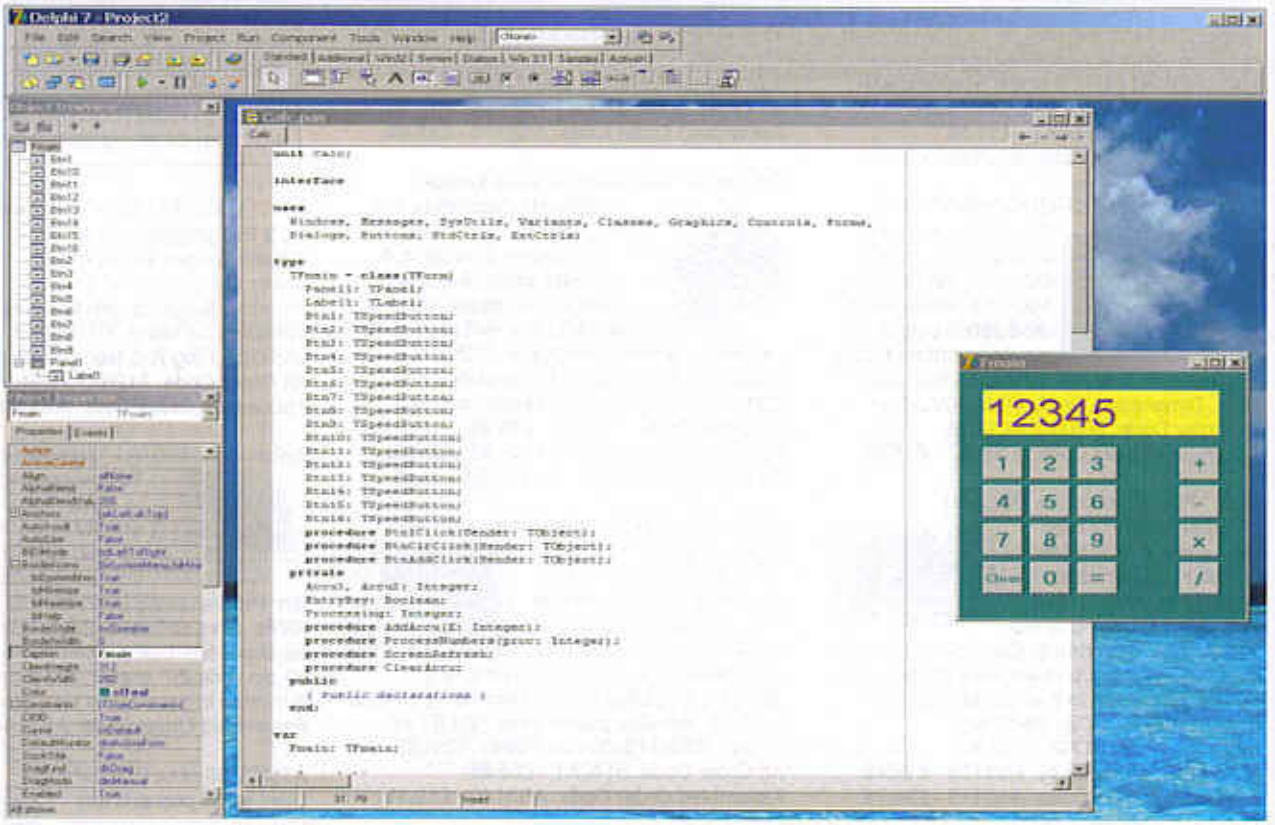
COURSE

DELPHI FOR ELECTRONIC ENGINEERS

Part 2 – Programming a calculator

Herman Bulle with thanks to Anton Vogelaar



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 instalment.
- 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 instalment 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 FormMain). 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 pallet 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 tugging 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 alClient. 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 later on, 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 recognise its function, such as 'CalculatorBtn1' (in our example, we choose the simple abbreviation 'Btn1').

Figure 1. The finished layout for the calculator.

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 you 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 boxes next to the items listed here, 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 TFmain = 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. Beneath this will

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 TFMain.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

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 (Btn1Clk). 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(Accu1);
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 Processing of
    1: Accu1:=Accu2 + Accu1;
    2: Accu1:=Accu2 - Accu1;
    3: Accu1:=Accu2 * Accu1;
    4: Accu1:=round(Accu2 / Accu1);
  end;
  Processing:=proc;
  EntryBsy := False;
end;
```

The variable EntryBsy 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;
```

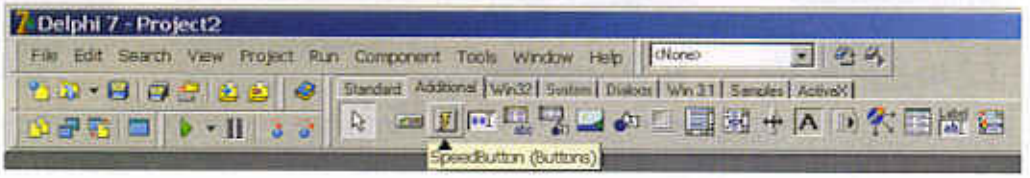


Figure 3. The SpeedButton icon is located on the Additional tab of the Component palette.

