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chip tuning

and

OBD-2 car diagnostics

**OBD-2 and a
souped up BMW**

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NEW Catalogue Out Now

PLUS!

12 Vehicle Diagnostics using OBD-2

The OBD interface has been standardised in the EU under the name EOBD, and is mandatory on all newly-registered cars, both petrol and diesel. At the same time, the number of different protocols used for transferring data has risen from three to five, with the CAN bus protocol becoming more and more successful. High time for an up to date backgrounder on OBD-2.

18 OBD-2 Analyser
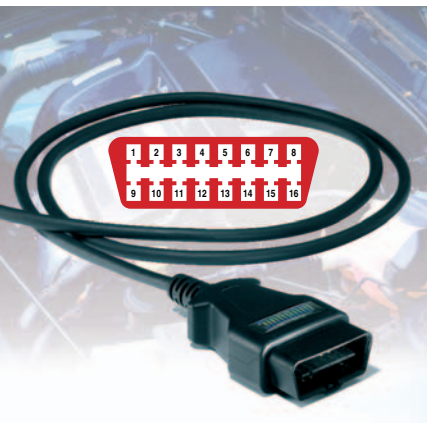
Modern cars are jam-packed with electronics. That's great until something goes wrong. Then you're at the mercy of the dealer. At least until now, because in many cases you can use the EOBD adapter described here to track down the problem yourself.

24 Chip Tuning

Can a car ever be powerful enough? As far as we're concerned, 'more is better'. Here we investigate how chip tuning (after all, we are an electronics magazine) can improve the performance of our sacred cow. Our testbed is a BMW 320d and we've also made use of the OBD2 analyser in this issue. The results, as it turned out, are worth the effort!

elektor electronics
leading the way

Summer

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Circuits 2005

Bold article title =
PCB design included

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LPC210x ARMee Development System

Dear Editor

I've discovered that some code lines for LEDtest program printed in the article on the LPC210x ARMee Board (April 2005) do not work as expected due to notation errors. After some experimentation I was successful in obtaining code that does work.

I would gladly offer it to your readers.

```
arm-elf-gcc -c ledtst.c
arm-elf-gcc -Tlpc2106-rom.ld -nostartfiles -W1,
    -nostdlib -s -o ledtst boot.s ledtst.o
arm-elf-objcopy —output-target ihex ledtst
    ledtst.hex
```

Mobile telephone masts near schools (2)

Dear Editor — mobile telephone masts are just another bogeyman the tabloids can fill space with.

They put out very little power (a few watts), and that diminishes with inverse square of distance. By the time it reaches people, it is miniscule.

People probably get more RF from phones right up against their heads. But of course people don't want to abandon those. Radio amateurs often have much higher RF output than phone masts, and as far as I know nobody has ever demonised them. If I remember correctly, phones do turn up the power to reach the nearest mast, so having a mast near a school may well mean that kid's phones don't have to transmit as loud. People often fail to perceive risks in perspective. Diarrhea and malaria for example dwarf any man-made causes of death.

Kryten (on EE Forum)

You seem to forget that radiation from the masts (and DECT base stations) is present around the clock, 365 days a year. The effects of long-term exposure to low-level SHF radiation are not known (yet).

Also, GSM/UMTS radiation is TDMA-pulsed at about 200-250 Hz which is well within the response of the human brain and nervous system.

I'm curious to see what *Elektor* has on the subject in the June issue. Their website poll (now removed) showed that the majority of respondents worried about the effects of mobile phone radiation (see p. 20-22, June 2005, *Ed.*)

Gonzo (on EE Forum)

This discussion may be continued on our website Forum under the topic 'Radiation a health hazard'.

I hope this is of use to other readers having experienced similar problems with the printed code.

Arne Crouwels (Belgium)

The author/designer, Tony Dixon, replies: I've looked into the problem and Arne is correct. There are a couple of typos in the command listing given in the article, for which I apologise. Please feel free to print Arne's corrected version and give him full credit.

Black Box for Model airplanes

Dear Jan — even though I am into R/C electric model planes I am not at all an electronic buff. However, I do hope you, or someone else, can come up with some advice on how to approach the subject: telemetry for RC model airplanes. Over the last few years several 'Black Boxes', 'Flight Data Recorders", 'RC Logs' — call it whatever you like — have been available on the market for model airplanes. You can either get the readouts in real time or stored on the onboard data logger I guess it's called. This is simply a matter of how much you will pay.

However, I believe it is much more challenging to see if you can create something on your own. I have a book called *Fundamentals of Radio Telemetry* by Marvin Tepper from 1959, (no typo) and I know very well that much has happened since then, so the book is more nostalgic.

For RC electrically powered model planes weight is of course a vital factor. Maybe you could run an article or explain how these small 'black boxes' work. I imagine it should be possible for an amateur like me to create something usable — call it a 'poor man's telemetry system'. Besides, I am sure many others like me would like to know how these gadgets work.

By the way I just read the article about Super Lithium Batteries and the Simple LiPo charger. Excellent stuff.

Torben Back Sorensen (Denmark)

Our resident R/C modelling enthusiasts Giel Dols and Paul Goossens may take up the project but to be able to do so they would appreciate the input and suggestions of other readers. This discussion may be continued in our on-line Forum so have a look there.

Keep 'm separated

Dear Editor — within the April 2004 edition of Elektor Electronics, the high-end pre-amplifier specification for channel separation at 20kHz is 62dB. This seems much lower than the other channel separation figure and cross talk figures. From the PGA2311 datasheet I am

unable to determine if this is a device specification, or the design implementation specification limit for the 62 dB figure. If possible, would you be able to confirm if this is a design implementation or IC specification limit ? Thanks.
Richard Shadbolt (UK).

Our in-house audio designer Ton Giesberts replies: the measurements of the Pre-Amplifier were made on the device as a whole. In this case the lower channel separation at higher frequencies is mainly caused by the input relays. But the rest of the circuitry (wiring, PCB, placing of the connectors and the PGA2311PA) also determines the overall channel separation.

Fond memories of SC/MP

Dear Jan — having only just started reading Elektor again after many years I was amazed by your editorial mentioning the SC/MP and the Retronics article (both in the April 2005 issue). I cut my

microprocessor teeth with the *Elektor* SC/MP projects back in 1978 and they were responsible for shaping my subsequent career path.

I was then an apprentice with BT and I had built Uncle Clive Sinclair's MK14 kit but what I wanted was a real computer with BASIC and a 'proper' VDU. My friend struggled with the *Practical Electronics* Motorola 6800 system which was complex and expensive. Then I discovered *Elektor* which seemed just a bit different to the UK magazines — interesting projects and best of all superb PCBs that really looked good. I built the SC/MP micro project and the teletypewriter — nearly frying myself in the process when I tried connecting composite video into the back of a TV set and hit the EHT instead…
I added the BASIC interpreter (integer arithmetic only — how we rejoiced!).

But crucially for me, it all worked — eventually. The fun for me was in the building, not the using, so I moved on to the legendary Z80. The net result of all this was to cause me to change career at BT into R&D where my first job as a newly qualified technician was to design the microprocessor circuits for a major BT project for the emergency services. Drawing heavily on my *Elektor* experience, it's still in service to this day which I find very satisfying. Ten more years at BT followed until I eventually broke away to start an assembly business of my own and now it's me that advertises in *Elektor*. So thank you *Elektor* — you truly were an inspiration to me and others. As a result of the MPU revolution which then led to the BBC Micro we had for a time a huge lead in programming capability in this country. I fear not for much longer though — my own kids are software users now, not creators. What we need is an SC/MP for the 21st century!
Peter Allgood (UK)

How about our 89S8251 Flash Micro Board Peter? So far about 3,000 of these have been sold and the project comes complete with a programming course. For the more ambitious microcontroller fans I'd suggest venturing out into ARM land with our LPC210x ARMee Development System (also in April 2005, no coincidence as the issue focused on microcontrollers 1978-2005).

LIN controlled alternator voltage regulator

International Rectifier recently introduced the local interconnect network (LIN)-controlled alternator-regulator for next-generation vehicles. IR's solution is claimed to optimize performance in intelligent automotive charging systems for increased efficiency and improved fuel economy.

Intelligent vehicular charging systems are used when dynamic control of the alternator output and torque is desired for optimal battery charging, electrical system power management, and alternator-engine interaction. Dynamic alternator control enables improved electrical system efficiency and reduces engine idle speed for greater fuel economy.

The IR LIN-controlled alternator regulator is assembled using thick-film hybrid technology for reliable high temperature opera-tion and excellent parametric stability over the entire operating temperature range of -40ºC to 150ºC. The hybrid circuit can be customized to the application to optimize performance and reliability, and can be assembled into a custom housing with an insert-moulded lead-frame specifically designed for flame-soldering or heavy wire bonding.

Thick-film technology also enables precise laser trimming of discrete resistors so that patented current sensing technology can be used to achieve the highest tolerance capability in the industry.

**International Rectifier,
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Tel. +44 (0)20 8645 8003
www.irf.com**

(057053-6)

Record temperature & humidity with dew diligence

The EL-USB-2 is reportedly the world's first standalone humidity & temperature data logger with direct USB interface. The unit is capable of recording relative humidity from 0 to 100%RH, temperature from −35° to +80°C and calculating dew point. Configuration of the unit is simple. After installing the software supplied with the unit, simply insert the logger into the computer's USB port and choose the required sampling rate, set high and low alarms for each parameter, and set the logger start time. Once configured, the EL-USB-2 can be removed from the computer and log independently. The waterproof plastic casing allows use of the logger in hostile environments if required. Two LEDs indicate when the unit is logging, when an alarm level has been reached, when the battery needs replacing or when the device has reached full memory capacity (32,000 readings). To download data, the user reconnects the unit to the USB port. A graphing utility in the software plots and displays relative humidity, temperature and dew point along with the time and date for each reading. Data can also be imported into many industry standard spreadsheet packages.
The EL-USB-2 is available immediately from Lascar Electronics at a price of £49.00.

(057091-3)

Lascar Electronics Limited, Module Hose, Whiteparish, Salisbury, Wiltshire SP5 2SJ. Tel. (+44) (0)1794 884567, Fax (+44) (0)1794 884616. Internet: www.lascarelectronics.com

World's smallest Ethernet controller

Microchip recently announced the ENC28J60 — the world's first 28-pin stand-alone Ethernet controller — which provides a low-pincount, cost-effective, easy-to-use solution for remote com-

munication between embedded applications and local or global networks.
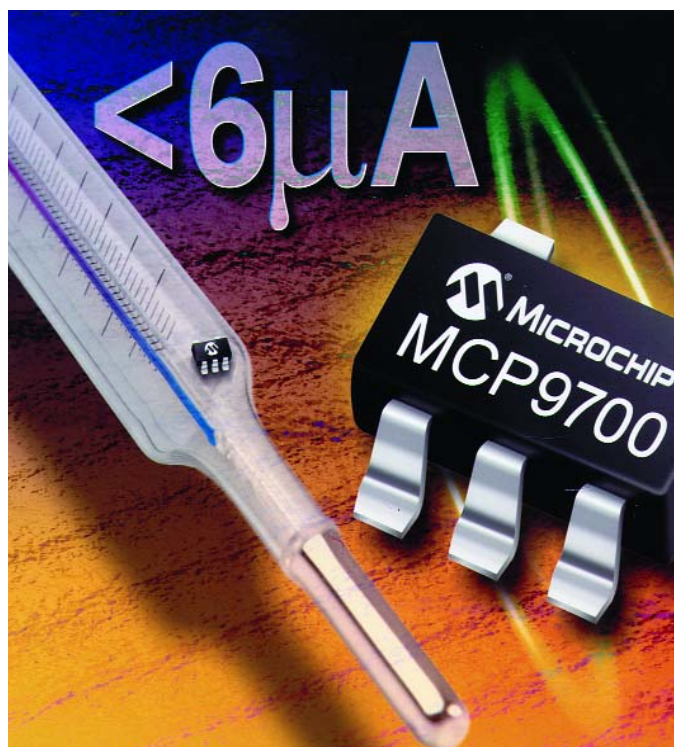
Designers who require communications for remote control or monitoring are often faced with the complexity of large-footprint, expensive Ethernet controllers that are tailored for personal-computing systems. While most Ethernet controllers come in greater than 80-pin packages, the IEEE 802.3-compliant ENC28J60 offers comparable features in a 28-pin package. The ENC28J60 Ethernet controller employs the industry-standard SPI™ serial interface, which only requires four lines to interface to a host microcontroller. These features, combined with Microchip's free TCP/IP software stack for PIC18 microcontrollers, provide the smallest whole-product Ethernet solution for embedded applications.

By adding Ethernet connectivity to an embedded system, microcontrollers can distribute data over a network and can be controlled remotely. Ethernet's infrastructure, performance, interoperability, scalability and

ease of development have made it a standard choice for embedded application communications, such as within the growing VoIP market.

Supporting development tools include the PICtailTM Ethernet Interface board (part # AC164121), designed to ease development with the ENC28J60 Ethernet controller, it plugs into a selection of Microchip's standard PICDEMTM demonstration boards and is expected to be available soon. Microchip's free TCP/IP stack, which is designed for all PIC18 host 8-bit microcontrollers, is available now for download from Microchip's web site. Information on a third-party stack for all PIC16 host 8-bit microcontrollers can also be found there.

Package options include 28-pin SPDIP, SOIC, SSOP and QFN.

(057091-1)

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Tiny, low-power temperature sensors

Microchip recently introduced two temperature sensors that offer low cost, a small SC-70 package and low current consumption of 6 microamps (typical), making them an attractive alternative to thermistors. The MCP9700 and MCP9701 temperature sensors provide a complete solution for thermal protection, temperature measurement or thermal calibration.

The low power consumption of 6 microamps (typical) is less than most of the thermal sensor ICs on the market, enabling longer battery life and reducing self-heating for better accuracy. The linear output slope of the MCP9701 is 19.53 millivolts per degree Celsius while the MCP9700 output is 10 millivolts per degree Celsius. Overall Temperature error is +/- 4 degrees Celsius (maximum) from 0 degrees Celsius to 70 degrees Celsius.

The low output impedance allows direct connection to an analog-to-digital converter input, without the need for buffering amplifiers. The devices are ideal for use with Microchip's 8-bit PIC

16-bit dsPIC digital signal controllers. The extremely small SC-70 package (40 percent smaller than a SOT-23 package) and the elimination of external components results in a more compact board layout.
The MCP9700 and MCP9701 temperature sensors are available today for sampling and volume production. For additional information visit the Microchip Web site.

(057091-2)

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Coldfire suite supports Freescale MCF547x/8x chips

Crossware, a leading embedded software tools developer, has enhanced its ColdFire® Development Suite by adding support for Freescale Semiconductor's MCF547x and MCF548x ColdFire microprocessors.
The MCF547x and MCF548x are high speed microprocessors based on the advanced V4e ColdFire Core. All microprocessors in the range have a wide range of connectivity peripherals, a memory management unit, a dual precision floating point unit (FPU) and an enhanced multiply and accumulate unit (eMAC).
The Crossware Suite includes a separate C header file for each microprocessor in the range. This ensures that the developer has access only to the structures that are relevant to the chosen microprocessor and cannot therefore inadvertently write code for a peripheral that the chosen microprocessor does not have.

The Crossware C compiler generates code that takes full advantage of the FPU and the Crossware simulator fully simulates both the FPU, including FPU exceptions, and the eMAC. This enables developers to run code that uses these units both with and without hardware.

Crossware's FireFly USB BDM (background debug mode) interface has also been enhanced to handle features that are specific to Freescale's System-on-Module (SOM) Fire Engine boards for these chips. This includes the programming of Intel's advanced K3 Strataflash memory chips.

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www.crossware.com**

(057053-8)

Vehicle-Diagnostics using OBD-2

We
published a do-it-yourself vehicle diag
Elektor Electronics back in October and November
it turned out to be! Since then, the interface has been
the name EOBD, and is mandatory on all newly-registe
At the same time, the number of different protocol
has risen from three to five, with the CAN b
more and more successfu

One connector, many protocols

Electronic diagnosis systems have been used in vehicles for almost as long as digital engine management units — some twenty years now. In order to monitor vehicle exhaust emissions more effectively, OBD (on-board diagnosis) systems have been mandatory in the USA since 1988. In 1995 the more highly-developed OBD-2 standard was introduced. This unified diagnostic interface, standardised across manufacturers, was used by the EU Commission as the basis for an EU directive, the effect of which is to oblige European manufacturers to incorporate a unified, accessible diagnostic interface, to make major parts of their existing diagnosis systems compatible with one another, and to publish information about them. The EOBD (European on-board diagnosis) system has been mandatory in the EU on all newly-developed models since 2000 for petrol engines and since 2003 for diesel engines. One year later, EOBD became mandatory on first registration for all vehicles (from 1 January 2001 for petrol engines, 1 January 2004 for diesel engines).

OBD-2 Diagnostics connector

The requirements for EOBD are mostly included in the ISO standards listed in **Table 1**. ISO 15031-3 mandates a 16-pin socket which, in contrast to earlier systems, must now be fitted near the driver's seat rather than in the engine compartment. It may be located, for example, below the dashboard, behind a flap in the central console, or even under the ashtray. Since this type of connector was already used by some manufacturers for the diagnostics system (for example, by VW and Audi since 1993), the presence of the connector by itself is no guarantee that the interface conforms to the EOBD stan-

dard. If the vehicle was first registered before the deadlines mentioned above, it may be necessary to make enquiries of the manufacturer or look on the Internet.

Some of the pins of the EOBD socket (**Figure 1**) may not be present. The actual number of pins depends on which protocols are used (see the next section). That is not to say, however, that pins not listed in the pinout charts (**Table 2**) will necessarily be absent. It can happen that a manufacturer will

use these pins for dedicated functions which do not form part of the EOBD standard.

Protocols

The electronics in a modern car consists of a network of microcomputer systems connected together over a bus, called, in automotive engineering circles, 'electronic control units', or ECUs. More complex systems such as engine management, ABS, ESP and airbags, each have their own ECU. Of

ufacturers preferred the relatively simple ISO 9141-2 protocol, which is similar to that handled by a UART. We described only these three protocols in the article on OBD-2 in *Elektor Electronics* in October 2002. Since then two further protocols have been added: the KWP2000 protocol, a derivative of the ISO 9141-2 standard (KWP stands for 'Key Word Protocol'), and our old friend the CAN protocol, which has only surprisingly recently started to become popular in diagnostics systems. As the footnote to Table 1 hints, the simpler serial protocols according to ISO 9141-2 and ISO 14230-4 (KWP2000) will only be permitted in the USA until the end
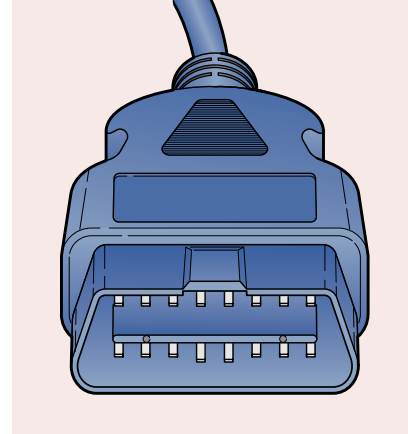
of 2007, and worldwide the CAN protocol is being used for the diagnostic socket on practically all new models. **Table 3** gives an overview of the five protocols which you might (still)

Table 1
Binding ISO standards to EOBD

ISO 9141-2   Communication link*

ISO 11519-4   Low speed serial data communication*

ISO 14230-4   Keyword protocol 2000*

ISO 15765-4   CAN-Requirements for emission-related systems

ISO 15031-3   Diagnostic connector

ISO 15031-4   Test tool characteristics

ISO 15031-5   Diagnostic services

ISO 15031-6   Emission related fault codes (DTC)

ISO 15031-7   Data link security

*not permitted in the USA from 1 January 2008.

Table 2
Connector pins standardised in OBD-2

Pin 2   J-1850 bus +

Pin 4   Vehicle ground

Pin 5   Signal ground

Pin 6   CAN high (J-2284)

Pin 7   ISO 9141-2 K output

Pin 10   J-1850 bus –

Pin 14   CAN low (J-2284)

Pin 15   ISO 9141-2 L output

Pin 16   Battery positive
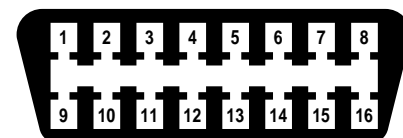
Figure 1. The 16-pin OBD-2 diagnostics socket (source: Gerhard Müller).

course, not all manufacturers use the same (serial) bus system to connect their ECUs together; a variety of bus systems can even coexist within one vehicle. When the OBD-2 diagnostics interface standard was drawn up the most widespread bus protocols in use at the time were considered: these were, in the United States, the PWM protocol used by Ford and the VPWM protocol used by General Motors. PWM stands for 'pulse width modulation' and VPWM for 'variable pulse width modulation'. European and Asian man-

encounter today on an OBD-2 diagnostics socket. A comprehensive overview of the protocols, organised by manufacturer and model, is available on Gerhard Müller's OBD-2 website [1] (in German with machine translation into English available). Gerhard Müller is the author of the OBD articles in *Elektor Electronics* in 2002.