This procedure calls ClearAccu to set Accu1 and Accu2 to zero and set EntryBsy to FALSE.

```
procedure TFMain.ClearAccu;
begin
  Accu1 := 0;
  Accu 2 := 0;
  EntryBsy:=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 you 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.

(040240-2)

Listing 1.
Complete listing of the calculator program.

```
unit Calculator;

interface

uses
  Windows, Messages, SysUtils, Variants,
  Classes, Graphics, Controls, Forms,
  Dialogs, Buttons, StdCtrls, ExtCtrls;

type
  TFmain = class(TForm)
    Panel1: TPanel;
    Label1: TLabel;
    Btn1:  TSpeedButton;
    Btn2:  TSpeedButton;
    Btn3:  TSpeedButton;
    Btn4:  TSpeedButton;
    Btn5:  TSpeedButton;
    Btn6:  TSpeedButton;
    Btn7:  TSpeedButton;
    Btn8:  TSpeedButton;
    Btn9:  TSpeedButton;
    Btn10: TSpeedButton;
    Btn11: TSpeedButton;
    Btn12: TSpeedButton;
    Btn13: TSpeedButton;
    Btn14: TSpeedButton;
    Btn15: TSpeedButton;
    Btn16: TSpeedButton;
    procedure Btn1Click(Sender: TObject);
    procedure BtnClrClick(Sender: TObject);
    procedure BtnAddClick(Sender: TObject);
  private
    Accu1, Accu2: Integer;
    EntryBsy: Boolean;
    Processing: Integer;
    procedure AddAccu(X: Integer);
    procedure ProcessNumbers(proc: Integer);
    procedure ScreenRefresh;
    procedure ClearAccu;
  public
    { Public declarations }
  end;

var
  Fmain: TFmain;

implementation

{$R *.dfm}

procedure TFMain.AddAccu(X: Integer);
begin
if EntryBsy = FALSE then
  begin
   Accu2    := Accu1;
   Accu1    := X;
   EntryBsy := TRUE;
   end
else
Accu1 := 10*Accu1 + X;
end;

procedure TFMain.ProcessNumbers(proc: Integer);
begin
  case Processing of
    1: Accu1 := Accu2 + Accu1;
    2: Accu1 := Accu2 - Accu1;
    3: Accu1 := Accu2 * Accu1;
    4: Accu1 := round(Accu2 / Accu1);
  end;
  Processing := proc;
  EntryBsy   := False;
end;

procedure TFMain.ClearAccu;
begin
  Accu1    := 0;
  Accu2    := 0;
  EntryBsy := False;
end;

procedure TFMain.ScreenRefresh;
begin
  Label1.Caption := IntToStr(Accu1)
end;

procedure TFmain.Btn1Click(Sender: TObject);
begin
  AddAccu((Sender as TComponent).Tag);
  ScreenRefresh;
end;

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

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

end.
```

BS2-IC

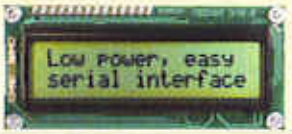
BS2-SX

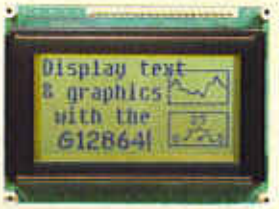
BS2E-IC

BS2P/24

BS2P/40

Parallax BASIC Stamps - still the easy way to get your project up and running!





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REPLACEMENT FOR HI

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

T BATTERY

A 90-volts inverter for vintage radios

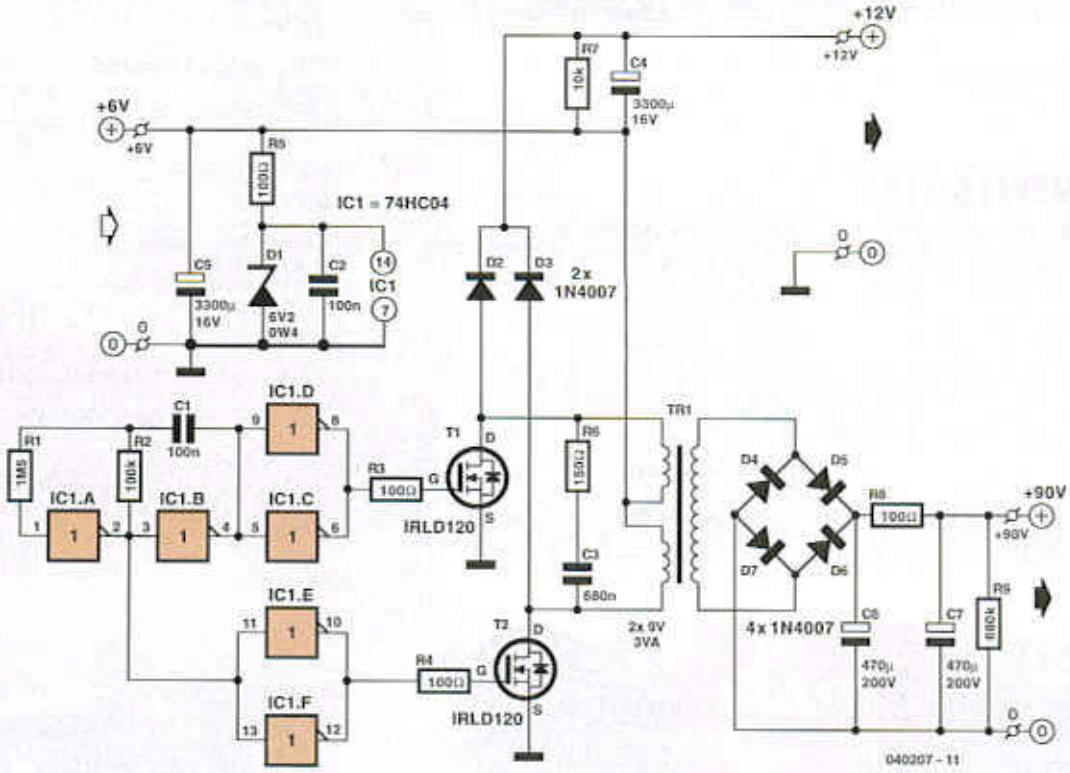


Figure 1. Circuit diagram of the 50-Hz switching step-up converter with +90-V output.

x 9 V, centre-tapped 170-mA secondary of a 'reverse-connected' mains transformer. The resulting alternating voltage at the primary side is rectified and filtered by two 'beefy' electrolytic capacitors. For simplicity's sake no regulation circuit is included, only two 'bleeder' resistors R7 and R9 lower the output voltage under no-load conditions while also discharging the reservoir capacitors.

The output voltage (at the 0 and +90 V sockets) is electrically isolated from the supply circuit at the primary side. The inverter proper is powered by five series connected NiMH cells of 1.2 V each. These cells may also double as a filament supply, for example, for 'E' valves requiring 6 volts. A separate converter output supplies +12 volts obtained by rectifying the switching signals applied to the transformer's primary winding, the diodes conveniently doubling as transistor surge protection devices. Components R5 and D1 protect IC1 against excessive supply voltage levels.

With no regulation available, the con-

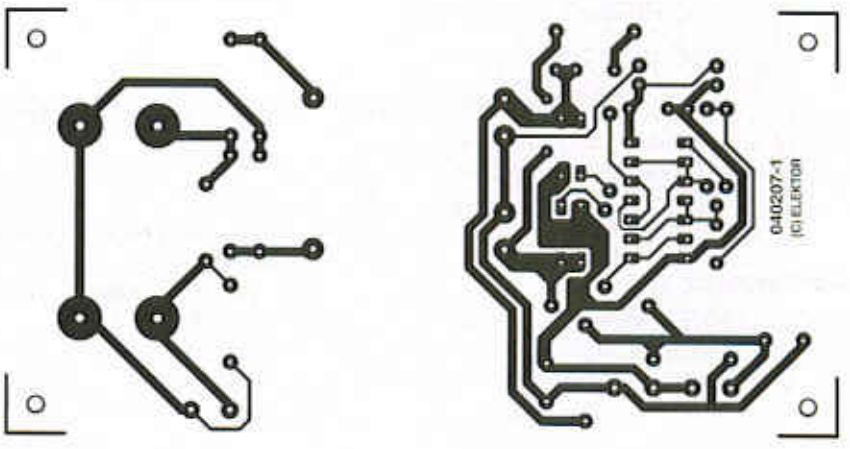
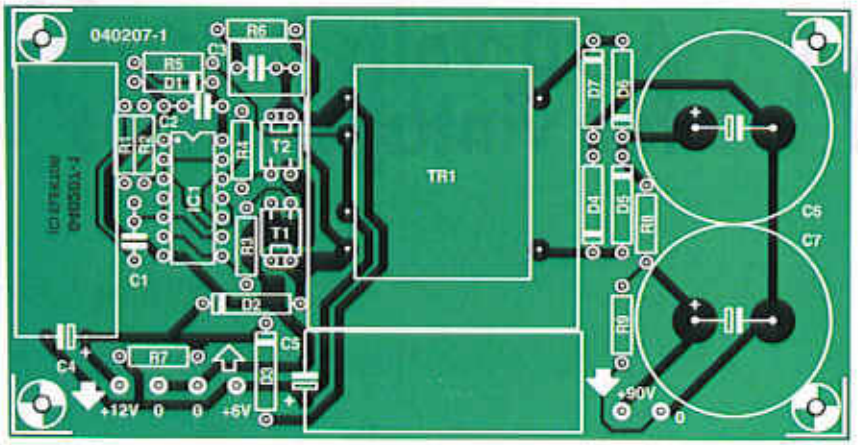


Figure 2. Copper track layout and ...



... component mounting plan.

COMPONENTS LIST

Resistors:
R1 = 1MΩ5
R2 = 100kΩ
R3,R4,R5,R8 = 100Ω
R6 = 150Ω
R7 = 10kΩ
R9 = 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 = IRLD120 (International Rectifier; Farnell # 362-1066)
IC1 = 74HC04

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

Table 1. Measured values (6 V supply voltage)

No load	
Current consumption	48 mA
12-V output	11.6 V
90-V output	115 V
12-V output loaded	
Current consumption	207 mA
12-V output, 80 mA	9.54 V
90-V output (not loaded)	100 V
90-V output loaded	
Current consumption (33 kΩ)	101 mA
Current consumption (22 kΩ)	121 mA
Current consumption (16.5 kΩ)	141 mA
12-V output (not loaded)	11.2 - 11.4 V
12-V and 90-V outputs loaded	
Current consumption	277 mA
12-V output (120 Ω)	8.9 V (ripple 85 mV_{pp})
90-V output (16.5 kΩ)	74 V (ripple 4 mV_{pp})

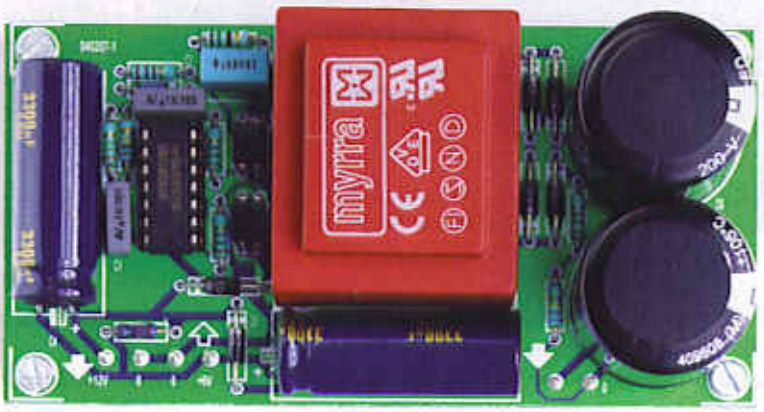


Figure 3. Finished prototype of the converter.

Figure 4. During our search for a photograph of a 'real' HT battery as used in vintage portable radios we came across this brilliantly styled kit from Kit Radio Company.

verter's output voltage is dependent on the load connected. Some test values obtained at a supply voltage of 6 V

the wire link between the transformer and T2.

If you want to keep hum levels to a

touched when the circuit is in operation and all relevant electrical safety precautions should be observed

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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-authorised user within radio range.

Hacking

In practice, however, totally open systems are a rarity. Using software like 'Airopeek' [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 less 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 unauthorised 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

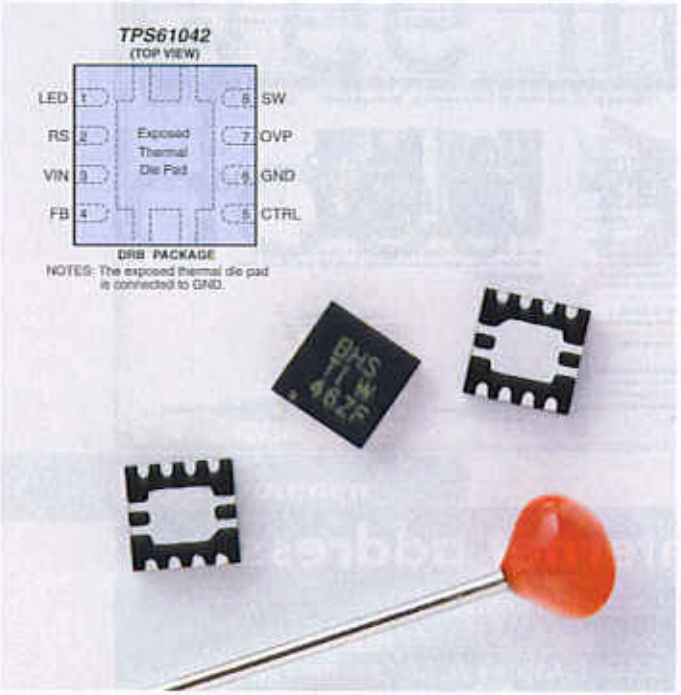