Getting to grips

The complexity of the circuit required to access the OBD-2 or EOBD port depends on which protocol it is possible (or necessary) to use. In the simplest case, the ISO 9141-2 protocol, a straightforward level-shifting circuit is all that is needed. The high level is defined as greater than 0.8 V_B and the low level as less than 0.2 V_B, where V_B

SAE J2012 Fault Code System

P 0 X X X

— Error code

1- fuel / air measurement
2- fuel inject
3- ignition failures
4- aggregate emissions
5- idle and speed check
6- vehicle computer
7- transmission
8- transmission

0 SAE J2012 defined
8 manufacturer defined

P powertrain
(transmission)
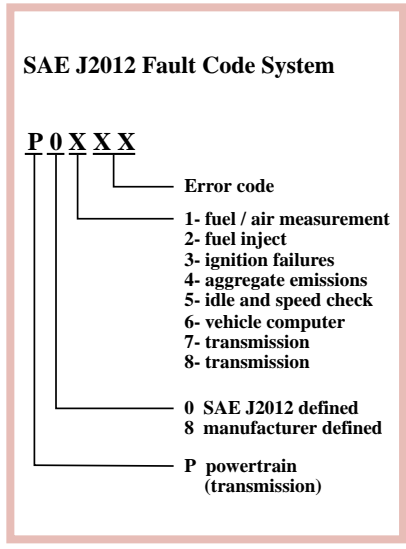
Figure 2. Standard fault codes according to SAE 2012 (source: Gerhard Müller).

is the car's battery voltage. A circuit to convert these levels to RS232 (with galvanic isolation!) is available on Jeff Noxon's website [2]. Using this simple interface it is possible to connect a PC, ideally a notebook, to the OBD-2 socket via its RS232 port. Everything else, from initialisation, baud rate setting and communication with the ECUs, to testing, processing and displaying the data codes etc., must then be carried out using suitable software in the PC. In the case of the ISO 9141-2 protocol a diagnostics program called VAG-COM is available, with the great advantage that there is a shareware version offering a relatively wide range of functions that can be downloaded over the Internet [3]. As you may have guessed from the name of the program, it is designed to be used with vehicles made by the

The CAN bus

(Contribution by Bülent Özen)

The Controller Area Network connects together a number of peered units (called nodes) using a two-wire bus. The CAN protocol was developed by Bosch in 1983 for use in vehicles.

ISO 11898 defines the physical characteristics of CAN and

interference, which tends to affect the two wires equally, is rejected. This is called common mode rejection.

The CAN high and CAN low signals carry the inverted and non-inverted serial data signal. Open-collector drivers are used (PNP to drive the CAN-H signal to V_{CC} and NPN to drive the CAN-L signal to GND), which means that multiple devices can be connected to the bus in parallel without causing short-circuits when bus conflicts occur.

The bus state where the CAN-H and CAN-L signals carry different voltage levels is called the 'dominant' state (with a volt-
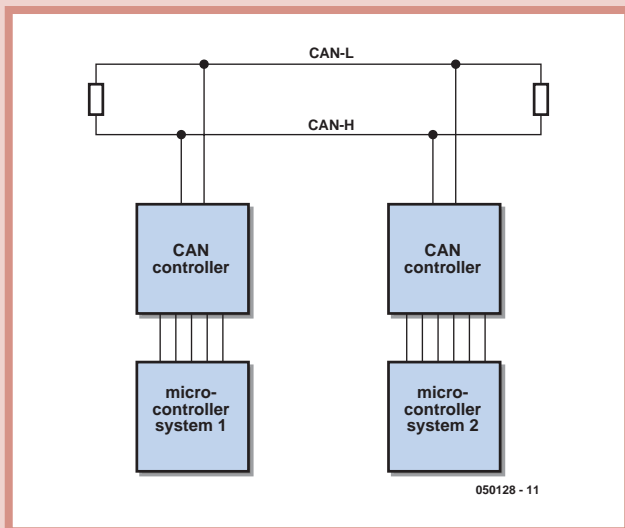
Block diagram of a CAN-bus network.
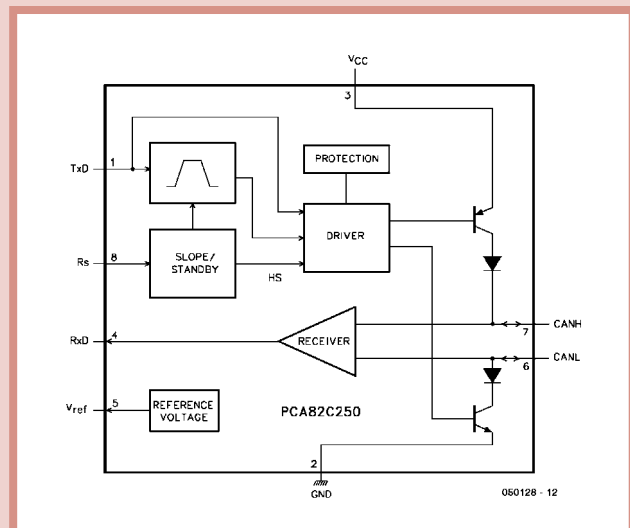
Block diagram of the Philips PCA82C250 CAN transceiver.

many other bus protocols, including, for example, PROFIBUS. There are many ICs available to meet this specification, including the PCA82C250 from Philips. One of the ways used to help protect against interference is to transmit a bit on two wires simultaneously using voltage swings in opposite directions: a so-called differential signal. Since the logic level is encoded by the voltage difference between the two wires,

age difference of greater than 3.5 V); the state where the levels are approximately the same (the difference is less than 1.5 V) is called the 'recessive' state. According to the definition of CAN, the dominant state corresponds to a logic zero: if one node applies a logic zero to the bus, it overrides a logic one applied by another node. The bus between the nodes thus in effect provides a wired-AND connection.

Volkswagen-Audi group. Since this manufacturer has been using the ISO 9141-2 protocol since around 1993, the software also works with older models from VW and Audi whose data transfer format is not compatible with OBD-2. Unfortunately VAG-COM will not work with cars from other manufacturers which are OBD-2 compatible.

A simple level shifter is not enough to run diagnostics on all OBD-2 compatible cars. In order to make the software running on the PC independent of the bus protocol used by the car, a microcontroller is needed in the OBD-2-to-RS232 interface to perform the necessary conversion to and from the car's protocol. This intelligent OBD-2 interface is able to decode the results it reads out and deliver them to the PC in plain ASCII characters. In the simplest case a terminal program is all we need on the PC; the user will then have to search out the various fault and sensor code tables available on the Internet in order to fathom the meaning of the received ASCII strings. Fortunately there is a Windows program available for this purpose [4], which offers a wide range of functions even in its shareware version.
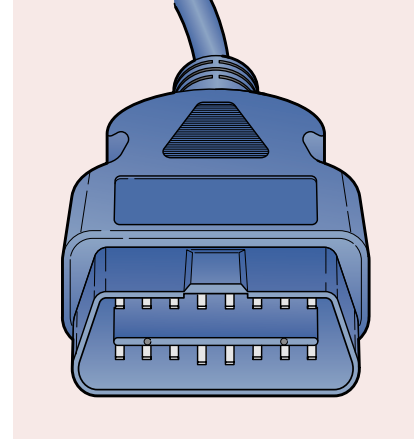
OBD-2-compatible solutions

The OBD-2 interface published in *Elektor Electronics* in November 2002 used a preprogrammed microcontroller made by a Canadian company, but could only be used with cars that use the ISO 9141-2 protocol. The VAG-COM approach has the advantage over this of being independent of any manufacturer. It is also suitable for use with any OBD-2-compatible car that uses the ISO 9141-2 protocol, which, at that time, was the case for most of the more modern cars from European and Japanese manufacturers.

The new OBD-2 Analyser presented in this issue uses a T89C51 microcon-

---

Format of a CAN message

A message needs to be formatted in a particular way for transmission on the CAN bus. The packet is called a 'frame'.
A frame consists of seven fields:
● Start of frame
● Message identifier
● Control bits
● Data (0 to 8 bytes)
● Check bits
● Acknowledge bit
● End of frame

There are two different identifier lengths available, giving rise to two types of frame:
● Standard frame (11-bit identifier)
● Extended frame (29-bit identifier)

Four different combinations of identifier length and bus speed are used in EOBD:
● 11-bit identifier at 250 kb/s
● 11-bit identifier at 500 kb/s
● 29-bit identifier at 250 kb/s
● 29-bit identifier at 500 kb/s

> **A CAN frame always contains eight data bytes. If not all are used, zero bytes must be added as padding. The first byte in the data field is called the PCI byte, and indicates whether we are dealing with a single frame or a multiple frame. In the single frame case the byte also indicates the number of bytes in the data field that are actually used.**
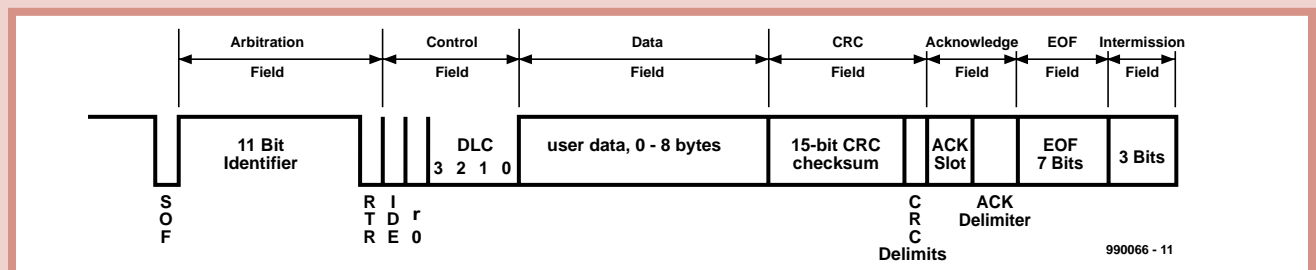
Format of a standard frame in accordance with CAN Specification 2.0A.

| 07 | DF | 02 | 01 | 0D | | | | | | | CRC |

EOBD request for speed sensor reading (11-bit identifier)

| 07 | E0 | 03 | 41 | 0D | W | | | | | | CRC |

EOBD reply containing speed sensor reading (11-bit identifier)

| 18 | DB | 33 | F1 | 02 | 01 | 0D | | | | | CRC |

EOBD request for speed sensor reading (29-bit identifier)

| 18 | DA | F1 | xx | 03 | 41 | 0D | W | | | | CRC |

EOBD reply containing speed sensor reading (29-bit identifier)

troller with firmware developed by Özen Elektronik from Turkey [5] which is currently the *nec plus ultra* in its field: it supports **all five protocols** (see Table 3)! This OBD-2 analyser is thus the first EOBD interface using a microcontroller that also supports the **CAN protocol**. In view of the migration of manufacturers to the CAN protocol, this support is essential for a future-proof system.

In most cases using the OBD-2 analyser in conjunction with a notebook will be the most powerful as well as the most cost-effective and appropriate solution. A stand-alone OBD analyser with built-in LCD has the advantage that it can easily be used while on the move, and it can even be installed permanently. Commercial hand-held OBD analysers are, however, still rather costly, although some hobbyists have built their own.

Functions available

In recent years OBD-2 has evolved in more than just the protocol used. The range of diagnostic facilities available over the standardised interface has increased considerably. It is certainly no longer the case (if it has really ever been the case) that OBD-2 can only be used for reading out data related to exhaust gases. Legislators have so far only required an OBD-2 or EOBD connection for control units associated with the power train. Other systems such as ABS, climate control etc., are left to the whim of the manufacturer: they can offer diagnostics over OBD-2

or they can use their own protocols instead, and take advantage of pins of the OBD-2 socket which are not reserved in the standard. Some manufacturers already make vehicles where all the control units are on an OBD-2 compatible network. The extended OBD-2 standard covers all currently-used control units as well as those expected in future, so in principle the diagnostics for the entire vehicle can be carried out over OBD-2 or EOBD. The EU Competition Commissioner could therefore consider the possibility of further extending the EOBD standard to cover all control units associated with vehicle maintenance.
The range of functions available is chiefly determined by the nine test modes in the standard:

01 - gives real-time data

02 - gives the so-called 'freeze frame' data

03 - gives fault codes

04 - erases fault codes and stored values

05 - gives the self-test results for the Lambda probes

06 - gives the self-test results for systems that are not continuously monitored

07 - gives the self-test results for systems that are continuously monitored

08 - dedicated control mode

09 - vehicle data request: information such as software version and VIN (vehicle identification number)

Many further test modes are specified in the standardised extension (according to SAE J2190). Provision is also made for future expansion and for manufacturer-specific uses. The number of standardised fault codes has also increased significantly, including a large number of manufacturer-specific fault codes. Manufacturers are required to define their own fault codes in relation to the standardised codes, although it is frequently not possible to deduce their meaning without the manufacturer's documentation. Full and shareware versions of diagnostics software are often differentiated by the number of fault codes they understand.

OBD-3

The next generation of technology, OBD-3, is already on the horizon in the USA. In the name of 'Homeland Security' data protection is taking a back seat and surveillance is now in the driving seat: OBD-3 reportedly will secretly and silently transmit its data to a central monitoring station by mobile radio or satellite.

(050128-1)

Digital reprints of these articles may be obtained from www.elektor-electronics.co.uk

Table 3

OBD-2/EOBD protocols

- 1.   **ISO9141-2**
- 2.   **KWP2000**
- 3.   **J1850-PWM**
- 4.   **J1850-VPWM**
- 5.   **CAN-BUS**

Web links:

[1] Gerd Müller's OBD-2 site: www.obd-2.de
[2] Jeff Noxon's VAG interface: www.planetfall.com/~jeff/obdii/
[3] VAG-COM: www.ross-tech.com/
[4] OBD-2 diagnostics program: www.scantool.net/
[5] Özen Elektronik: www.ozenelektronik.com/

Further reading:

1. Car Diagnosis Systems, Elektor Electronics October 2002, p. 50.
2. Vehicle Diagnostics Adapter, Elektor Electronics November 2002, p. 24 and December 2002, p. 82.
3. Controller Area Network (CAN) parts 1-5, Elektor Electronics September 1999 through January 2000.

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OBD-2-Analyser: Check

If you're like most of us, you occasionally notice that there's something not quite right with your car. When all sorts of little lights go on, it's pretty clear that there's something wrong. In some cases your car even starts to talk to you and simply refuses to shut up. There can also be a vague sort of problem that is very difficult to describe to the mechanic. And although the service light indicates that something isn't right, it doesn't give you any sign of what it might be. That means you have to make an appointment with the garage.

Besides all this, many car owners would simply like to know more about everything that is happening in their cars. The problem is how to figure that out in all the jumble of electronics. The information must be there, but how can you get you hands on it? Fortunately, European legislation lends us a bit of a helping hand here. Car manufacturers are now required to provide access to all sorts of data about the engine and the trouble conditions. Readers of *Elektor Electronics* can use the adapter described here to easily read out a lot of useful information.

Modern cars are jam-packed with electronics. That's great until something goes wrong. Then you're at the mercy of the dealer. At least until now, because in many cases you can use the EOBD adapter described here to track down the problem yourself.

B. Özen (Özen Elektronik)

Will it work with my car?

In principle, it's all very simple. All cars with petrol engines made from 2001 onwards, and all cars with diesel engines made from 2004 onwards, must be fitted with a standardized EOBD interface. The parameters and values that can be read out via the EOBD connector are also standardized. Unfortunately, the manufacturers could not agree on the protocol to be used for data transfer, with the result that there are five different protocols. The adapter described here can read all five protocols. You don't have to know which protocol your car uses, because the adapter figures that out on its own.

What can you read out?

The European standard divides the data into groups, which are also called 'services'. The first four services are presently available, and they are also constantly being modified and extended.

In Service Mode 1, you can read out the values measured by various sensors. Naturally, you can only read the values from the sensors that are actually fitted in your car. Some examples of sensor values are motor rpm, driving speed, calculated engine power (based on air consumption), cooling water temperature, and turbocharge pressure.

In Service Mode 2, you can retrieve stored data (which is called 'Freeze Frame' data). That generally consists of engine data stored while the car is underway so it can be analysed afterwards to determine whether the measured values stayed within the stipulated limits (including the environmental limits).

Service Mode 3 contains the trouble codes (DTC). Thousands of trouble codes have already been defined, and new ones are constantly being added. Here the manufacturers have a lot of freedom with regard to making the codes publicly available. You can find a more complete list at www.obd-codes.com. That list is still constantly being enlarged. Refer to the links at the end of the article for more information.

Finally, Service Mode 4 simply allows the trouble codes in Service Mode 3 to be reset. Be careful here: all of the codes will be deleted! If despite your troubles you have to take your car to the garage for service later on, the mechanic will not be able to see which trouble codes have occurred if you have deleted them.

What you need

Nowadays nothing works without software and a computer, so you'll need a PC (desktop or notebook) and a program that can deal with the codes. No

your car's condition

loaded for free from www.ozenelektronik.com. If you simply register and log in (no charge), you can download 'mOByDic Computer Interface Version 1.2b' from the Downloads page.

Another option is the Scanmaster program. It provides a well-organised graphic interface (see **Figure 1**). Scanmaster can be downloaded from www.wgsoft.de or the author's website www.ozenelektronik.com. The nice thing about this program is that it translates the codes into intelligible texts, which makes things a lot easier to understand. It will shortly also be available in non-freeware 'professional' version. The professional version will be more extensive and will include many more trouble codes.

Hardware

The EOBD interface adapter is built on a printed circuit board that is available by itself from *Elektor Electronics* Reader Services or as part of a complete construction kit. The assembled board enables the computer to understand the signals provided by the EOBD connector in your car. Besides converting the signals on the EOBD lines to RS232 levels, this also requires matching the protocols to each other. It shouldn't come as any surprise that

special requirements are placed on the computer, as long as it has a standard serial port. If your computer only has a USB port, you can use a USB-to-RS232 adapter.

As regards the software, there are various options.

The first option is a simple program called MOByDic Computer Interface. It actually amounts to little more than a terminal emulator program that you can use to send and receive codes. The advantage of this program is that the Delphi source code is available on the author's website, so you can adapt it to your own purposes. It can be down-

---

Table 1.
Service modes

OBD operational data (SAE J1979 standard, ISO/DIS 15031-5)

Mode 1	Relevant actual exhaust gas values and system diagnostic data
Mode 2	Data from the engine region (Freeze Frame data)
Mode 3	Trouble codes related to exhaust gasses
Mode 4	Delete the trouble codes
Mode 5	Values from the control loop of the lambda sensor
Mode 6	Tests results (not continuously monitored)
Mode 7	Test values (continuously monitored)
Mode 8	Content different for each manufacturer; can be read out
Mode 9	Identification codes
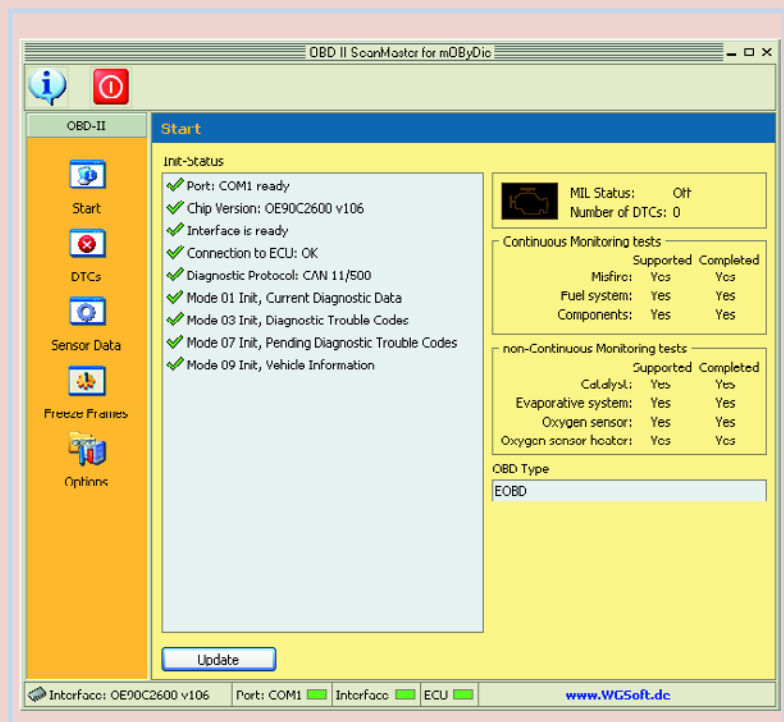
Figure 1. The screen of the Scanmaster program. The various service modes can be conveniently selected using the icons on the left-hand side.
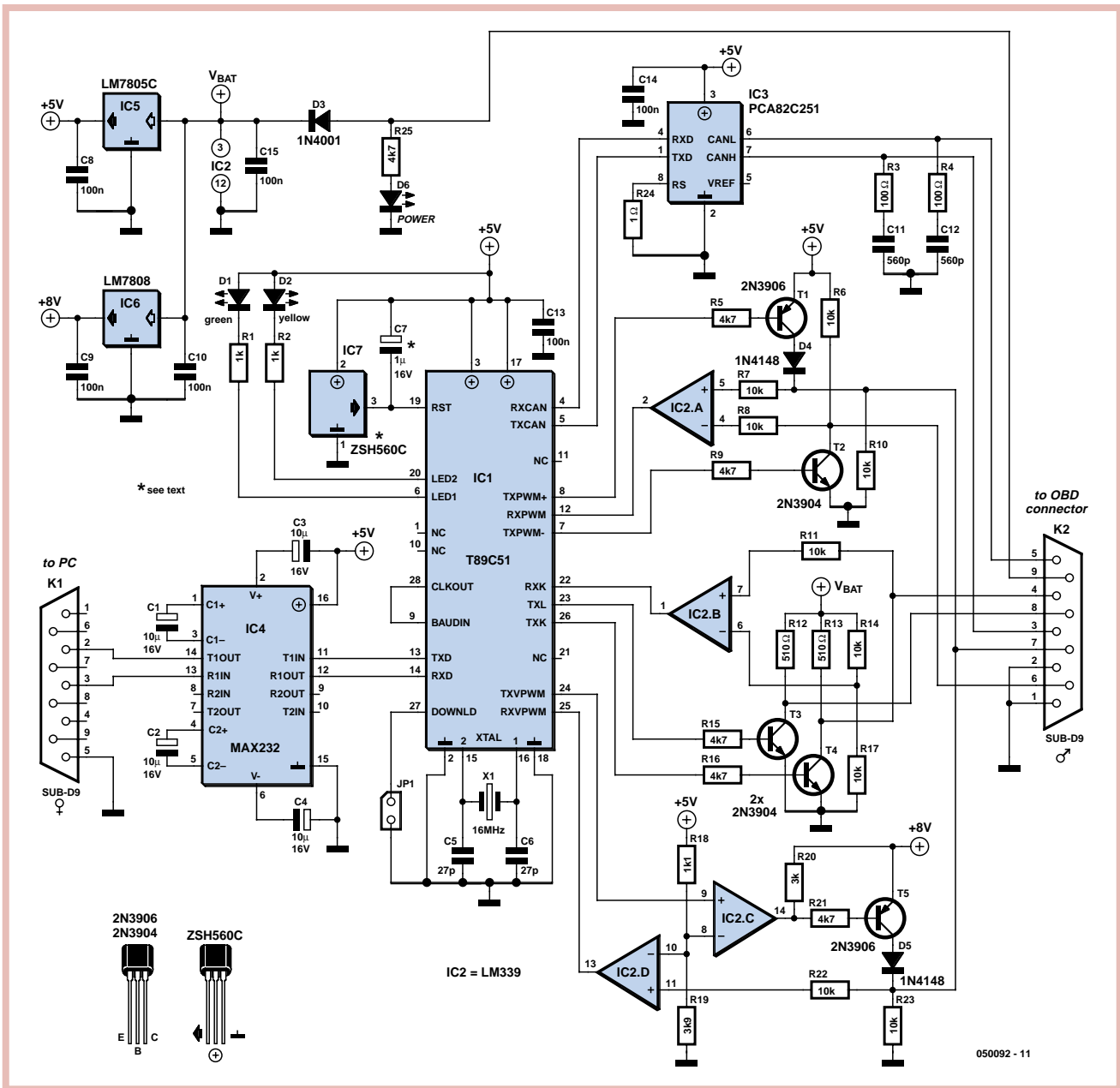
Figure 2. Schematic diagram of the EOBD adapter. Note: fit either C7 or IC7.

a microcontroller (T89C51) is used for the latter task (see **Figure 2**). It would exceed the scope of this article to fully describe the five protocols that the adapter can process, so here we'll limit ourselves to saying that they differ quite significantly from each other. In any case, you don't need to know anything about the protocols to be able to use the adapter successfully.

Incidentally, it appears that within a few years practically all car manufacturers will change over to the more standardized CAN bus protocol. That will make things a lot easier from a technical perspective, because it means that the EOBD interface will simply become another node in a network. For readers who would like to know more, the entire CAN bus was

described extensively in the September through November 1999 issues of *Elektor Electronics*.

Thanks to its built-in CAN controller, the T89C51 microcontroller can communicate with all of the EOBD protocols. The external 16-MHz clock signal is doubled internally. That means the chip works at 32 MHz. IC7 generates the reset signal and monitors the 5-V supply voltage, which is derived from the battery voltage by a 7805. It's possible (and less expensive) to replace IC7 by capacitor C7. The microcontroller drives two low-current (5 mA max.) LEDs that act as state indicators. The serial interface is provided by the well-known Maxim MAX232, so the signal transfer with the PC takes place using nicely standardized RS232 levels.

A different part of the hardware is used for each protocol. For the ISO9141-2/KWP2000 protocol, transistors T3 and T4 provide level adjustment. According to the ISO standard, each of the two data lines must be fitted with a 510-Ω load resistor. The ISO signals are transmitted via the transistors. A comparator (IC2b) is used to receive the ISO signals. The reference input is connected to half the battery voltage (V_{bat}). The microcontroller's internal pull-up resistor provides an adequate load for the open-collector output of the comparator.

In the case of the J1850-PWM protocol, T1 and T2 are used to transmit the differential signal. The received differential signal is processed by the comparator to yield the RX-PWM signal. R7 and R8

Table 2.

Protocols supported by the adapter

- **ISO9141-2**
- **KWP2000**, as defined in ISO14230-1...4
- **J1850-PWM**, as defined in SAEJ1850
- **J1850-VPWM**, as defined in SAEJ1850
- **CAN-BUS**, as defined in ISO15765-1...4
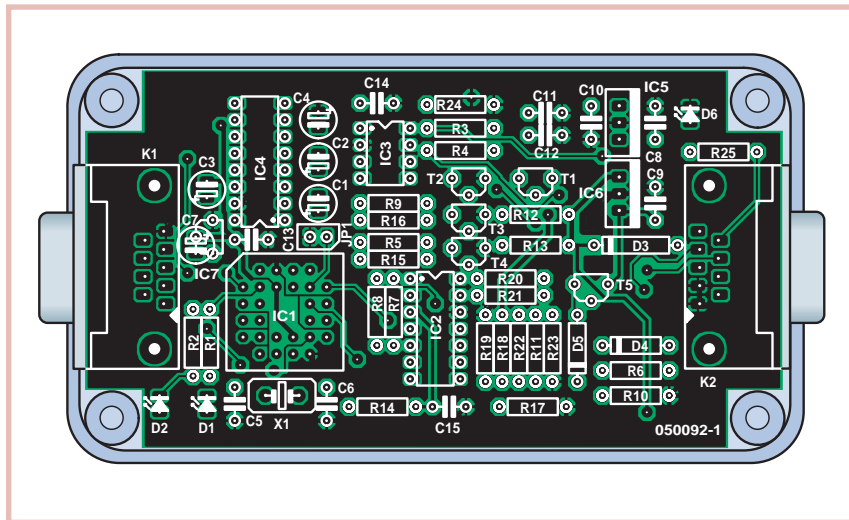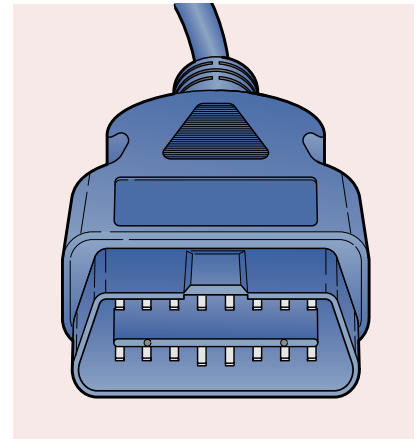
Figure 3. The circuit board is quite densely populated. That is made necessary by the various signal conversion options.

protect the comparator inputs against excess voltages on the J1850 bus.

The signal voltage required by the J1850-VPWM standard is provided by a standard 7808 voltage regulator. A reference voltage of 3.9 V is also necessary for transmitting and receiving data. During transmission, the TTL level is raised to 7.25 V by the comparator and the combination of T5 and D5. R23 acts as a standard load resistor. During reception, the VPWM signal is converted back to TTL levels by using comparator IC2d to compare it with the 3.9-V reference voltage.

The internal CAN controller of the T89C51 is connected to a PCA82C250/51, which in turn drives the CAN bus. R3, R4, C11 and C12 suppress reflections on the CAN bus. The required baud rate of 250 or 500 kbaud is generated by the internal CAN controller in combination with the Identifier.

The PCA82C251 is functionally identical to the PCA82C250 but suitable for use with 24 V. If you work with lorries, you should use the PCA82C251 ver-

sion. If you only plan to use the adapter with passenger cars, the PCA82C250 is suitable.

If you find the American transistor numbers strange, you can use the European BC546B in place of the 2N3904 if you fit it rotated by 180 degrees. A BC4556B can be used in place of the 2N3906, again rotated by 180 degrees. In case of doubt, consult the relevant transistor data sheets to be certain.

The printed circuit board, whose layout is shown in **Figure 3**, fits exactly in the specified Hammond enclosure. You only have to make cutouts for the connectors at the two ends. The board is held in place between the lid and the vertical ribs of the enclosures without any additional fixing hardware.

Initial use

The EOBD interface has two DB9 connectors: one male and one female. Connect the female connector to the serial port of a PC using an RS232 extension

cable. Be sure to use a 1:1 cable for this, not a null-modem cable.

The other DB9 connector is connected using a special cable that has a female DB9 connector at one end and a male OBD plug at the other end (see **Figure 4**). The most convenient solution is to buy this cable along with the PCB. It is specially made for this application. Connect the OBD plug to the OBD service connector in your car. Note: be sure to connect the OBD plug **after** all other connections have been made, due to the risk of static charges (see the inset).

It may take a bit of searching to find the OBD connector in your car, but according to the EU standard it should be within 1 meter of the driver's seat. Naturally, that means it can always be under the bonnet. If you can read a bit of German, there's a handy website at www.obd-2.de/tech_dtc.html. It identifies the location of the connector for many different types of cars.

The circuit is powered from the car. That means that the red LED (power indicator) should light up as soon as you switch on the ignition. After this, the adapter automatically searches for the right protocol. That is indicated by an irregular blinking of the yellow LED. As soon as the protocol has been found, the green LED lights up. If no valid protocol is found, the green LED remains off, and after a while the yellow LED will start blinking regularly at a 3-second interval. That means that no communication is possible.

After the green LED on the adapter has lit up as a sign that communication has been successfully established, you can start the desired PC program. Here we assume that you are using the Scanmaster program. Immediately after being started, the program starts to look for the adapter. You may have to configure the correct COM port and baud rate (9600). If you click on
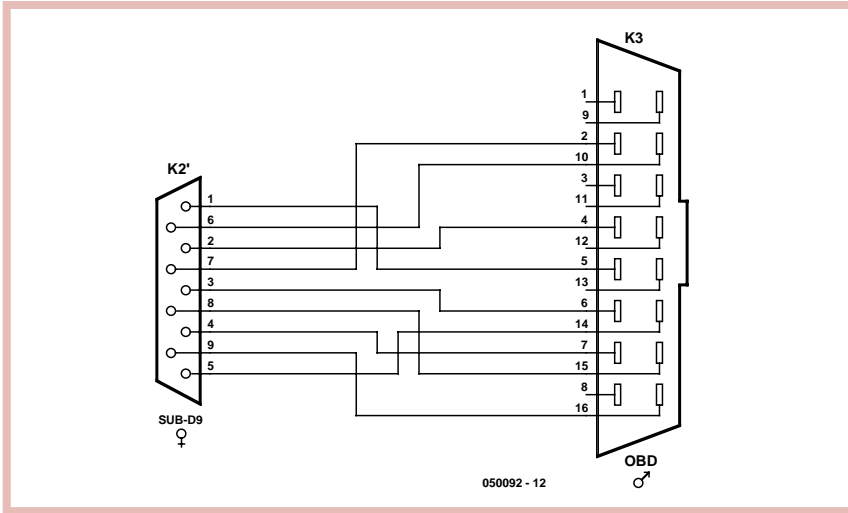
Figure 4. Signal connections in the OBD-to-serial cable.

'Update' at the lower left, the data will appear on the screen (see **Figure 1**). Now you're ready to use the program. Don't forget to click on 'Read' in the 'Sensor Data' menu, since otherwise everything will stay at zero (see **Figure 5**).

Although the mOByDic Computer Interface program does not present the data in such a nice graphic form, it does allow the measured data to be shown in the form of a chart. That

gives a very clear picture of measurements made over a length of time. Finally, we'd like to note that wireless data readout is also possible. A Bluetooth adapter for the serial port is available, and it can be used to link the OBD interface adapter to the PC without using a cable. In any case, we hope you enjoy building the adapter and using it to measure data.

(050092-1)

Figure 5. Data can be read out in tabular form (using 'Table data' at the upper left) or graphic form.

COMPONENTS LIST

Resistors:
R1,R2 = 1kΩ
R3,R4 = 100Ω
R5,R9,R15,R16,R21,R25 = 4kΩ7
R6,R7,R8,R10,R11,R14,R17,R22,R23 = 10kΩ
R12,R13 = 510Ω
R18 = 1kΩ1
R19 = 3kΩ9
R20 = 3kΩ
R24 = 1Ω

Capacitors:
C1-C4 = 10µF 16V radial
C5,C6 = 27pF
C7 = 1µF 16V*
C8,C9,C10,C13,C14,C15 = 100nF
C11,C12 = 560pF

Semiconductors:
D1 = LED, high efficiency, green
D2 = LED, high efficiency, yellow
D6 = LED, high efficiency, red
D3 = 1N4001
D4,D5 = 1N4148
T1,T5 = 2N3906
T2,T3,T4 = 2N3904
IC1 = T89C51CC02UA, programmed, Publishers' order code **050092-41** ** or from www.ozenelektronik.com; ref. type OE90C2600
IC2 = LM339 in DIL14 case
IC3 = PCA82C251 of PCA82C250, in DIL8 case
IC4 = MAX232, in DIL16 case
IC5 = LM7805C, in TO220 case
IC6 = LM7808C, in TO220 case
IC7 = ZSH560C, in TO92 case *

Miscellaneous:
K1 = 9-way sub-D socket (female), angled pins, PCB mount
K2 = 99-way sub-D plug (male), angled pins, PCB mount
JP1 = 2-way SIL pinheader
X1 = 16MHz quartz crystal, 32pF parallel capacitance
28-way PLCC socket
Case: Hammond type 1591B
RS232 extension cable, non crossed, (1:1) male-to-female
Adapter cable, female DB9 to OBD wired according to Figure 4. Available ready-made, Publishers order code **050092-72** **
PCB, Publishers order code **050092-1** **

A complete kit of parts is available from the Publishers; order code 050092-71 **

Content of kit:
● PCB
● programmed microcontroller
● all other parts
● OBD-to-DB9 adapter cable
● Case

* mount **either** C7 **or** IC7
** see Elektor SHOP pages or www.elektor-electronics.co.uk

Static charges

The adapter is not electrically isolated. That would have made the circuit quite a bit more complicated, and it would require a separate power supply. The OBD plug has two ground pins (4 and 5) that are somewhat longer than the other pins, so the ground connection is always made first to allow any potential difference to be equalized before contact is established between the signal lines. However, if you think there is a large potential difference you should always neutralise the potential difference before connecting the plug. The best way to do that is touch the circuit or PC (for example, by firmly grasping the metal shell of the DB9 plug) and then touch the car with your other hand to equalize the potential. In this case your body acts as a conductive link between the PC and the car. Do not connect the plug until after you have equalised the potential.
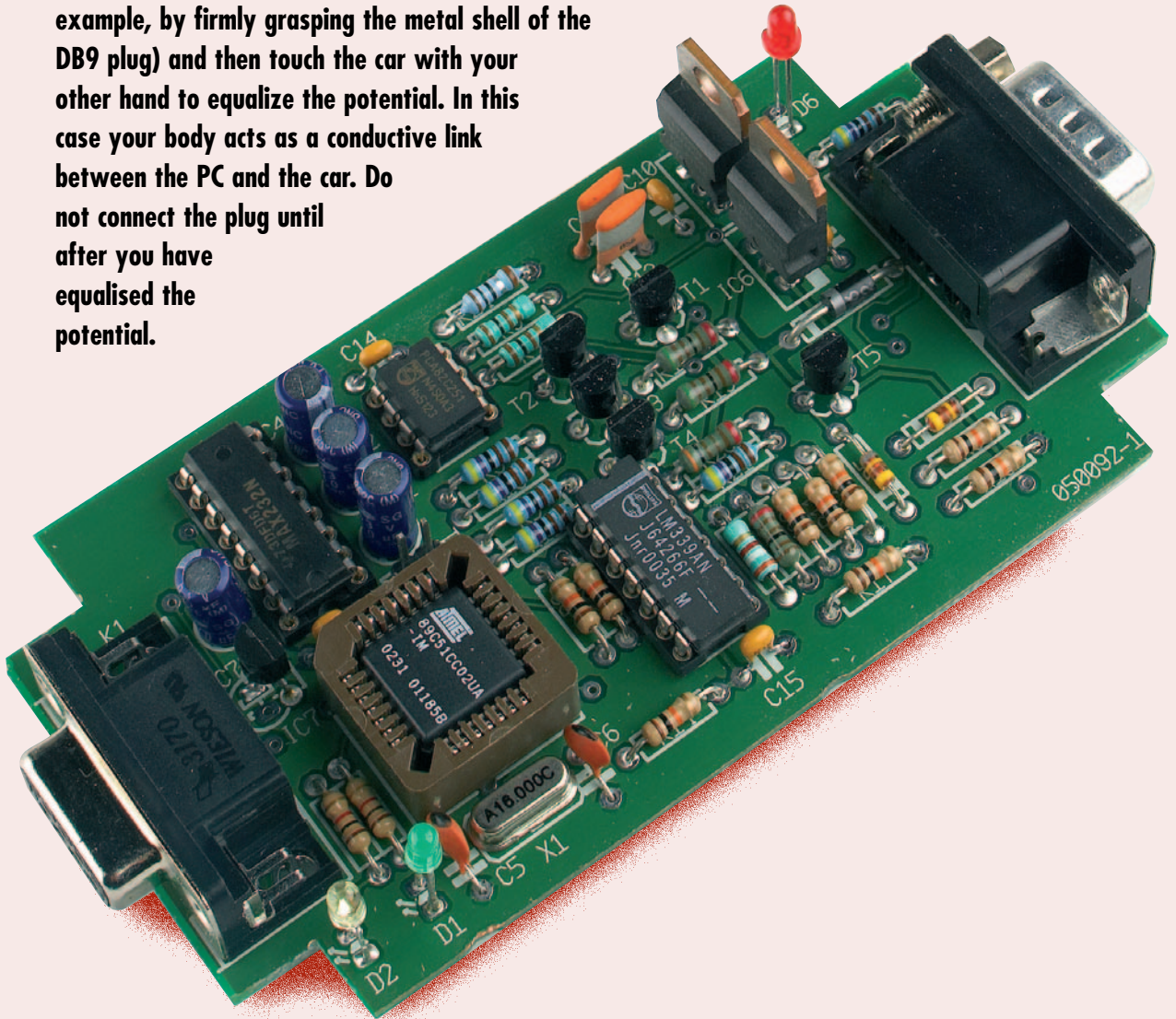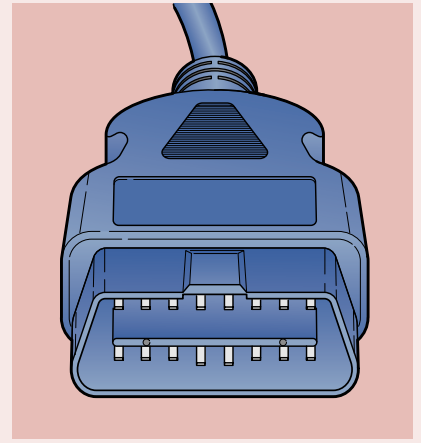
Links

www.ozenelektronik.com
www.obdiidiag.com (This website will be entirely dedicated to the EOBD adapter. It was not quite ready when this article was written, but it is intended to be operational when the article appears in print.)