Finally, we would like to mention a few links to so-called 'hotspot directories' [5, 6, 7 and 8] . These are guides on the Internet listing locations of publicly accessible wireless networks. However, most access points found in these directories are not actually 'free' and access has to be paid for.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

(045103-1)

Internet addresses

[1] Airopeek WLAN analyzer: www.wildpackets.com/products/airopeek_nx/
[2] AirSnort key recovery: airsnort.shmoo.com
[3] WEPCrack: wepcrack.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

WEP	WPA	WPA2
Wired Equivalent Privacy	WiFi Protected Access	WiFi Protected Access Version 2 (802.11i)
Won't Even Protect	*Will Protect Alright*	*Will prove airtight*
Weak, static keys	Improved security by rotating keys	Strong encryption and authentication options



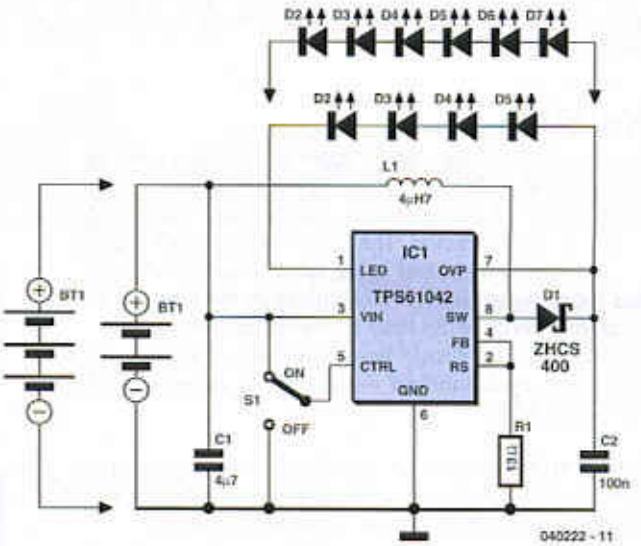
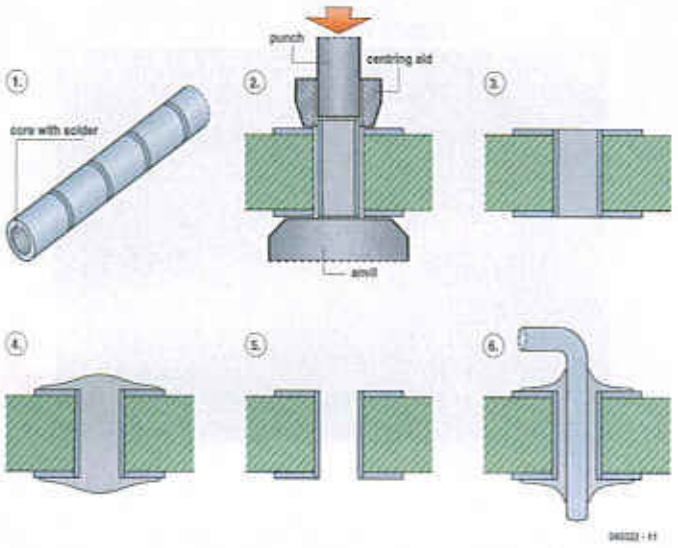
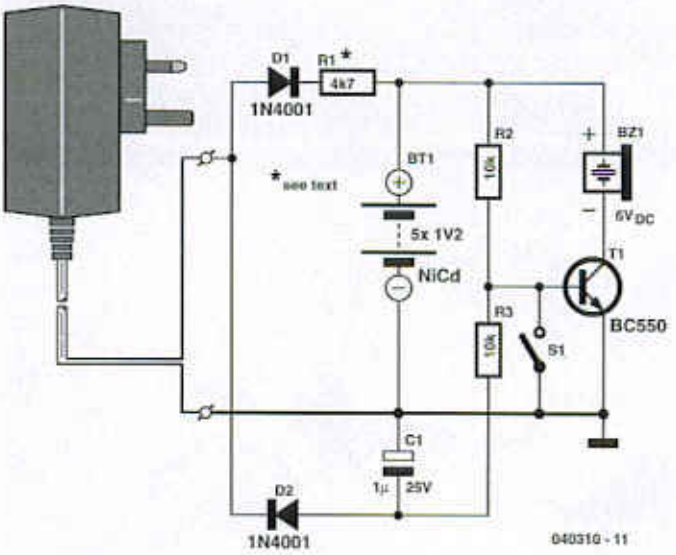


Figure 1. Step-up converter TPS61042 for operation with up to six white LEDs.





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 those holes in the board that establish a contact between tracks or pads at the component and solder side. A common error made by beginners is 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 trough-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 larger 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 (Farnell) but fortunately the bail bar tubes are also sold separately and what's more they are easy to handle with just common-or-garden tools. The system is suitable for boards with a thickness of up to 1.6 mm.

(040322-1)

Supplier: www.farnellinone.com

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 binned because of a duff 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.

(040310-1)

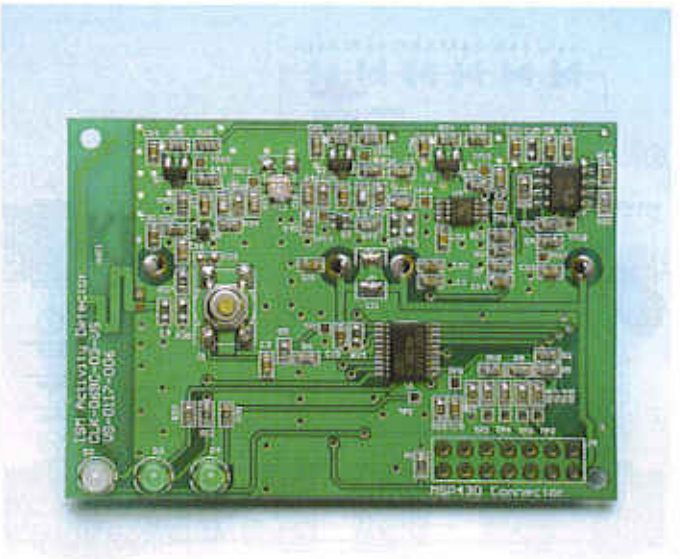