The following websites (among others) provide information about OBD error codes:
www.obd-2.de/tech_dtc.html   www.troublecodes.net/technical

For additional information, see:
www.elmelectronics.com   www.obd-2.de
www.scantool.net   www.sae.org
www.iso.org

These parameters protect the engine from overheating and limit the car's top speed. We leave the protection untouched, but increase the top speed by 10 km/h.

More power th
CHIP TUNING

The torque limiter. This graph is changed significantly, but within reason.

Thijs Schoonbrood

In the past carburettors and distributors ruled the roost, but nowadays mainly injectors and sensors are found under the bonnet. The biggest difference between then and now is the way in which the engine is controlled. In a traditional system the carburettor 'automatically' controlled the fuel-mixture depending on the pressure and the size of the nozzles. A sophisticated mechanical system with centrifugal and vacuum advance continuously adjusted the ignition timing according to the revs and the engine load.

It's all very different these days: the engine management system is in total control. An *electronic control unit* ('ECU') receives information from sensors regarding the state of the engine. This includes the revs, the engine temperature, the ambient temperature, the position of the accelerator, the angle of the camshaft and the turbo pressure. The ECU controls the timing and the length of the fuel injection on the basis of this information. Is the engine still cold? Then more fuel is injected because part of the fuel condenses on the cylinder walls of a cold engine. Has the driver put the 'pedal to the metal'? The engine management system can then temporarily increase the turbo pressure, or just ignore its guidelines for economical driving so the car becomes more responsive.

The 'driver's wish' controls how the engine reacts to the accelerator pedal.

The ECU has a type of mini database on board that contains numbers for the ideal amount of fuel, the right time for fuel injection and, for petrol engines, optimal ignition timings. And all these numbers are available for various conditions.
But are these numbers as good as possible? Manufacturers have to keep a large range of criteria in mind. For example, every engine has to have a similar performance despite small variations in its construction or when a less than optimal fuel is used. They also have to stay below certain emission and consumption levels. On top of this the manufacturers often include large safety margins. The resulting set of parameters in a standard ECU is therefore a compromise, which the manufacturer feels is right for the international market. This does however leave some room for fine-tuning, which is exactly what we'll do next.

OBD and chip tuning
The parameters for the ECU (the professional tuner calls these 'maps') are stored in an EPROM or Flash memory. These memory chips can be easily read, copied and modified using a universal programmer. With the intro-

The turbo pressure is increased a bit as well.
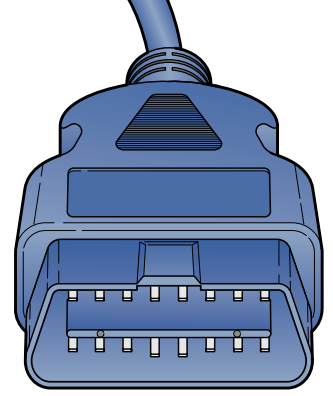
hanks to electronics

Can a car ever be powerful enough? As far as we're concerned, 'more is better'. Here we investigate how chip tuning (after all, we are an electronics magazine) can improve the performance of our sacred cow. Our testbed is a BMW from an enthusiastic reader and we've also made use of the OBD2 analyser that is elsewhere in this issue. We won't give anything away yet, but the results are worth the effort!

duction of OBD (*On Board Diagnostics*) it became even simpler to read the ECU memory, since you no longer had to gain physical access to the memory.

In the first case we talk about chip tuning, in the second it's called OBD tuning. Although the names are different, they effectively refer to the same procedure: modifying the ECU parameters to retune the engine.

ECUs are usually built round a microprocessor. Apart from the parameter tables, the memory also contains a program. This software can interpolate the values from the parameter tables and also deals with the stream of information coming from the sensors. For our objectives there is no need to modify the program and it is even undesirable. In any case, it is often only possible to gain access to the program with an EPROM programmer; it's not possible via the OBD.

Do-it-yourself?

Many electronics hobbyists probably already have access to the required hardware (EPROM programmer) or they can build it themselves (OBD interface). But you need more than just the hardware to successfully tune a car, such as an in-depth knowledge of engines. Which parameters can be modified and what values are safe to use? Changing values by trial and error can have disastrous consequences, so only attempt this when you are absolutely sure what you're doing. First we have to find out the memory addresses of the parameter tables. For obvious reasons, the manufacturers are not very forthcoming with this information, which is often subject to change as well. Fortunately there are companies that provide such information. It is also possible to examine the memory yourself, but this requires a lot of patience and experience. If you decide to go ahead with chip tuning you should take a look at www.dimsport.com, the website of the Italian Dimensione Sport. This company supplies software whereby the addresses for the parameter tables are supplied as separate modules. You therefore only pay for the type of car that you want to retune. The parameters are also shown in a graphical format, which makes it easier to make the modifications.

It is outside the scope of this article to show you exactly which parameters should be modified; this is best left to the engine specialist. A number of parameters, such as the speed and rev limiters, are fairly obvious, but even here you should hold back a little.

Are the tuned parameters to your liking? They can then be written to the EPROM, but not before a new *checksum* has been calculated. If you only change the parameters
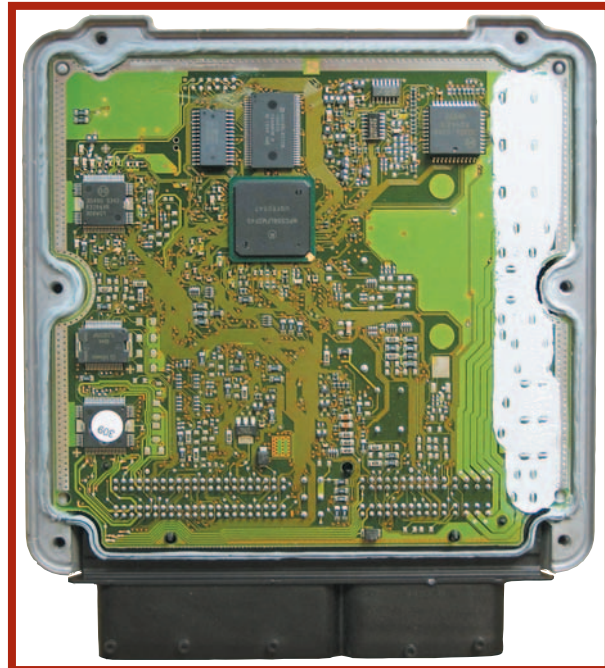
A look inside a modern ECU.
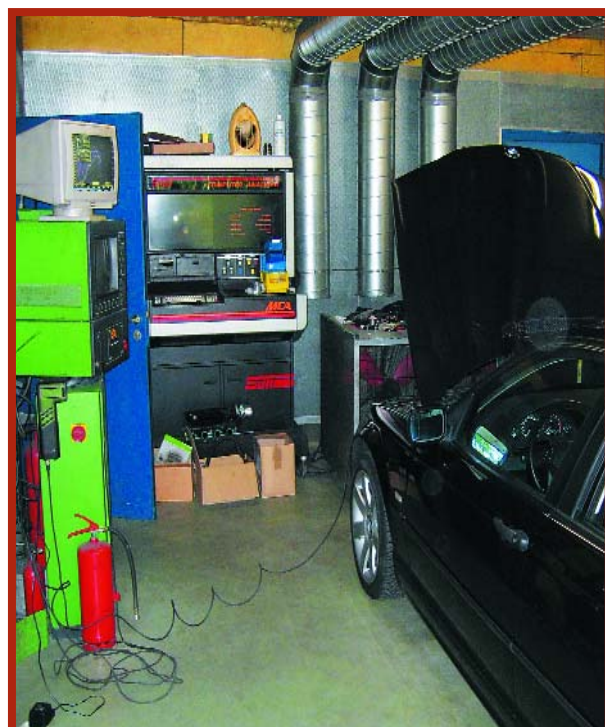
The BMW is prepared for the rolling road.

A special sensor extracts the rpms of the engine from the vibrations.

On the rolling road we increase the speed until the rev limiter kicks in.

On our way to 220 km/h.

We retune the car via the OBD.

Powerbox

There are other ways than OBD/chip tuning to improve engine performance. One of these is via the use of so-called 'powerboxes'. These are small modules that are placed in the signal path between the sensors and the ECU. By changing the signals the performance increases and the engine management can remain unchanged. The advantage of powerboxes is their relatively low cost. You normally fit the modules in your car yourself. They are usually supplied with adapters so that the original wiring loom can stay intact. When you take your car to the dealer, or you need to sell it, you can remove the powerbox in no time.

A powerbox is generally not as good as real chip tuning because such a module can only alter the information going into the ECU.

the ECU will think that the memory is faulty. In that case, the party-lights on the dashboard will probably come on and the car won't start. Good quality tuning software knows how to calculate the checksum and where to store it, so that you don't need to concern yourself with these trivialities.

In practice

We called in the help of a professional to demonstrate the potential of chip tuning. The subject of our test is a jet-black BMW 320d belonging to an Elektor reader. Mark Verhoeven from Engine Management Systems had the honour of converting this sports car into a true power-house. First Mark connects a laptop to the BMW via a special OBD interface and reads the current values of the tables. His software already knows the addresses of all relevant characteristics and it displays these in both numerical and graphical formats.

The first table we look at is the *fahrerwunsch*. This is used to translate between the position of the accelerator pedal and the amount of fuel. BMW has chosen the values for this table to give a smooth ride. The more the pedal is pushed down, the more torque is produced by the engine. The relationship between the two is normally about linear. So when the pedal is pushed down halfway the engine will produce half the amount of power possible. If the table is adjusted so that half the torque is produced when the pedal is only a third of the way down, the car reacts more quickly to the accelerator pedal. Don't overdo this though; otherwise the car becomes undrivable because the accelerator would turn into an on/off switch.

The amount of fuel that was determined by the above method isn't injected without further ado; there are a few other tables that introduce restrictions. The most important of these is the torque limiter. Limiter? That implies a tuning possibility! And it turns out that these values can be adjusted as well. Mark explains: "At certain revs this engine can produce more torque than the gearbox and driveshaft can cope with. The limiter normally has a very large safety margin. With this BMW it's quite possible to increase the power a bit without causing any damage." We now know how much diesel has to be injected. The fuel pump supplies fuel at a constant pressure to the injectors. Since the pressure is constant, the engine management can only adjust the amount of injected fuel by changing the injection times. Note that this involves *two* variables: the time at which the injectors open and the length of time they're open for.

It could report a turbo pressure to the ECU that is lower than the real value. This causes the wastegate, which protects the engine against a high pressure, to open a bit later. This unsubtle trick works with petrol engines because the electronics will automatically increase the fuel injection at a higher pressure. This does cause an extra strain on the engine, so it's not a very nice tuning technique.

This won't work with diesel engines, which run with a lean fuel/air mixture. Powerboxes for these engines make the fuel pump work harder, causing more fuel to be injected for the same opening times. This puts a greater stress on the fuel system and causes faster wear and tear. Another trick is to leave the injectors open a bit longer. This overcomes the disadvantage of extra wear, but it increases the chance of black exhaust fumes, especially when the powerbox doesn't receive information for the engine revs.

It is better to get your car chipped by a competent tuner than to install a powerbox, even though it's cheaper.
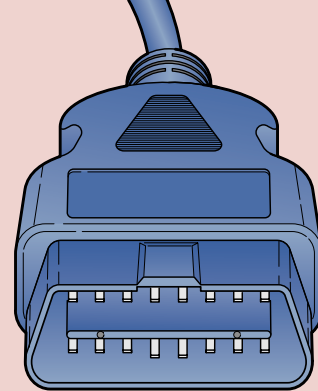
But when is the right time to inject? Not too late, otherwise you can't inject enough fuel or the engine starts smoking. But certainly not too early either because the diesel could ignite too early. This would cause knocking of the engine and could even damage it.
To increase the amount of fuel injected we open the injectors for a longer period and also open them slightly earlier. OBD/chip tuning is different from, for example, most powerboxes because the injectors are not only left open for longer but they're also opened earlier. Finding the right settings for the opening and closing of the injectors is an important aspect of the art of tuning and is best left to the professionals.
As to the question if there are more parameters that restrict the engine, Mark answers: "Certainly. This, for example, is the speed limiter. The standard car won't go faster than 211 km/h, but this is easily changed. And this table shows another interesting restriction: when the engine heats up as a result of heavy loading, the ECU automatically cuts back the power a little bit. This could be changed as well, but I'd rather leave it alone."

Rolling road

Up to now it's all been theory, but has our BMW really gained extra power? And if so, how much extra acceleration can we expect when we pull away from traffic lights? We decide to get some exact figures and send the BMW for a rolling road test.
For comparative measurements we first need to see how the standard car performs and we load the standard tables back into the ECU. The results are as expected: the 320d delivers 140 bhp. This is a little bit more than the quoted 136 bhp, but it's nothing to write home about. The maximum torque was 318 Nm. The *tuner* connects his equipment to the OBD interface and reprograms the ECU with the modified tables. We're curious what the results are. They meet our expectations and the meter now shows over 155 bhp! We try a few other settings and manage to get a maximum power of nearly 160 bhp. There is a considerable increase in torque as well. In the end, the BMW has nearly 380 Nm, which is an increase of about 20 percent. The chip tuning has certainly borne fruit.
We then take the car out onto the open road to see if the performance increase is clearly noticeable in practice. And it certainly is: the *beamer* has, especially at medium and higher revs, a noticeable increase in acceleration and it shoots off into the distance. This makes us wonder why we didn't stick a chilli up its tailpipe before …

(050133-1))
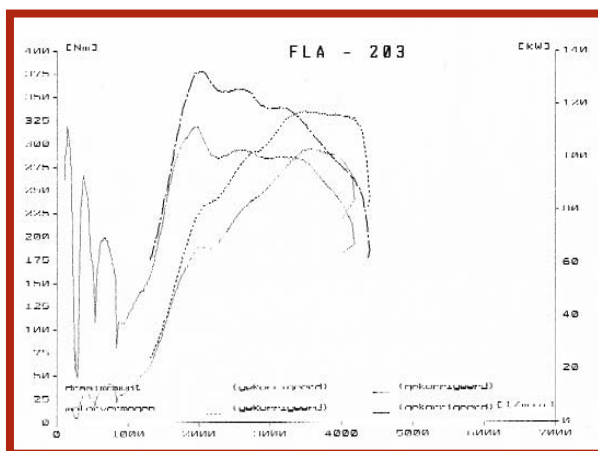
We saw a 20% improvement in torque with our BMW 320d.

This brings the 'pleasure to drive' feeling to life.

digital filters without headaches
Signal Wizard v.2 from UMIST

Paul Goossens
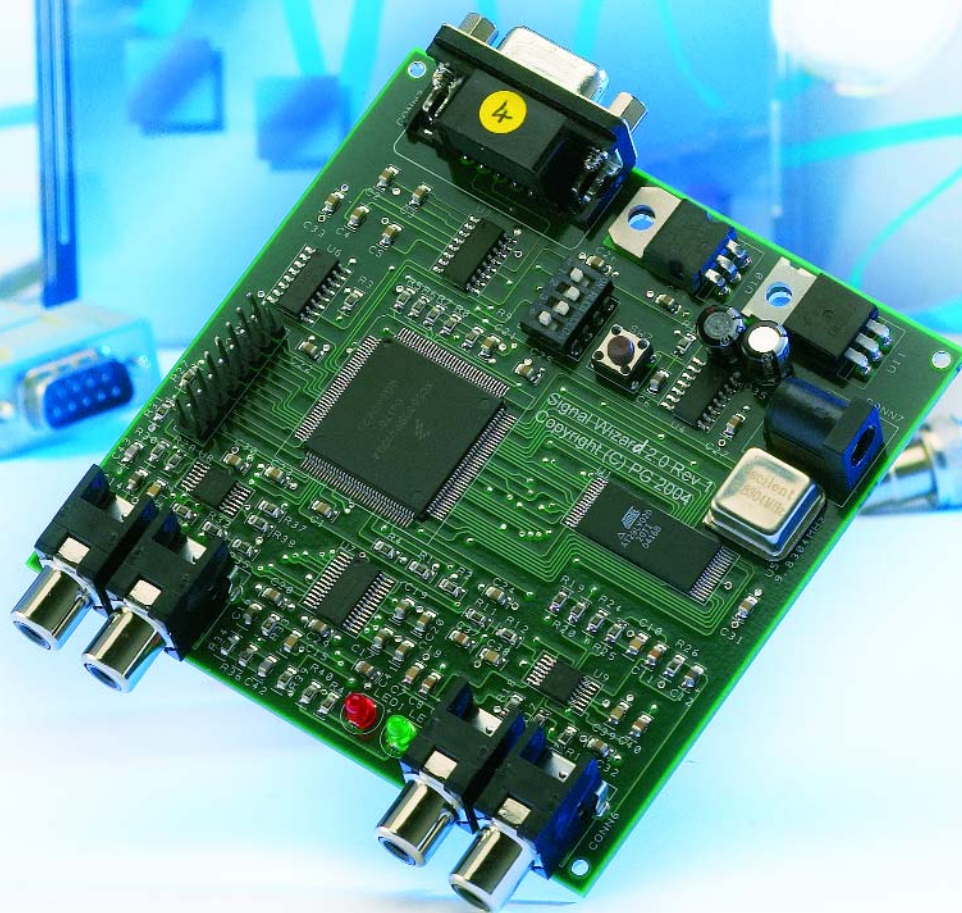
Filter designing is a competence and taken very seriously in audio and measurement and control technology. The associated theory is massive, most textbooks concentrating on analogue approaches. Thanks to a tremendous increase in computing power of today's chips, the art of filter design is shifting to the digital domain. However, converting an analogue filter to digital is not too easy, and that is why Manchester University have released Signal Wizard, a hardware/software suite to help the budding designer get to grips with DSP-based filters.

The Signal Wizard package is, in a way, a virtual breadboard for digitally implemented filters, not forgetting that the kit may also be used for a suitably developed stand-alone application. The latter may turn out to be great solution for one-offs and low-volume applications. The circuit board in the package contains, among others, a Freescale DSP chip, a Flash memory and the required 24-bit D/A and A/D converters. There's also a programmer link in the form of an RS232 connector. The audio connections on the board are cinch (RCA 'Line') sockets and a cinch-to-jack adapter cord is supplied, as well as a mains adapter and an RS232 cable.

Although the hardware outfit is pretty comprehensive, it needs a software complement.

Software

The software that comes with Signal Wizard is capable of first defining filters in various ways. Next, it will generate a filter program for the DSP chip and allow the chip to be actually programmed. All this is possible without deep knowledge of DSPs and/or digital filters.

Having launched the software and set up the SW hardware we're 'ready for take off'. It is just possible you will get a number of error reports like 'not a floating point value'. In that case you will need to change the lan-

FIR and IIR

When reading up the subject of digital filters you'll soon stumble on the terms FIR and IIR. FIR stands for Finite Impulse Response and IIR, for Infinite Impulse Response. Great, but what does it all mean?

Any filter has its own characteristic response to a pulse applied to its input. As soon as we know the impulse response we are in a position to calculate back towards the filter's amplitude and phase behaviour. The reverse also applies — if we ensure that our 'transfer function' exhibits a certain response at the output we have in fact created a filter. This property is exploited with a FIR filter. Each sample is separately considered as a pulse and allowed to cause a response at the output, with the value of the input sample determining the level. The pulse response may comprise just 10 consecutive samples, but equally well, several thousands!

The formula for a FIR filter is

$$y[n] = x[n]*c0 + x[n-1]*c1 \dots x[n-N]*cN$$

where y[n] is the output signal at instant 'n', x[n] the input signal at instant 'n', c_k the impulse response (from 0 to N) and N the number of samples in the pulse response.

Of course, an IIR filter also has a certain impulse response, but compared with the FIR variant these are a bit harder to read from the coefficients. The reason is that feedback is used in an IIR filter.

Mathematically an IIR filter may be described as

$$Y[n] = a_1*y[n-1]+a_2*y[n-2] \dots a_k*y[n-k] + b_0*x[n] + b_1*x[n-1] \dots b_k*x[n-k]$$

which clearly shows that the output signal Y is fed back to the input.

The advantage of an IIR filter is that a reasonable filter may be created with just a few coefficients, where a FIR variant may require a worrying number of these. Also, an IIR filter requires less computing power than an FIR equivalent. An FIR filter, on the other hand, is not only easier to design but may also achieve absolutely flat phase response thanks to the pulse response being entirely subject to defining. FIR filters are also unconditionally stable while their IIIR counterparts when poorly designed are prone to instability and, in the worst case, oscillation effects

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guage setting of your Windows operating system. This is best done by changing the Country settings in Control Panels. Select US/UK settings, i.e., the point (.) for the decimal and the comma (,) for the thousands separator. This may be just the other way around in some other European countries. The UK/US settings will prevent further error reports from appearing.