Figure 1. With SMDs you can put a lot of functionality into a key fob.

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 aerial printed on the PCB followed by a few filter and amplifier stages. 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

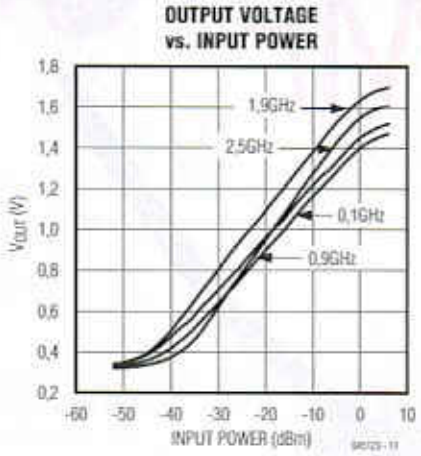


Figure 2. The output voltage of a log amp is a logarithmic function

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LED BEDSIDE LAMP

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Eduard Heger

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.

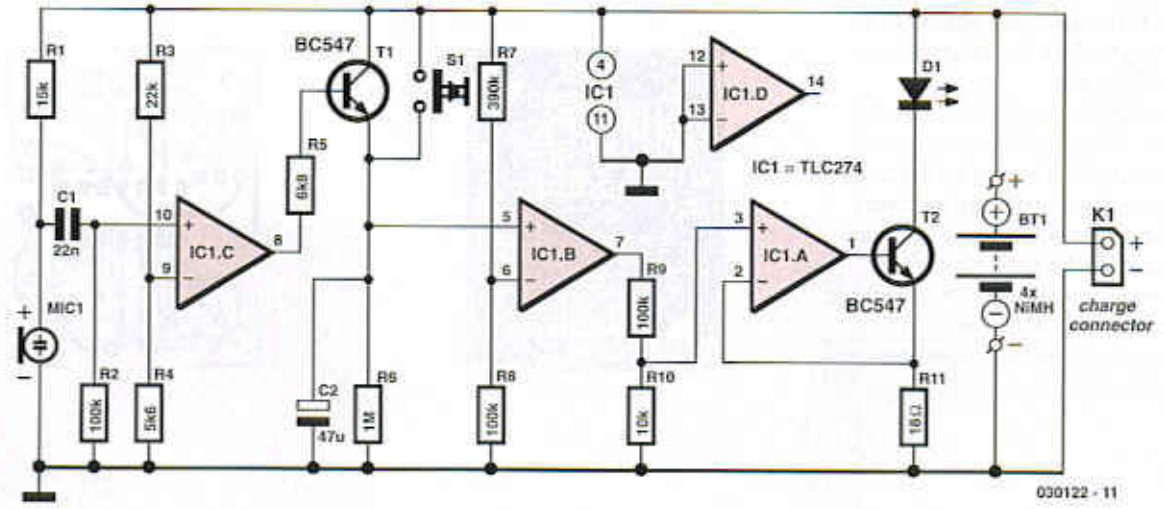

Figure 1.

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 (I_{LED} = 0.44 V/R11). 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:

$$U_{PIN\,6} = U_{BT1} \times R8 / (R7+R8)$$

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

$$U_{C2} = U_{BT1} \times e^{-t / R6C2}$$

Rearranging the equation for t:

$$U_{C2} / U_{BT1} = e^{-t / R6C2}$$

$$\ln (U_{C2} / U_{BT1}) = -t / R6C2$$

$$t = -R6C2 \times \ln (U_{C2} / U_{BT1})$$

U_{C2} and $U_{PIN\,6}$ should be equal so substituting:

$$t = -R6C2 \times \ln (U_{BT1} \times R8 / (R7+R8)) / U_{BT1})$$

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

$$t = -R6C2 \times \ln (R8 / (R7+R8))$$

Substituting actual component values we get:

$$t = -106 \times 47 \times 10^{-6} \times \ln (10^5 / 4.9 \cdot 10^5) = 75 \text{ s}$$

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.

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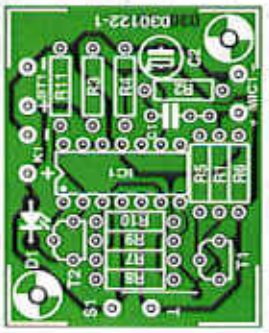

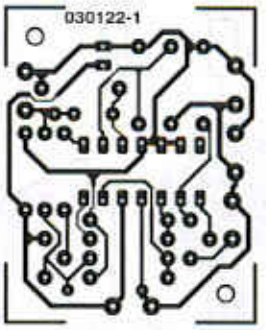

Figure 2.

COMPONENTS LIST

Resistors:
R1 = 15kΩ
R2,R8,R9 = 100kΩ
R3 = 22kΩ
R4 = 5kΩ6
R5 = 6kΩ8
R6 = 1MΩ
R7 = 390kΩ
R10 = 10kΩ
R11 = 18Ω

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

Semiconductors:
D1 = LED, white, e.g., Conrad Electronics # 153867