DSP program is created containing all relevant filter coefficients. All it takes is one more mouse click and the software is actually programmed into the DSP chip on the SW board.

Conclusion

Signal Wizard is excellent if you want to develop skills in designing digital filters *fast*. The great thing about it is that filters can
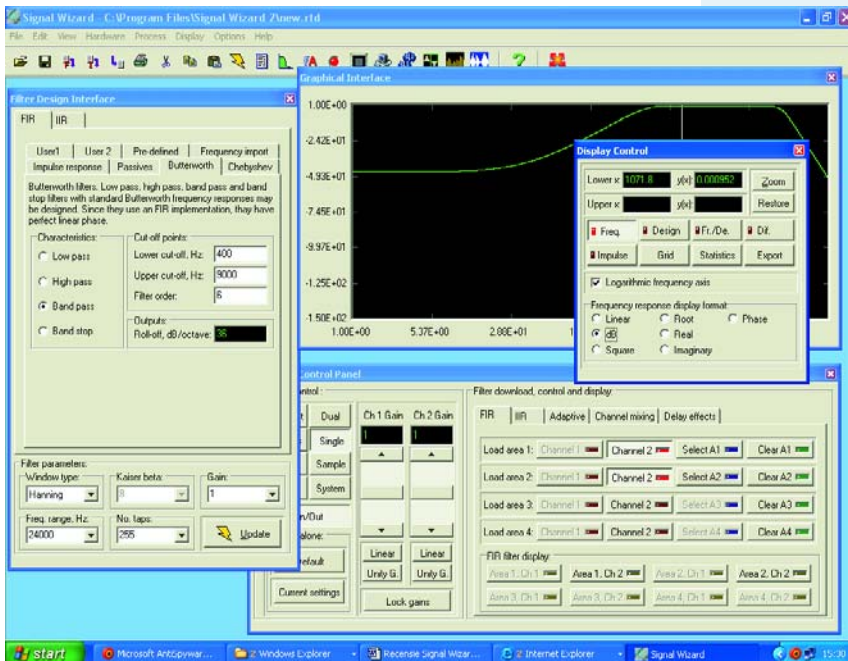
The 'Filter Design Interface' window allows us to design our own filters. The first selection we need to make is between FIR or IIR filter (see inset). Independent of the way we wish to implement the filter, it is now possible to design simple filters, Chebychev or Butterworth filters. All of this is remarkably simple.

FIR filters offer some more options like accurately defining the desired frequency response, whereupon the software will compute the necessary coefficients.

Testing

During the design phase the filter's transfer function is conveniently shown in the 'Graphical Interface' window. The graph is constantly updated on every change in the design window, providing a very quick way to check the response of the filter to changes you're making.

As soon as you're finished tweaking the filter response, a

also be tested in practice, allowing a designer to see what's ahead of him/her while experimenting with all the bells and whistles of digital filters.

For everyone else who's keen on delving deeper, there is no alternative to start (or continue) studying digital filter theory. Fortunately, Signal Wizard offers plenty of power and options to achieve above average results in audio signal processing and filtering.

(050129-1)

FT639 One-Chip Servo Controller

Luc Lemmens

To beginners in electronics, servos have a great appeal, probably because you can do lots of real-life 'things' with them. However, long faces soon appear and pages are turned when a servo control has to be designed and built. Even if that can be done with the good old 555 chip and a handful of parts, the next objection from the new generation is that '*it ain't computer-controlled*'.

The edeFT639 is an 8-pin chip that will control five servos through one 2400-baud serial line. As you can see from the schematic, the only external components required are a decoupling cap, plus two resistors and a diode to withhold the negative swing of the RS232 line the circuit is connected to. In case TTL-swing (5 V) serial control is available, such as in PIC or Parallax Stamp systems, the control signal to the edeFT639 may be applied directly to pin 4.

The serial data format is a dead simple **2400 bits/s, no parity, 1 stop bit** so you can practice away using any ter-

minal emulation or general purpose serial comms utility like HyperTerminal.
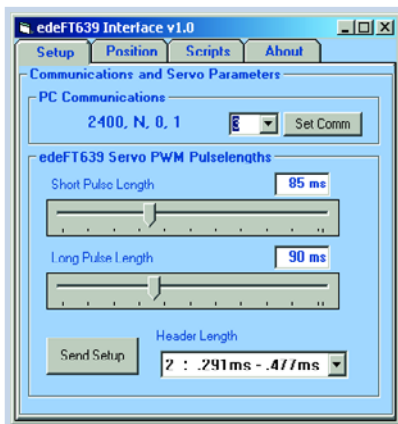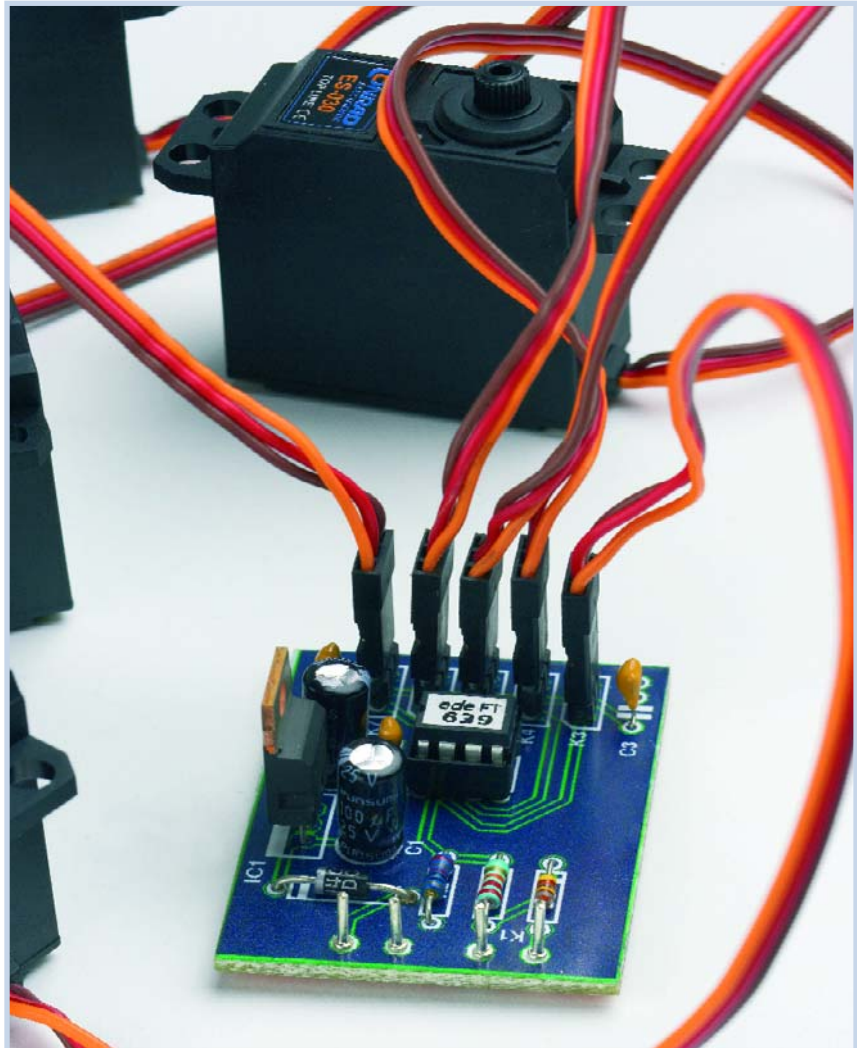
The edeFT639 will always start in Setup mode, then switch to Active Mode. The chip can set a servo to one of 256 positions from 0 to 90 degrees using a 'short' pulse (1 ms) or from 0 to 180 degrees using a 'long' pulse length. The starting position of each individual servo can also be adjusted by using a different header length. Full details about bit-banging the device over a 2400-baud serial line are given in the 'FT639 Ferret' datasheet, which also contains a simple program (in QBASIC) showing the nitty-gritty of talking

054016 - 11
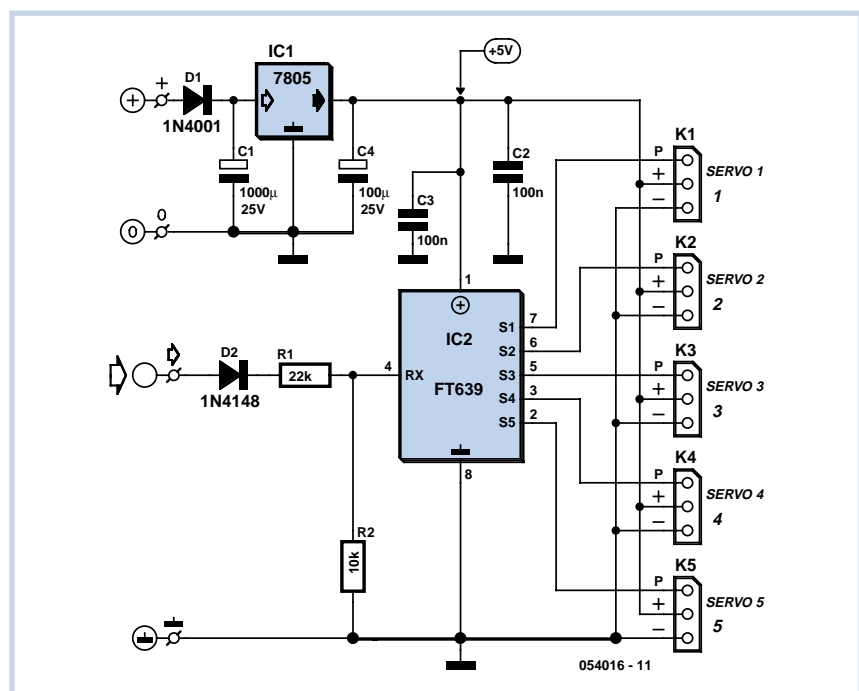
to the device using software and the PC's printer port (LPT:). The 'get-to-know-u' program can be downloaded from the Elab Inc. website (see below) and should not be too difficult to convert into PIC or AVR code. On the same website we also found a Visual BASIC programming example complete with source & executable code to illustrate how the edeFT639 servo controller can be driven via Windows and RS232 (see screendump).

Apart from the edeFT639 chip and its input protection network R1/R2/D1, the PCB shown here also accommodates a simple step-down voltage regulator. RC Modellers wishing to use the circuit in a plane or boat may want to exchange the 7805 for a low-drop regulator and omit
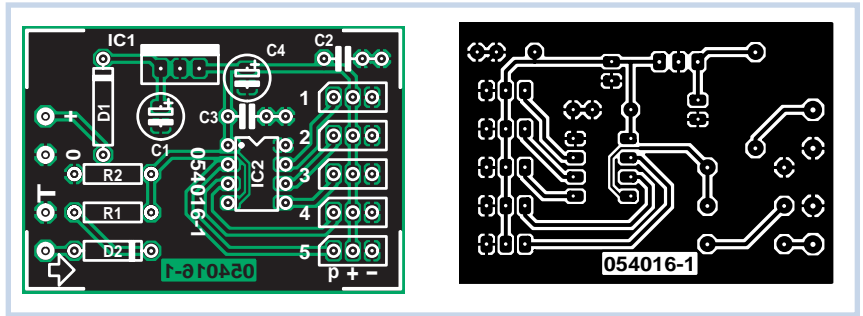
D1 in order to juice the craft battery. The servos are connected via the usual 3-pin connectors. As servo manufacturers use different pinouts for pulse (p), ground and +5 V on their connectors, you should check the data available.

(054016-1)

Source:
Elab Inc. (formerly FerreTronics) FT639 Ferret datasheet. www.elabinc.com

COMPONENTS LIST

Resistors:
R1 = 22kΩ
R2 = 10kΩ

Capacitors:
C1,C4 = 100µF 25V radial

C2,C3 = 100nF

Semiconductors:
D1 = 1N4001
D2 = 1N4148
IC1 = 7805
IC2 = edeFT639 (Elab Inc.; www.elabinc.com)

Miscellaneous:
5 off 3-way SIL pinheader
Evaluation software (VB application) from Elab Inc. wesbite
PCB, ref. 054016-1 from The PCBShop

GigaBit Crossover Cable

002

Henri Derksen

We previously described a crossover cable in last year's Summer Circuits issue ('Home Network for ADSL', p. 81). However, that cable cannot be used for Giga-Bit links, since all eight conductors are important in that case.

A GigaBit link uses four signal pairs. If the cable is longer than 8 metres, it is also necessary for each paired set of conductors to be twisted together. Otherwise crosstalk will occur, which will cause data communication errors.

A crossover cable that is suitable for 1000-Mbit networks must have all of the conductors connected differently at one end. TX is thus connected to RX, and the two other pairs are also swapped. The connection scheme is shown clearly in the drawing.

Naturally, such a cable can also be used in a 10-Mbit or 100-Mbit network, but it is not suitable for use in combination with lines for an analogue telephone, such as was suggested in the article in the 2004 Summer Circuits issue.

(050046-1)

003
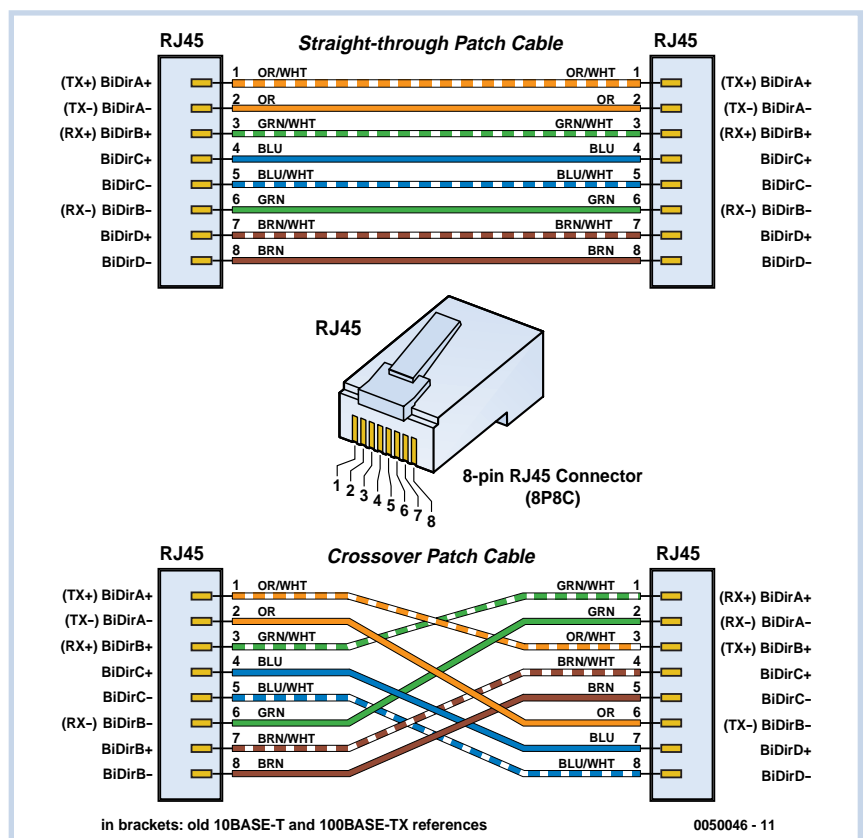
Toslink Repeater/Splitter

Ton Giesberts

The purpose of this circuit is not only to extend an optical digital audio connection (Toshiba Toslink) but also to function as a splitter, so that two devices can be connected to one Toslink output.

The circuit consists of the standard application for the Toslink receiver module TORX173 (IC1) and the Toslink transmitter module TOTX173 (IC2 and IC3), that we have used on previous occasions. Inverters from a 74HCU04 are connected between the input and output and act as pulse restorers. To keep the quality as high as possible, each of the transmitter modules is driven individually. The first inverter is AC-coupled and ensures that the received S/PDIF signal is centred on the threshold of the inverter. The other inverters (except one) amplify the signal to the maximum output voltage before presenting it to the transmitter modules.
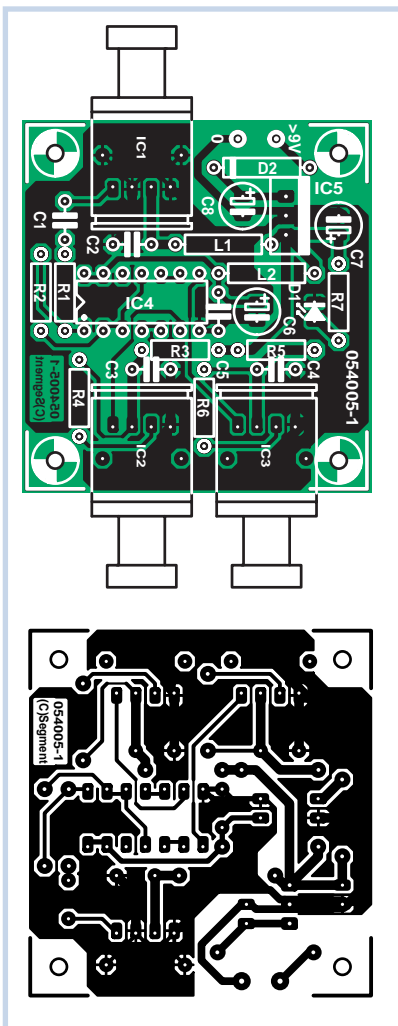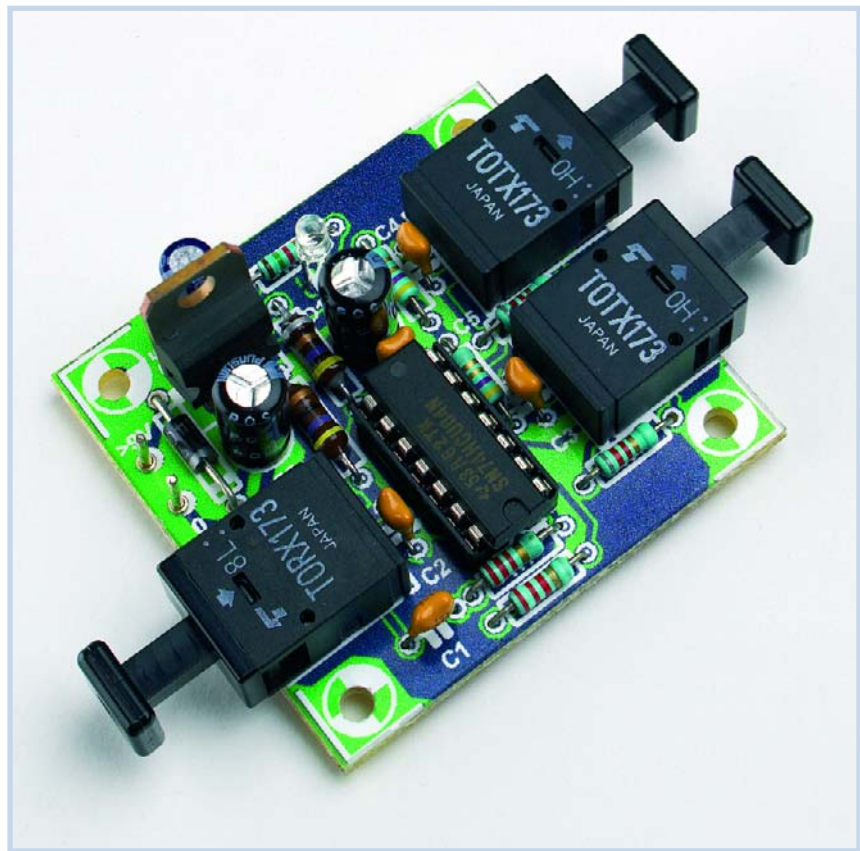
For the power supply a standard 7805 was selected with D2 as reverse polarity protection. L2 decouples the power sup-

ply voltage of IC4 some more. This does L1 for IC1 and R3 and R5 for IC2 and IC3 respectively. R4 and R6 are required
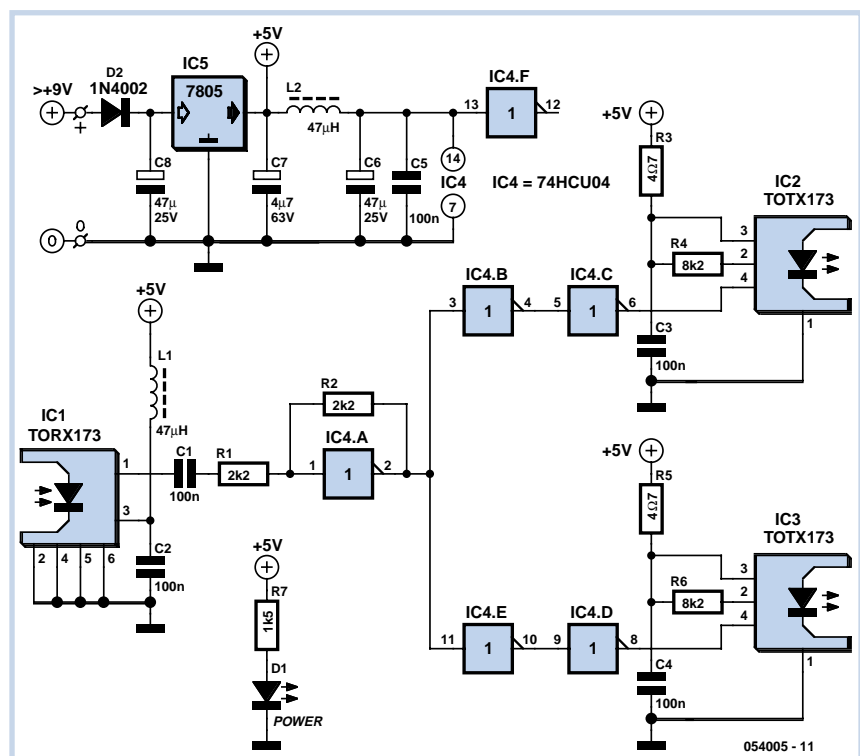
for the internal adjustment of the transmitter modules. The required power supply voltage amounts to a minimum of 9 V and can be provided by a mains adapter. A panel mount socket can be fitted in the enclosure (that you can choose yourself) to suit the plug on the mains adapter. A printed circuit board has been designed for the circuit that contains all the components. Two pins are provided to connect the power supply. LED D1 indicates that the power supply is present. The current consumption without optical signal is 103 mA. When the cables are connected and with a frequency of 48 kHz, the current is 70 mA. This is because the transmitter modules will now turn the internal LEDs on and off (when there are no

cables connected, the LEDs are on continuously). At 96 kHz the current is about 3 or 4 mA higher.

An FFT (fast fourier transform) analysis

shows that the noise floor with a 16-bit PCM signal is about 40 to 45 dB higher compared to a 24-bit PCM signal.

(054005-1)

Optical Mixer

004

Peter Lay

Mixing signals at different frequencies is common practice in many areas of electronics. Audio systems, communications systems and radio systems are typical application areas.

With conventional frequency mixers, feedback capacitance can cause the signal sources to be affected by the output signal, thus making supplementary filter circuits necessary. The signals from the individual signal sources can also affect each other.

In an optical mixer, LEDs or laser diodes are used to first convert the signals to be mixed into optical signals. The light beams are then aimed at a shared photosensor (a light-sensitive resistor, photodiode, phototransistor, or photovoltaic cell). The current in the output circuit is thus controlled by the mixed input signals, so signal from the photosensor is the sum of the input signals. The amount of feedback capacitance can be made quite small, depending on the construction. Another benefit is that the input and output circuits have separate grounds, which can be electrically connected if necessary. This operating principle directly encourages experimentation. Additional input stages can be added to act on the shared photosensor. If the receiver signal is applied to a component with a curved characteristic, such as a diode, this produces amplitude modulation, which can be used in a heterodyne receiver. If the difference between the frequencies of the two

040202 - 11
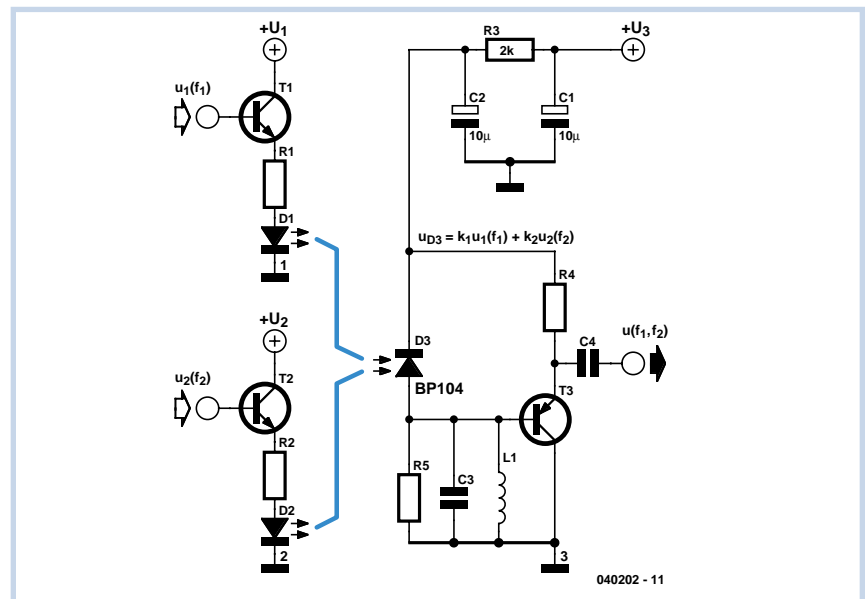
Formulas

Input signal voltages:

$$u_1(f_1) = \hat{u}_1 \sin(\omega_1 t + \varphi_1)$$

$$u_2(f_2) = \hat{u}_2 \sin(\omega_2 t + \varphi_2)$$

Voltage across the photosensor: $u_{D3} = k_1 \hat{u}_1 \sin(\omega_1 t + \varphi_1) + k_2 \hat{u}_2 \sin(\omega_2 t + \varphi_2)$

Key:

$u_1(f_1)$ — first input signal at frequency f_1

$u_2(f_2)$ — second input signal at frequency f_2

u_{D3} — receiver signal generated by superposition of the two input signals

k_1, k_2 — optoelectronic coupling factors (empirically determined)

input signals is small, a beat effect occurs. The components must be selected accord-

ing to the frequency range that is used.

(040202-1)

005

Mobile Phone Operated Code Lock

050077 - 11

X1 = 3.579545 MHz
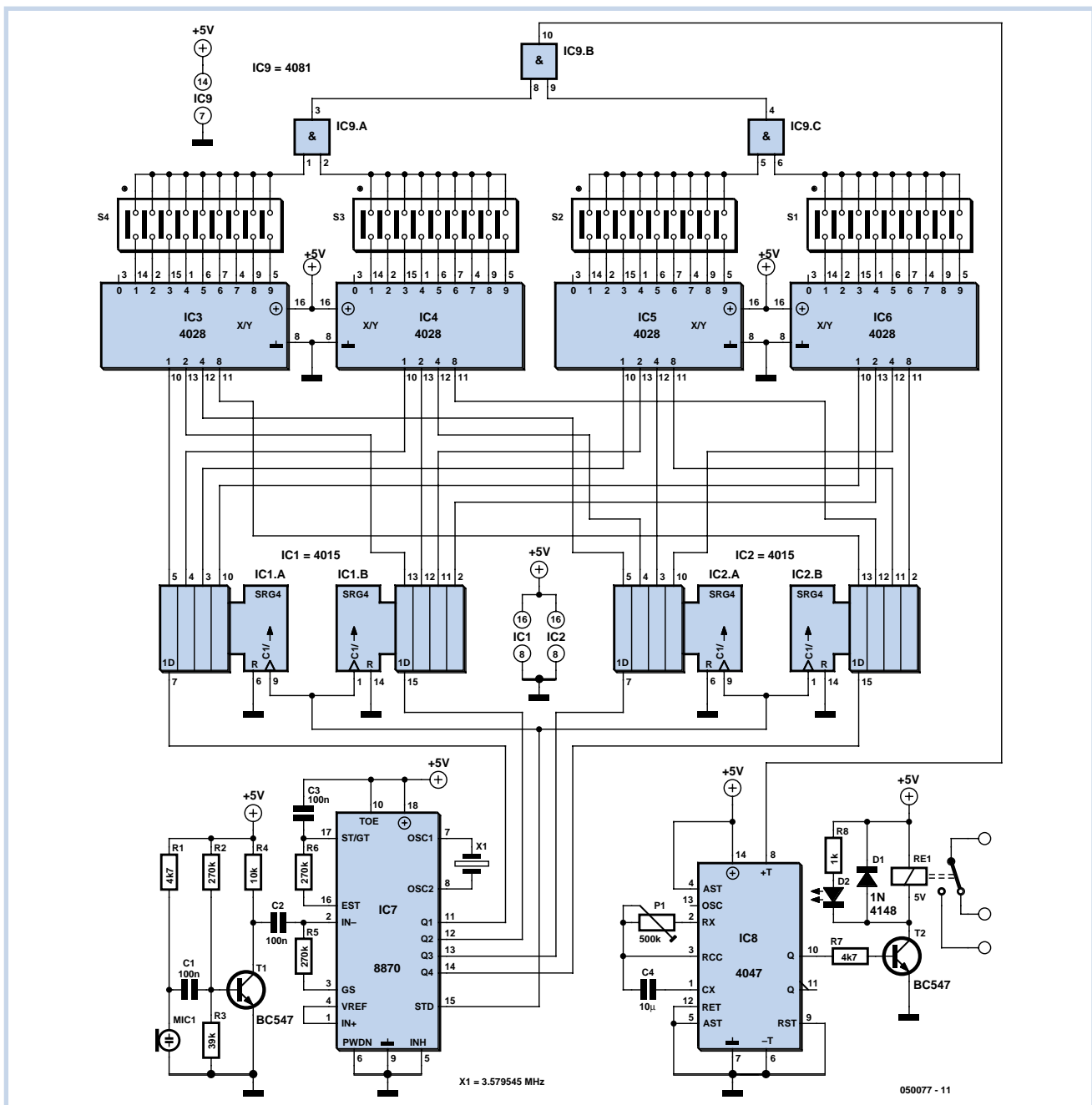
Heikki Kalliola

Suitcase numberwheels and doorside keypads have evolved from well-known code locks, to hot topics now mainly due to Dan Brown's bestseller novel *The daVinci Code*.

The main ideas behind the lock described here are minimum obtrusiveness and minimum user interface.

A typical code lock is operated with a four-digit secret code and the lock can be opened by presenting this code. The lock described here has no buttons or keypad

at all, a small hole or other hiding place for the microphone capsule is enough.

Nowadays practically everyone has a keypad in the pocket — it's on your mobile phone! The lock listens to mobile phone keytones (DTMF tones) and responds to the valid, pre-set four digit code. No visible interface is needed as the microphone capsule can be located behind a small hole. Note that the mobile is used 'off-line', so no phone expenses are involved.

Electret microphone M is connected via transistor amplifier stage T1 to the input

pin (2) of DTMF-receiver/decoder IC7. The decoder's four-digit output word (on pins 11, 12, 13, 14) and 'valid digit present' flag (pin 15) are connected to two shift registers, IC1 and IC2. A rising edge on pin 15 of the '8870 chip triggers each shift register to read its input code and shift it by one increment.

Shift register outputs are connected to BCD to Decimal-converters type 4028 (IC3-IC6). The register status is shown as a high signal level at certain pins of DIP switches S1-S4. Depending on the switch settings, one combination causes High

levels at all AND gate inputs and the lock is opened for a moment.

Due to the operation of the shift registers, the latest input digit appears on IC3's outputs. So if the desired code is, for example, 2748, S1 contact 2, S2 contact 7, S3 contact 4 and S4 contact 8 are closed.

When four digits in sequence match with the code set by the switches, relay RE1 is activated for a user-defined time. Upon a rising edge on input pin 8, monostable multivibrator (MMV) IC8 pulls pin 10 high for a moment, activating relay Re1 via transistor T2. The duration of active time can be adjusted with the preset between

pins 2 and 3. A green LED can be connected across the relay coil to indicate lock opening.

The minimum distance from the microphone is about 20 cm.

(050077-1)

Minimalist Microcontroller

006

Christoph Fritz

They say that things were always better in the old days, although perhaps they were not thinking of microcontrollers and their complex support circuitry. In the ATmega8, microcontroller specialists Atmel have introduced a device that lets you construct a prototype circuit using just two resistors and one potentiometer in addition to the microcontroller chip. Not even a crystal is required: an internal 8 MHz oscillator provides the clock. We thus have a four-component circuit that is a powerful and practical development kit; not only that, it can be programmed directly from the parallel port of any PC without additional hardware. Incredible! The circuit shown offers a number of I/O pins and an A/D converter input; not only that, it is ready to be connected to a commercially-available liquid crystal display. The whole thing can be built on a simple prototyping board, and no heroic soldering skills are required.

Software, in the form of a C compiler (AVR-GCC under Linux or WinAVR under Windows) is available for free on the Internet. Example applications, expansion ideas, programming tools and code collections are also widely available. And, since the circuit is so simple, it can easily be modified to use other types of microcontroller from Atmel: just take a look at the relevant data sheets and determine which pins are used for the various functions.

(040218ts)

Links:

Introduction to development tools
● for Linux etc.:
www.nongnu.org/avr-libc/
user-manual/install_tools.html
● for Windows:
www.avrfreaks.net/Tools/
showtools.php?ToolID=376

040218 - 11

040218 - 12
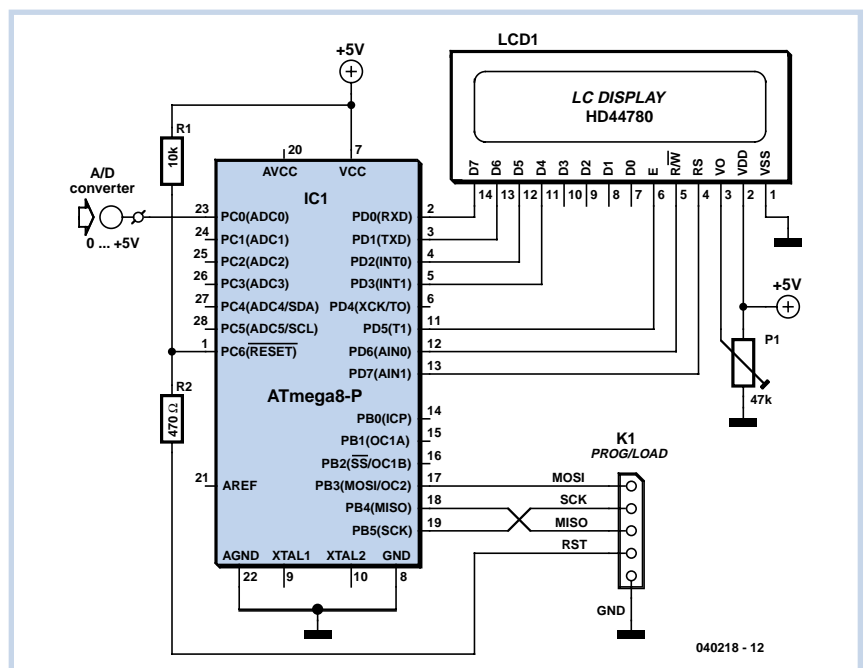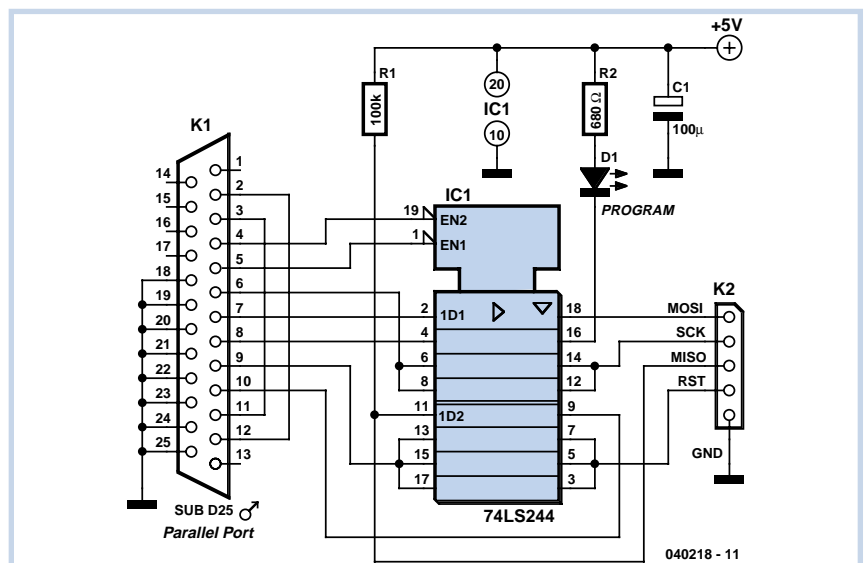
Procyon AVRlib
(examples and libraries):
http://hubbard.engr.scu.edu/
embedded/avr/avrlib/index.html

JTAG-Hardware:
http://avr.openchip.org/bootice
WinAVR:
http://winavr.sourceforge.net

Energy-saving Switch

Helmut Kraus

Lights do not always need to be on at full power. Often it would be useful to be able to turn off the more powerful lights to achieve softer illumination, but this requires an installation with two separately-switchable circuits, which is not always available.

If the effort of chasing out channels and replastering for a complete new circuit is too much, then this circuit might help. Normal operation of the light switch gives gentle illumination (LA1). For more light, simply turn the switch off and then immediately (within 1 s) on again. The circuit returns to the gentle light setting when switched off for more than 3 s. There is no need to replace the light switch with a dual version: simply insert this circuit between switch and lamp.

How does it work? Almost immediately after switch-on, fast-acting miniature relay RE2 pulls in, since it is connected directly after the bridge rectifier. Its normally-closed contact then isolates RE1 from the supply, and thus current flows to LA1 via RE1's normally-closed contact. RE1 does not have time to pull in as it is a power relay and thus relatively slow. Its response is also slowed down by the time constant of R1 and C1. If the current through the light switch is briefly interrupted, RE2 drops out immediately. There is enough energy stored in C1 to activate RE1, which then holds itself pulled in via a second, normally-open, contact. If current starts to flow again through the light switch within 1 s, LA2 will light. To switch LA1 back on it is necessary to turn the light switch off for more than 3 s, so that C1 can discharge via R2 and RE1. The printed circuit board can be built into a well insulating plastic enclosure or be incorporated into a light fitting if there is sufficient space.

(040159-1)
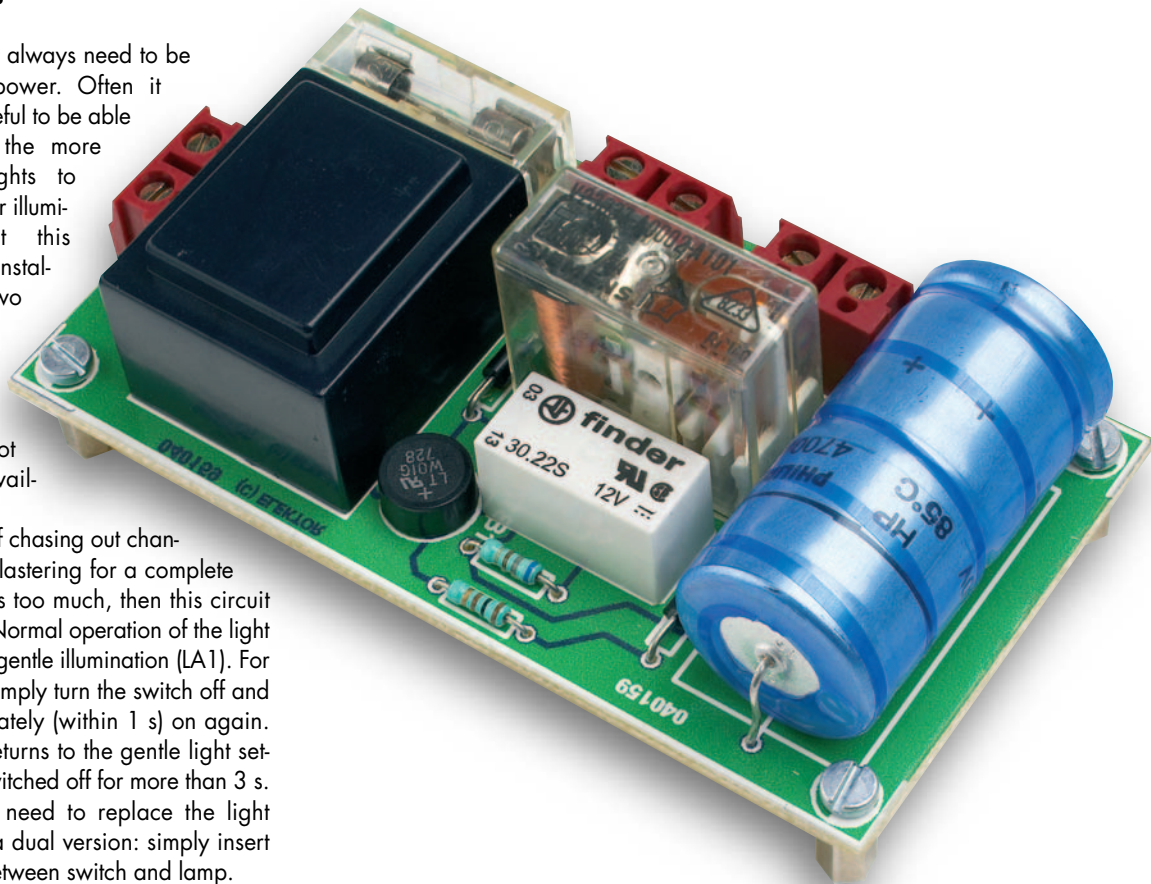
Caution:
the printed circuit board is connected directly to the mains-powered lighting circuit. Every precaution must be taken to prevent touching any component or tracks, which carry dangerous voltages. The circuit must be built into a well insulated ABS plastic enclosure.