IC1 = TLC274
T1,T2 = BC547B

Miscellaneous:
Bt1 = battery holder for 4 NiMH cells
K1 = charge socket for batteries
MIC1 = electret microphone capsule
S1 = pushbutton, 1 make contact
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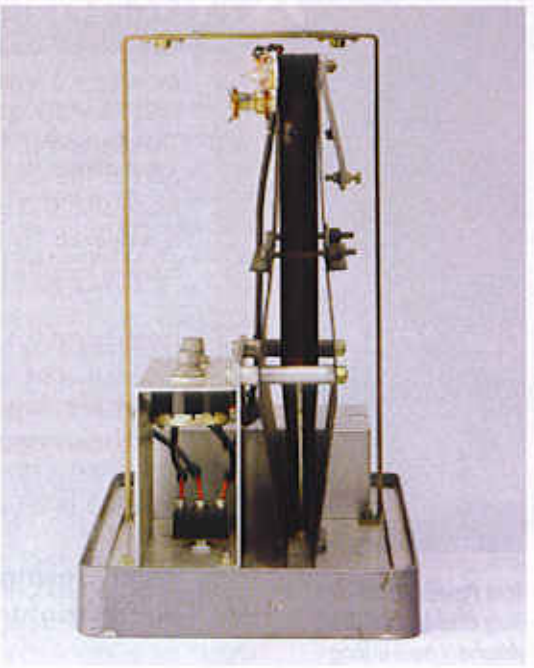


Marconi TF1152 RF Wattmeter

Jan Buiting

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 Teflon 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 (1) *always* properly loaded and (2) 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 Ω' above the N-style input socket. These meters also come in 75 Ω guise which I believe is mostly for use in professional systems employing 75-Ω coax cables. Yes, N connectors also exist in a 75-Ω variety and only experts can see the difference with 50-Ω counterparts.

For years I dreamt of owning a Bird 'Termaline' (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 wideband dummy load and accurate RF power meter in a single lightweight case painted a dull 'techno-grey'. Mine has a 13-digit number engraved in 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: 0-10 W and 0-25 W. 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 shacks covered in thick cigar smoke. The meter needle will faithfully indicate 200 mW or less of RF power even on 70 cms. The needle response enables you to do TX PA trimmer 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 compound 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-Ω 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 re-calibrate 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.

(045099-1)

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

QUIZZ'AWAY

Martin Ohsmann is a Professor of Electrical Engineering and Information Technology at FH Aachen and a long-time contributor to Elektor Electronics. Through Quizz'away he aims at stimulating thought, speculation, construction and simulation as well as raise interesting questions.