040159 - 11
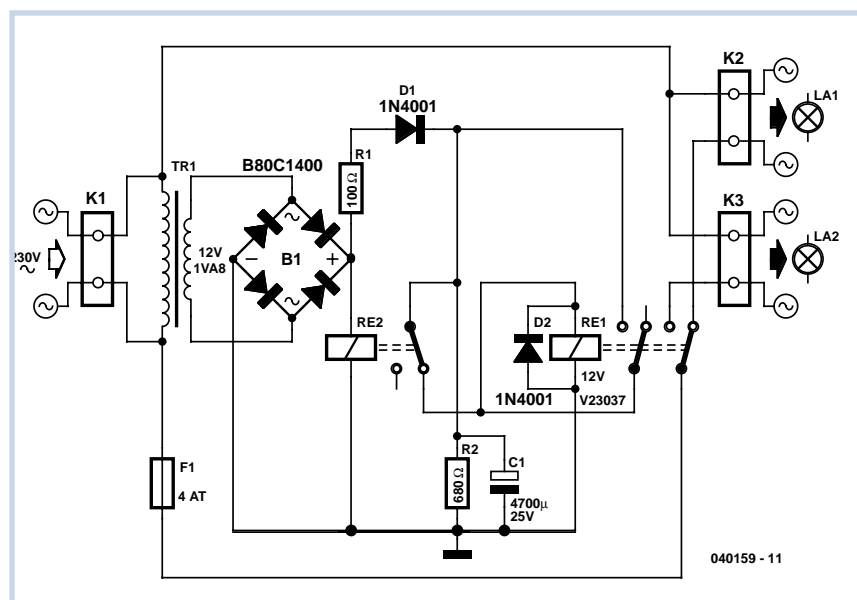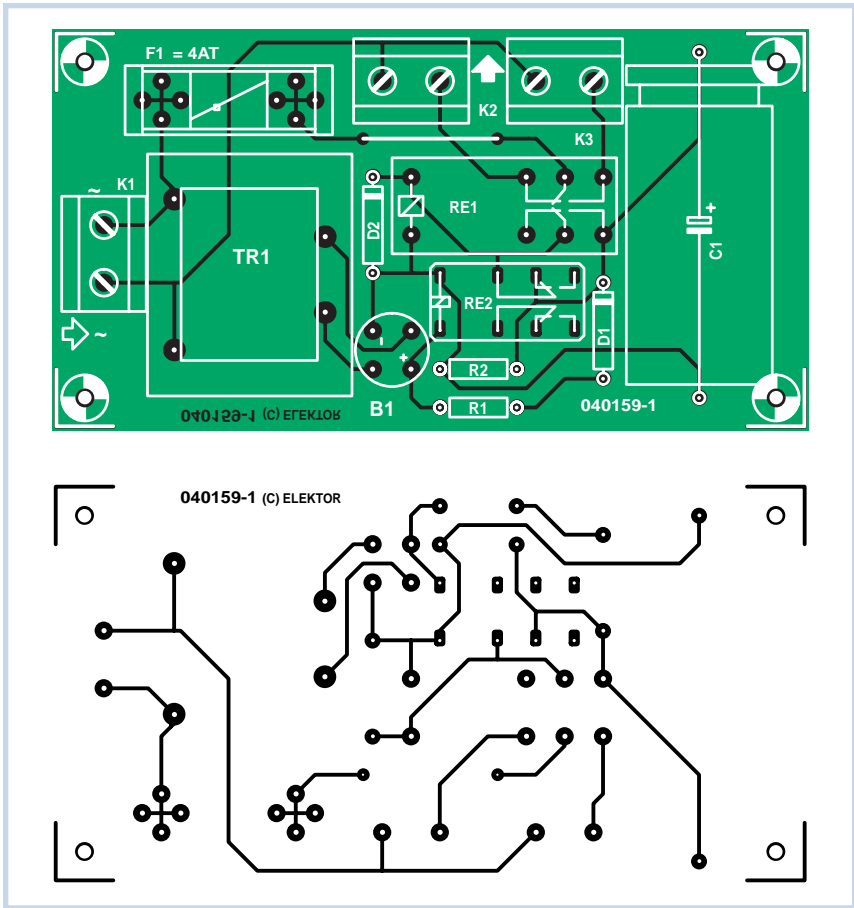
COMPONENTS LIST

Resistors:
R1 = 100Ω
R2 = 680Ω

Capacitor:
C1 = 4700µF 25 V

Semiconductors:
D1,D2 = 1N4001

Miscellaneous:
K1,K2,K3 = 2-way PCB terminal block, lead pitch 7.5 mm
F1 = fuse, 4AT (time lag) with PCB mount holder
TR1 = mains transformer, 12V @ 1.5 VA, short-circuit proof, PCB mount
B1 = B80C1400, round case (80V piv, 1.4A)
RE1 = power relay, 12V, 2 x c/o, PCB mount
RE2 = miniature relay, 12V, 2 x c/o, PCB mount

ELEKTOR	□
230V ~	50Hz
No. 040159	
F = 4A T	

Overcurrent Cutout Switches

008

Gregor Kleine

Overcurrent sensors using external low-resistance sense resistors are fairly common. However, the members of a new family of ICs from Maxim (www.maxim-ic.com) feature an internal sensor resistor and a switch for disconnecting the load if the current limit is exceeded. The members of this IC family are listed in the table.

There are two sorts of overcurrent switches in the family. The types listed in the 'Latching' column store any occurrence of an overcurrent condition and indicate it at the FLAG output until they are switched off and then on again by a pulse on the ON input. The types in the 'Auto-Retry' column automatically attempt to reconnect the load after a delay time. When the delay time expires, they check whether an overcurrent recurs, and if necessary they immediately switch off again. The auto-retry types do not have a /FLAG output. They switch on for approximately 40 ms every 300 ms (typical) to measure
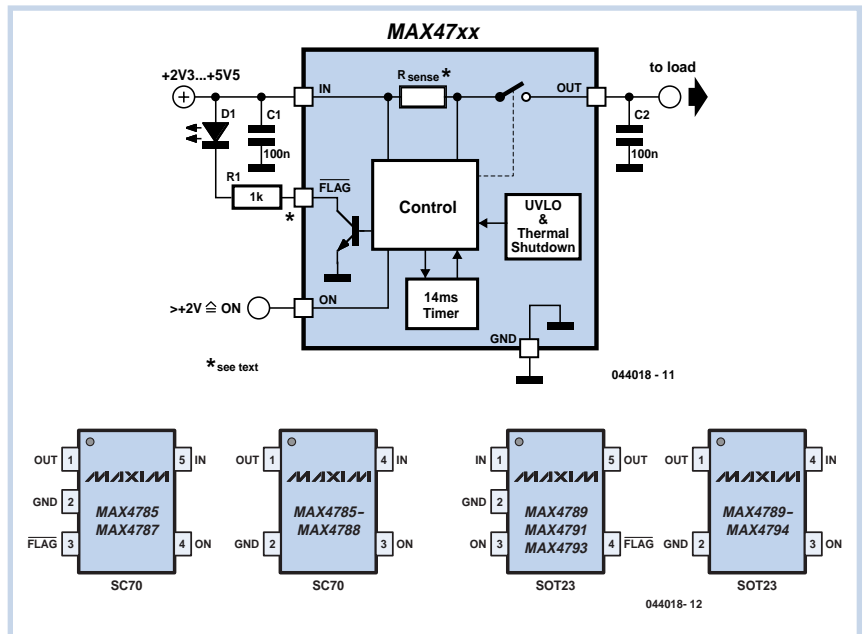
the current. During this 40-ms 'blanking time', the IC checks whether the current is less than the selected limit level. The latching types have the same time delay before

the switch opens and the FLAG output is asserted. The FLAG output can act as signal for a microcontroller or simply drive an LED. In the latter case, the input voltage

must be greater than the forward voltage of the LED. R1 must be dimensioned for the desired current through the LED. Capacitors C1 and C2 provide decoupling and prevent false triggering of the IC by spurious voltage spikes.

The MAX47xx family of ICs operates over a supply voltage range of +2.3–5.5 V. The ICs have undervoltage lockout (UVLO) and reliably switch off when the current exceeds the type-specific limit, even if the current flows in the reverse direction (from the load to the input). The table indicates the possible range of the overcurrent threshold for each type. For instance, a given MAX2791 might switch off at a current as low as 250 mA. However, other examples of the same type will not switch off until the current reaches 350 mA. The same threshold values

Latching	Auto-Retry	min. Limit	max. Limit	Package
MAX 4785	MAX 4786	50 mA	120 mA	SC70
MAX 4787	MAX 4788	100 mA	240 mA	SC70
MAX 4789	MAX 4790	200 mA	300 mA	SC70
MAX 4791	MAX 4792	250 mA	375 mA	SOT23/143
MAX 4793	MAX 4794	300 mA	450 mA	SOT23/143

apply to reverse currents. An overtemperature cutout circuit protects the IC against thermal destruction.

The latching types come in a 5-pin SMD package, while the auto-retry types without a /FLAG output manage with only four pins. The 50-mA and 100-mA versions fit into the tiny SC70 package. The types for higher current levels require an SOT23 or SOT143 package.

There are also other Maxim ICs with similar functions, such as the MAX4795–MAX4798 series with typical cutoff thresholds of 450 mA and 500 mA. Finally, there are the MAX4772 and MAX4773, which have a programmable threshold that can be set to 200 mA or 500 mA using a Select input. However, the IC types mentioned in this paragraph require a different circuit arrangement than what is shown here.

(044018-1)

009 Simple Oscillator / Pipe Locator

Rev. Thomas Scarborough

Sometimes the need arises to construct a really simple oscillator. This could hardly be simpler than the circuit shown here, which uses just three components, and offers five separate octaves, beginning around Middle C (Stage 14). Octave # 5 is missing, due to the famous (or infamous) missing Stage 11 of the 4060B IC. We might call this a Colpitts 'L' oscillator, without the 'C'. Due to the reactance of the 100-µH inductor and the propagation delay of the internal oscillator, oscillation is set up around 5 MHz. When this is divided down, Stage 14 approaches the

frequency of Middle C (Middle C = 261.626 Hz). Stages 13, 12, 10, and 9 provide higher octaves, with Stages 8 to 4 being in the region of ultrasound.

If the oscillator's output is taken to the aerial of a Medium Wave Radio, L1 may serve as the search coil of a Pipe Locator, with a range of about 50 mm. This is tuned by finding a suitable heterodyne (beat note) on the medium wave band. In that case, piezo sounder Bz1 is omitted. The Simple Oscillator / Pipe Locator draws around 7 mA from a 9-12 V DC source.

(040253-1)

040253 - 11
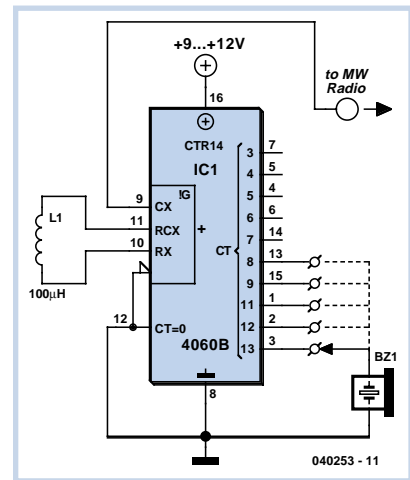
010 Audio Click/Pop Suppressor

Gregor Kleine

Audio amplifier circuits with a single supply voltage have output coupling capacitors that produce audible clicking or popping sounds when the supply voltage is switched on, since they must be initially charged to half the supply voltage. Similarly, a clicking or popping noise can be

produced by the discharge current when the supply is switched off. The capacitance (C_{out}) of the output capacitors cannot be reduced, since it determines the lower limit of the frequency range. The process of establishing the DC operating point in upstream amplifier stages also generates switch-on and switch-off noises. For headphone outputs in particular, this can be

remedied using an 8-pin IC from Maxim (www.maxim-ic.com), the MAX9890, which can be connected between the output stage and the output capacitors to suppress irritating clicks and pops.

The secret of the MAX9890 is that it changes the shape of the charging current for the output capacitors from an abrupt (and thus audible) step to an opti-

mised S-shaped curve that has such a low frequency that it does not produce any audible sound. After the capacitor has been charged, two integrated switches are enabled to connect the audio amplifier outputs to the already charged coupling capacitors. When the supply voltage is switched off, these switches open immediately and the coupling capacitors discharge slowly via internal 220-kΩ resistors. There is also an undervoltage detector that opens the switches if the supply voltage is less than +2.5 V. A shutdown input (/SHDN, pin 2) allows the headphone output to be selectively disabled. Inside the IC, the *Startup and Shutdown Control* section controls the switches and the *Ramp Up and Ramp Down Control* section controls capacitor charging and discharging.

Capacitor C_{EXT} generates a switching time delay after the supply voltage is applied. During the switch-off process, it powers the internal circuitry responsible for discharging the coupling capacitors. A 100-nF capacitor is adequate for this purpose.

The switch-on delay is 200 ms (MAX9890A) or 330 ms (MAX9890B). The A version is adequate for coupling capacitors up to 100 µF, with the B ver-

sion being preferred for capacitors up to 220 µF. With coupling capacitor values larger than this, switch-on noises may still be audible under certain conditions.
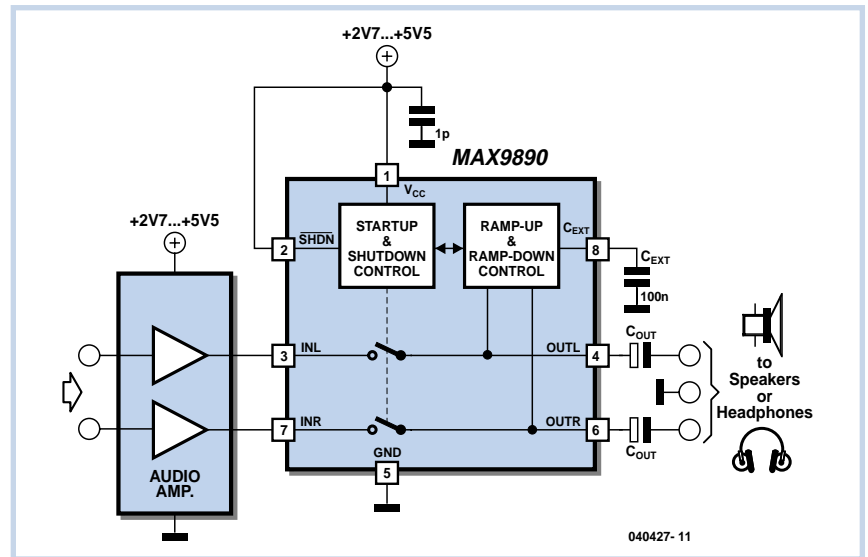
The MAX9890 operates over a supply voltage range of +2.7–5.5 V, draws only around 20 µA of current, and is specifically protected against electrostatic discharges up to ±8 kV. The input voltage on INL and INR must lie between 0 V and the supply voltage level. Click and pop suppression

is 36 dB. The additional distortion factor is specified by the manufacturer as 0.003 % (THD+N) for a 32-Ω headphone load. The power supply rejection ratio is typically 100 dB. The IC is available in two different SMD packages; the pinout shown here is for the TDFN package.

(040427-1)

http://pdfserv.maxim-ic.com/ en/ds/ MAX9890.pdf

IR Testing with a Digital Camera

011

Dirk Gehrke

If a device fails to respond to an IR remote control unit, the problem is often in the remote control, and it usually means that the batteries are dead. If the remotely controlled device still doesn't respond to the IR remote control after the batteries have been replaced, you're faced with the question of whether the remote control is not sending a signal or the device isn't receiving it properly. After checking for trivial errors, such as incorrectly fitted or defective batteries, the next thing you should check is whether the remote control transmits a signal. In the past, you would have needed an IR tester or a special IR detector card (as shown in the photo) for this. Nowadays you can use a digital camera (still or video), which is commonly available in most households. That's because the CCD chip is sensitive to infrared as well as visible light, which allows pictures to be taken at night to a certain extent.

If you switch on the camera and the dis-

play, aim the remote control unit toward the camera, and press one of the buttons on the remote control, you should see a blinking light coming from the IR

LED. If the LED remains dark, you can safely assume that the remote control unit is defective.

(040446-1)

Proximity Switch

Rev. Thomas Scarborough

This circuit is for an unusually sensitive and stable proximity alarm which may be built at very low cost. If the negative terminal is grounded, it will detect the presence of a hand at more than 200mm. If it is *not* grounded, this range is reduced to about one-third. The Proximity Switch emits a loud, falling siren when a body is detected within its range.

A wide range of metal objects may be used for the sensor, including a metal plate, a doorknob, tin foil, a set of burglar bars — even a complete bicycle. Not only this, but any metal object which comes within range of the sensor, itself becomes a sensor. For example, if a tin foil sensor is mounted underneath a table, metal items on top of the table, such as cutlery, or a dinner service, become sensors themselves.

The touch plate connected to the free end of R1 detects the electric field surrounding the human body, and this is of a relatively constant value and can therefore be reliably picked up. R1 is not strictly necessary, but serves as some measure of protection against static charge on the body if the sensor should be touched directly.

As a body approaches the sensor, the value of C1 effectively increases, causing
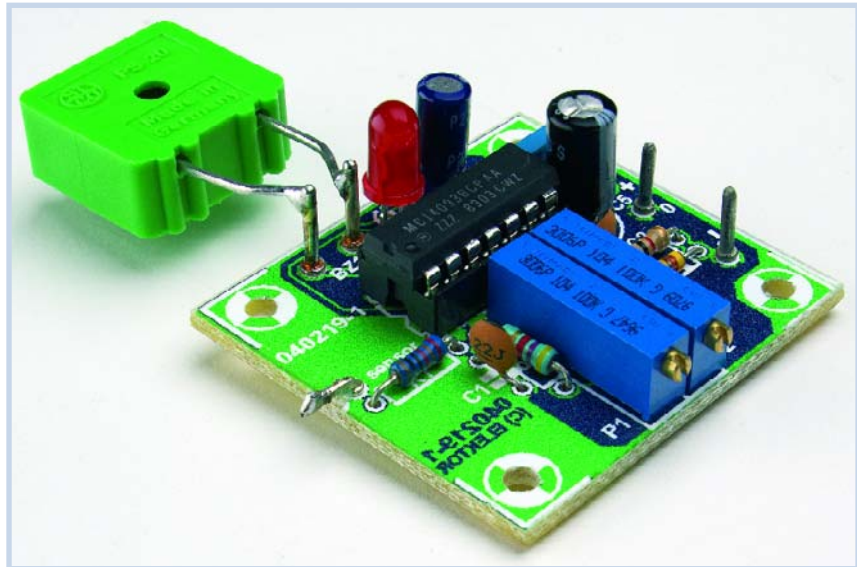
the frequency of oscillator IC1.A to drop. Consequently capacitor C2 has more time to discharge through P2, with the result that the inputs at IC1.B go Low, and the output goes High. As the output goes High, so C3 is charged through LED D2. D2 serves a dual purpose —namely as a visual indication of detection, and to

lower the maximum charge on C3, thus facilitating a sharper distinction between High and Low states of capacitor C3. The value of R4 is chosen to enable C3 to discharge relatively quickly as pulses through D2 are no longer sufficient to maintain its charge. The value of C3 may be increased for a longer sounding of the

COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2 = 4kΩ7
R3 = 1kΩ
R4 = 47kΩ
R5 = 47kΩ
P1,P2 = 100kΩ multiturn cermet, horizontal

Capacitors:
C1,C2 = 22pF
C3 = 22µF 40V radial
C4 = 10nF
C5 = 100µF 25V radial

Semiconductors:
D1 = 1N4148
D2 = LED, red
IC1 = 4093

Miscellaneous:
BZ1 = AC buzzer
PCB, ref. 040219-1, from The PCBShop
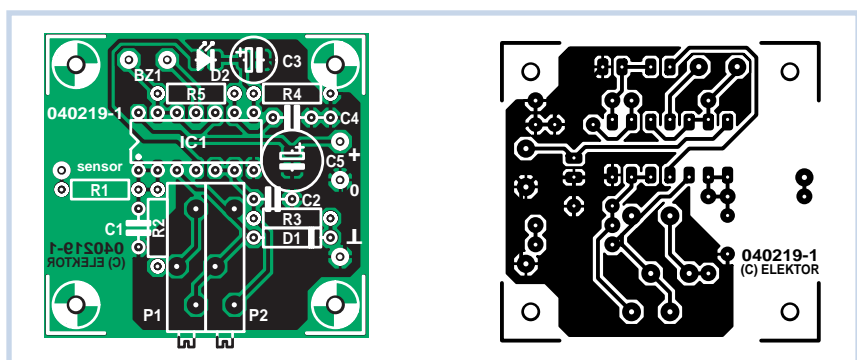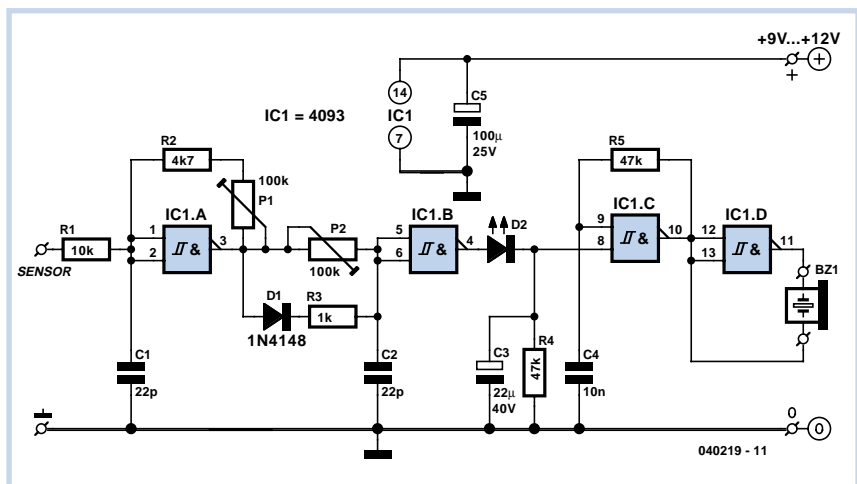
siren, with a slight reduction in responsiveness at the sensor. When C3 goes High, this triggers siren IC1.C and IC1.D. The two NAND gates drive piezo sounder X1 in push-pull fashion, thereby greatly increasing its volume. If a piezo tweeter is used here, the volume will be sufficient to make one's ears sing.