Lamp intensity

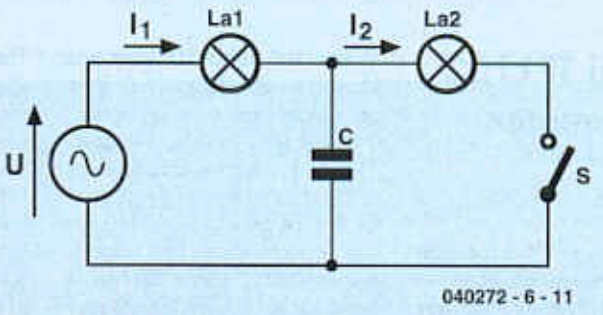
This time consider the circuit in **Figure 1**. Lamps La1 and La2 each have a nominal power $P = 1$ watt. Lamp La1 has an internal resistance of R1 = 100 Ω while for lamp La2, R2 = 200 Ω. Both resistance values are applicable at the nominal lamp power. The alternating voltage source show supplies a voltage $U = 22.63$ V at a frequency of 50 Hz. The value of capacitor C is such that the component also represents a reactance of 200 Ω 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 La1 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 La1 increase, decrease or remain the same?

Followed by a second question:

After closing the switch, which of the two lamps La1 and La2 lights brighter?



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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 TN5 7WY, England.
Fax (+44) (0)1580 200616.
Email: editor@elektor-electronics.co.uk, subject: 'quizzaway 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.

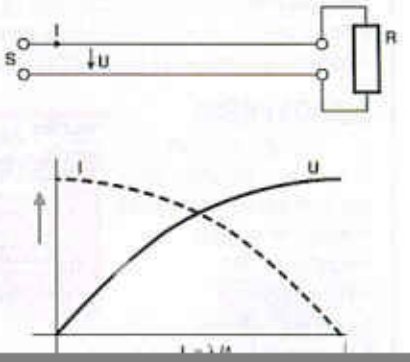
As of the September 2004 issue Quizz'away is a regular feature in Elektor Electronics.
The problems to solve are supplied by Professor Martin Ohsmann of Aachen Technical University.

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

in the case of the correct lamp connected up, $R = z_0$ then the line is perfectly matched and an impedance $R = z_0$ 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.



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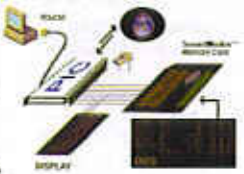

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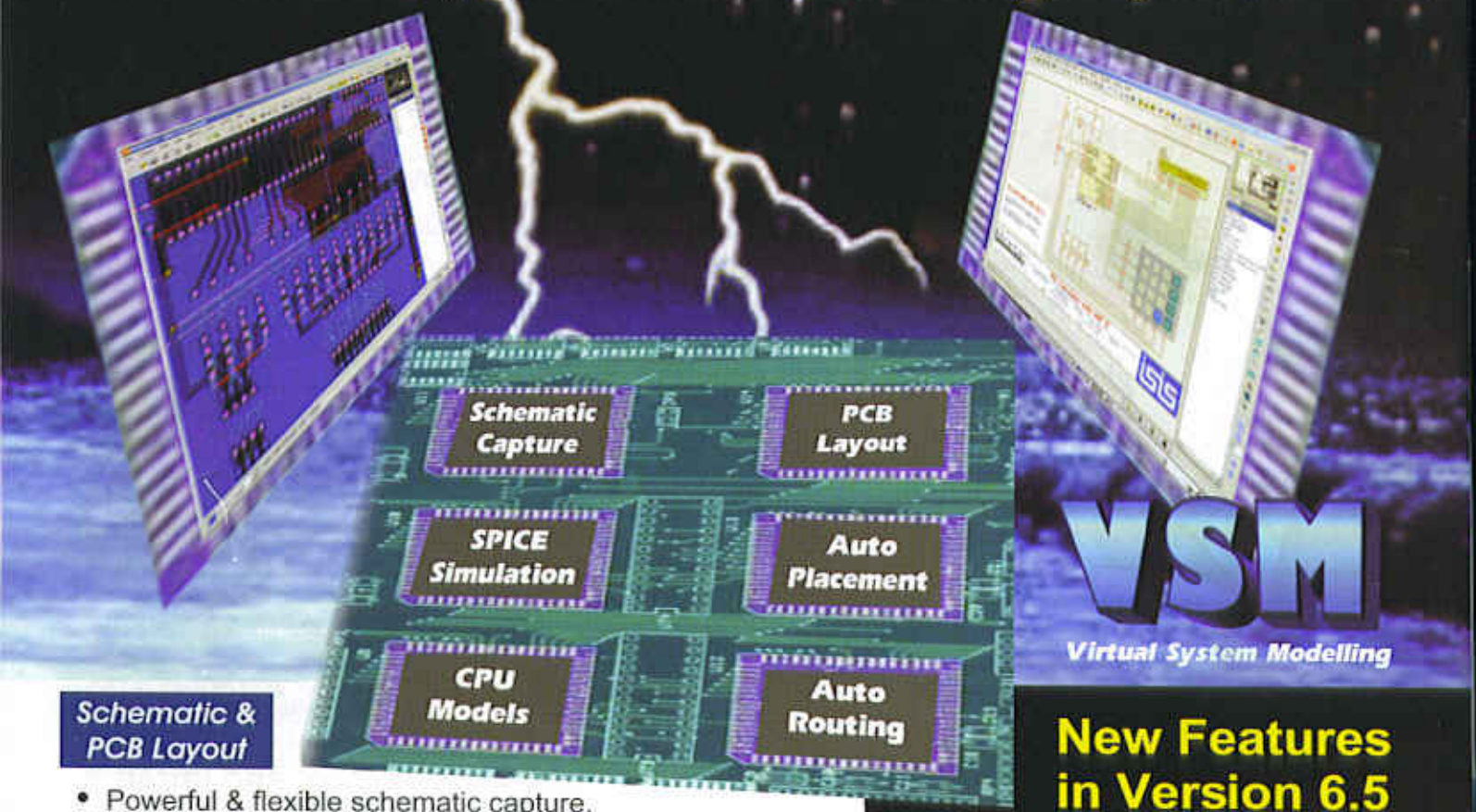

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