The current consumption of the circuit is so low a small 9-V alkaline PP3 battery would last for about one month. As battery voltage falls, so sensitivity drops off slightly, with the result that P1 may require occasional readjustment to maintain maximum sensitivity. On the down side of low cost, the hysteresis properties of the 4093 used in the circuit are critical to operation, adjustment and stability of the detector. In some cases, particularly with extremely high sensitivity settings, it will be found that the circuit is best powered from a *regulated* voltage source. The PCB has an extra ground terminal to enable it to be easily connected to a large earthing system. Current consumption was measured at 3.5 mA stand-by or 7 mA with the buzzer activated.

Usually, only P1 will require adjustment. P2 is used in place of a standard resistor in order to match temperature coefficients, and thus to enhance stability. P2 should be adjusted to around 50 k, and left that that setting. The circuit is ideally adjusted so that D2 ceases to light when no body is near the sensor. Multiturn presets *must* be used for P1 and P2.

Since the piezo sounder is the part of the circuit which is least affected by body presence, a switch may be inserted in one of its leads to switch the alarm on and off after D2 has been used to check adjustment. Make sure that there is a secure connection between the circuit and any metal sensor which is used.

(040219-1)

Discharge Circuit

Gregor Kleine

The author encountered a problem with a microcontroller system in which the +5-V supply voltage did not decay to 0 V sufficiently quickly after being switched off. A certain residual voltage remained, and it declined only very slowly. As a result, certain system components could not perform a clean reset if the power was quickly switched on again.

To remedy this problem, a very simple circuit was used to discharge the +5-V supply. It consists of two resistors and a type Si9945 dual MOSFET from Vishay Siliconix (www.vishay.com/mosfets). These MOSFETs switch fully on at a threshold gate voltage between +1 V and +3 V. MOSFET T2 connects discharge resistor R2 for the +5-V supply line to ground if the voltage on its gate exceeds the threshold voltage.

When the +5-V supply is switched off, the first MOSFET (T1), whose gate is connected to the +5-V supply voltage, no longer connects pull-up resistor R1 to ground, so the standby voltage is applied to the gate of T2 via R1. This requires the standby voltage to remain available for at least as long as it takes to discharge the +5-V supply, even when the system is switched off.

R2 is dimensioned to avoid exceeding the 0.25-W continuous power rating of a type 1206 SMD resistor. It may be necessary to change the component value for use in other applications.

The circuit can be constructed very compactly, since the dual MOSFET is housed in an SO8 SMD package, but it can also be built using 'ordinary' individual FETs, such as the BS170.
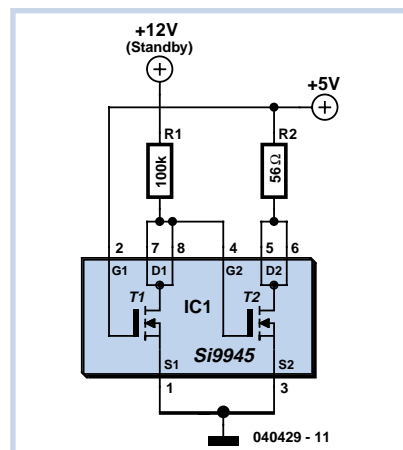
(040429-1)

http://www.vishay.com/doc?70758

040429 - 11

Gentle Battery Regulator

Wolfgang Zeiller

This small but very effective circuit protects a lead-acid battery (12-V solar battery or car battery) against overcharging by a solar module when the incident light is too bright or lasts too long. It does so by energising a fan, starting at a low speed when the voltage is approximately 13.8 V and rising to full speed when the voltage exceeds 14.4 V (full-charge voltage). The threshold voltage (13.8 V) is the sum of the Zener diode voltage (12 V), the voltage across the IR diode (1.1 V), and the base-emitter voltage of the 2N3055 (0.7 V).

In contrast to circuits using relays or IC amplifiers, the circuit has a gradual switching characteristic, which avoids relay chatter and the constant switching on and off near the switching point produced by a 'hard' switching point. The circuit does not draw any current at all (auto power-off) below 13 V.

Pay attention to the polarisation of the Zener and IR diodes when building the circuit. The transistor must be fitted to a heat sink, since it becomes hot when the fan is not fully energised (at voltages just below 14 V). A galvanised bracket from a DIY shop forms an adequate heat sink. The indicated component values are for

a 10-W solar module. If a higher-power module is used, a motor with higher rated power must also be used. The circuit takes advantage of the positive temperature coefficient of the lamp filament. The filament resistance is low at low voltages and increases as the voltage rises. This reduces the speed of the fan to avoid generating an annoying noise level. The lamp also provides a form of finger protection. If you stick your finger into the fan blade, the lamp immediately takes over the majority of the power dissipation and lights brightly. This considerably reduces the torque of the fan. An ordinary 10-W or 20-W car headlight (or two 25-W headlights in parallel) can be used for the lamp.
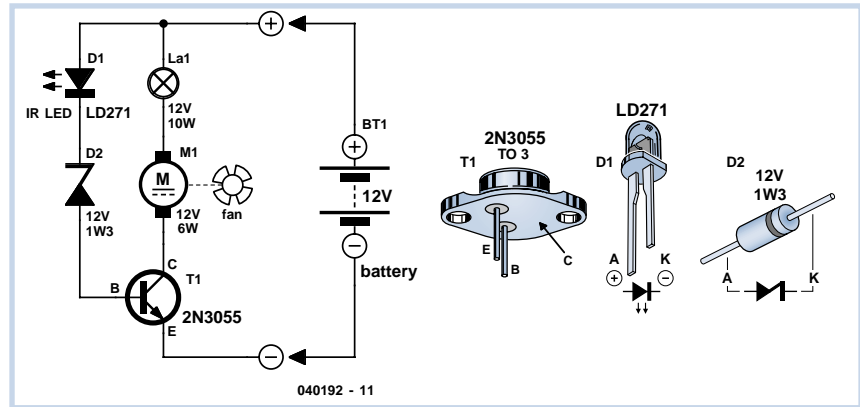
040192 - 11

Don't try to replace the LED by two 1N4001 diodes or the like, replace the ZPY12 by a ZPY13, or fit a series resistor for the LED. That would make the 'on' region too large.

(040192-1)

Telephone Line Watchdog

Dick Sleeman

Circuits have been published on earlier occasions that keep an eye on the telephone line. This simple circuit does it with very few components and is completely passive.

The operating principle is simplicity itself. The circuit is connected in series with one of the two signal lines. It does not matter which one of these two is used. When the telephone receiver is lifted off the hook, or the modem makes a connection, a voltage will appear across the four diodes. This voltage is used to drive the duoLED. Depending on the direction of the current,

either the red or the green part of the duoLED will light up.

In some countries, the polarity of the telephone line voltage is reversed after a few seconds. This does not matter with this circuit since a duoLED has been used.

Depending on the polarity of the line, the current will flow through either one branch or the other. The 22-Ω resistor is used as a current limiter, so that both colours are about the same brightness.

The duoLED can be ordered from, among others, Conrad Electronics (part number 183652). You can, of course, also use another, similar LED. For the diodes use the ubiquitous 1N4148.

(040182-1)

040182 - 11
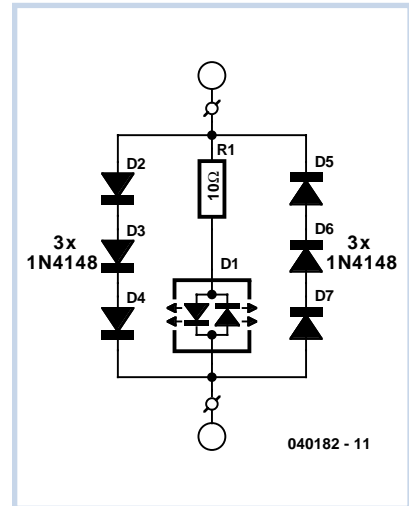
Comparing Signed Integers

Paul Goossens

Every once in a while it is necessary to compare two signed integers with each other. Unfortunately, some programming languages do not support signed integers. This problem presented itself with a design in Verilog. This language has a direct method of comparing two unsigned integers. With comparing we mean determining whether integer A is more than or

less then integer B, or equal.
After some thought for an efficient solution we found the following:
By inverting the MSB (Most Significant Bit) of both signed integers, both can be compared as unsigned integers with the correct result. "How can this be?", you will ask. The solution is simple.
The difference between an unsigned integer and a signed integer is that the MSB of an unsigned integer has a value of 2^n,

while that same MSB of a signed integer has the value -2^n. With positive numbers nothing special happens, that means, the value is the same whether they are treated as signed or unsigned. With a negative number (where the MSB=1 and is therefore significant) the value increases by $2*2^n$ (instead of -2^{n-1} the weight of the MSB becomes 2^{n-1}). By inverting the MSB, 2^{n-1} is added to both negative and positive numbers. A necessary condition is that the

MSB of a signed value is equal to '1' (thus indicating a negative value) and zero for an unsigned value. In this way the relative difference between the two numbers remains exactly the same. In the example you can see clearly that after the operation the value of each has been increased by exactly 128, provided they are both considered as unsigned integers. This is independent on whether the original integer was positive or negative. Now both numbers can be compared as unsigned integers with (of course) the correct result!

(054004-1)

Decimal value of bits within an 8-bit integer								
7	6	5	4	3	2	1	0	
−128	64	32	16	8	4	2	1	signed
128	64	32	16	8	4	2	1	unsigned

Example:
10011100 = signed −100
inverting MSB:
00011100 = unsigned 28
00001111 = signed 15
10001111 = signed 143

Resistor Colour Band Decoder

017

Carlos Alberto Gonzales

Despite claims to the contrary by the non-initiated, electronics is still very much an exact science, so unless your memory is rock-solid you can not afford to make a mistake in reading a resistor value from the colour bands found on the device. So why not use the computer for the job? The program supplied by the author comes as an Excel spreadsheet that does all the colour-to-value converting for you in response to a few mouse clicks.
The program is extremely simple to use. Just click on the various colours to put them on the virtual resistor. Check the colour band structure against the real resistor on a board, on the floor or in the 'spares allsorts' drawer. The window below the colour bands will indicate the resistor's E series, nominal, high/low values and tolerance. The program supports the E6 and E12 through E192 series.

The program may be obtained free of charge from www.elektor-electronics.co.uk as archive file **040203-11.zip** (July/August 2005).

(040203-1)
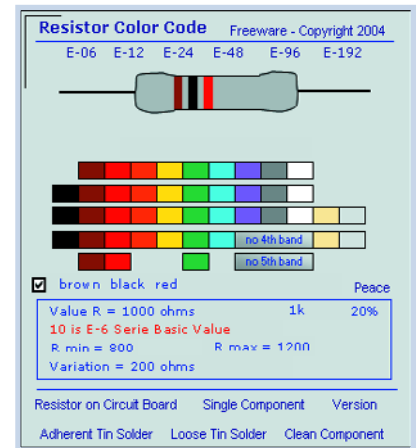
MSP430 Programmer

018

Dirk Gehrke

For many applications, programming a microcontroller after it has been soldered to the circuit board in the target application is more convenient than using a separate programmer. With the Texas Instruments MSP430F11x1, this can be done quite easily using the JTAG pins.
The Flash Emulation Kit makes it very easy to develop programs for the MSP430, debug the programs and program them into the microcontroller. However, prototype testing usually reveals a need for minor improvements to the software. The MSP430 has a JTAG port that can be enabled by applying a High level to the
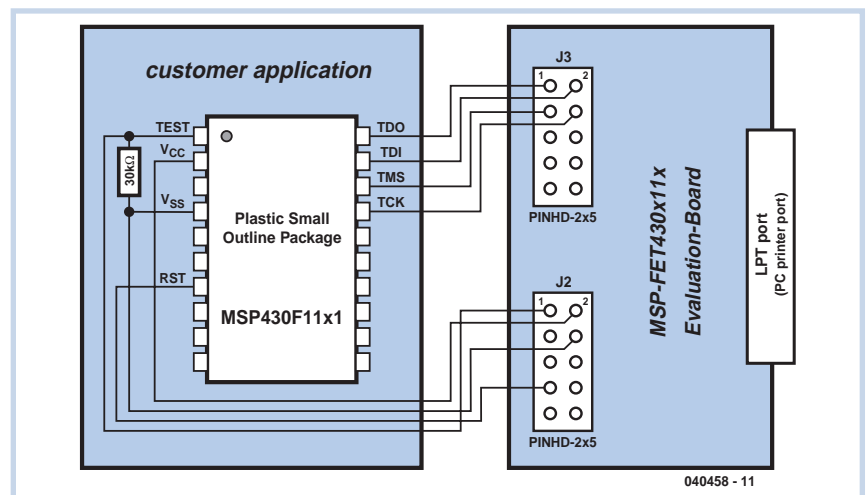
TEST pin. The registers, RAM and Flash memory can be read and written via this interface. Naturally, this feature can also be used in the target application. However, it's important to bear in mind that the associated pins have dual functions. For in-circuit programming, you will need a 20-way SOJ test clip (available from 3M, for example) that can grip the pins of the SO IC package in the soldered-in state. A total of eight pins must be connected to the Flash Emulation Kit to allow the microcontroller to be programmed.

It's important to ensure that a High level is applied to the /RST pin for the duration of the programming process, and a supplementary 30-kΩ resistor must be connected to the TEST pin to ensure a well-defined Low level.

(040458-1)

References and software

[I] IAR Embedded Workbench Kickstart Version 3 Rev. D
Document ID: slac050d.zip

[2] MSP430F11X(1) Flash Emulation Tool (US $49)

[3] MSP-FET430 Flash Emulation Tool [http://focus.ti.com/lit/ug/slau138a/slau138a.pdf]

[4] http://www.msp430.com

019

Micropower Voltage Regulator

Reinhold Oesterhaus

This circuit was developed to power an AVR microcontroller from a 12 V lead-acid battery. The regulator itself draws only 14 µA. Of course, there are dedicated ICs, for example from Linear Technology or Maxim, which can be used, but these can be very hard to get hold of and are frequently only available in SMD packages these days. These difficulties are simply and quickly avoided using this discrete circuit.

The series regulator component is the widely-available type BS170 FET. When power is applied it is driven on via R1. When the output voltage reaches 5.1 V, T2 starts to conduct and limits any further rise in the output voltage by pulling down the voltage on the gate of T1. The output voltage can be calculated as follows:

$$U_{OUT} = (U_{LED} + U_{BE}) \times (R4 + R2) / R4$$

where we can set U_{LED} at 1.6 V and U_{BE} at 0.5 V. The temperature coefficients of U_{LED} and U_{BE} can also be incorporated into the formula.

The circuit is so simple that of course someone has thought of it before. The author's efforts have turned up an example in a collection of reference circuits dating from 1967: the example is very similar to this circuit, although it used germanium transistors and of course there was no FET. The voltage reference was a Zener diode, and the circuit was designed for currents of up to 10 A. Perhaps *Elektor Electronics* readers will be able to find even earlier examples of two-transistor regulators using this principle?

(050061-1)

050061 - 11

020
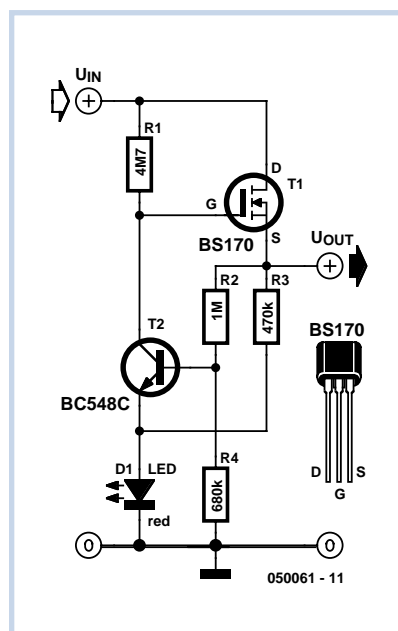
Garage Timer

Daniel Lomitzky and Mikolajczak Tyrone

The circuit described here is a testament to the ingenuity of two young designers from a specialist technical secondary school. The 'garage timer' began as a school electronics project and has now made it all the way to publication in our Summer Circuits special issue of *Elektor Electronics*. The circuit demonstrates that the application possibilities for the 555 and 556 timer ICs are by no means exhausted. So what exactly is a 'garage timer'?

When the light switch in the garage is pressed, the light in the garage comes on for two minutes. Also, one minute and forty-five seconds after the switch is pressed, the outside light also comes on for a period of one minute. The timer circuit is thus really two separate timers. Although the circuit for the interior light timer is relatively straightforward, the exterior light timer has to deal with two time intervals. First the 105 second period must expire; then the exterior light is switched on, and after a further 60 seconds the light is turned off. To realise this

sequence of events, a type 556 dual timer device, a derivative of the 555, is used. The first of the two timers triggers the second after a period of 105 seconds. The second timer is then active for 60 seconds, and it is this timer that controls the exterior light. The interior light timer is triggered at the same moment as the dual timer. In this case a simple 555 suffices, with an output active for just two minutes from the time when the switch is pressed. Push-button S1 takes over the role of the wall-mounted light switch, while S2 is provided to allow power to be removed from

the whole circuit if necessary. The circuit could be used in any application where a process must be run for a set period after a certain delay has expired.

For the school project the two garage lights are simulated using two LEDs. This will present no obstacle to experienced hobbyists, who will be able to extend the circuit, for example using relays, to control proper lightbulbs. The principles of operation of type 555 and 556 timers have been described in detail previously in *Elektor Electronics*, but we shall say a few words about the functions of IC1a, IC1b and IC2. When S1 is pressed (assuming S2 is closed!) the trigger inputs of both IC1a and IC2 are shorted to ground, and so the voltage at these inputs (pins 6 and 2 respectively) falls to 0 V. The outputs of IC1a and IC2 then go to logic 1, and D2 (the interior light) illuminates.

Capacitors C1 and C8 now start to charge via P1 and R2, and R8 and P3 respectively. When the voltage on C8 reaches two thirds of the supply voltage, which happens after 120 seconds, the output of IC2, which is connected as a monostable multivibrator, goes low. D2 then goes out. This accounts for the interior light function.

Likewise, 105 seconds after S1 is closed, the voltage on C1 reaches two thirds of the supply voltage and the output of IC1a goes low. Thanks to C4, the trigger input of IC1b now receives a brief pulse to ground, exactly as IC1a was triggered by S1. The second monostable, formed by
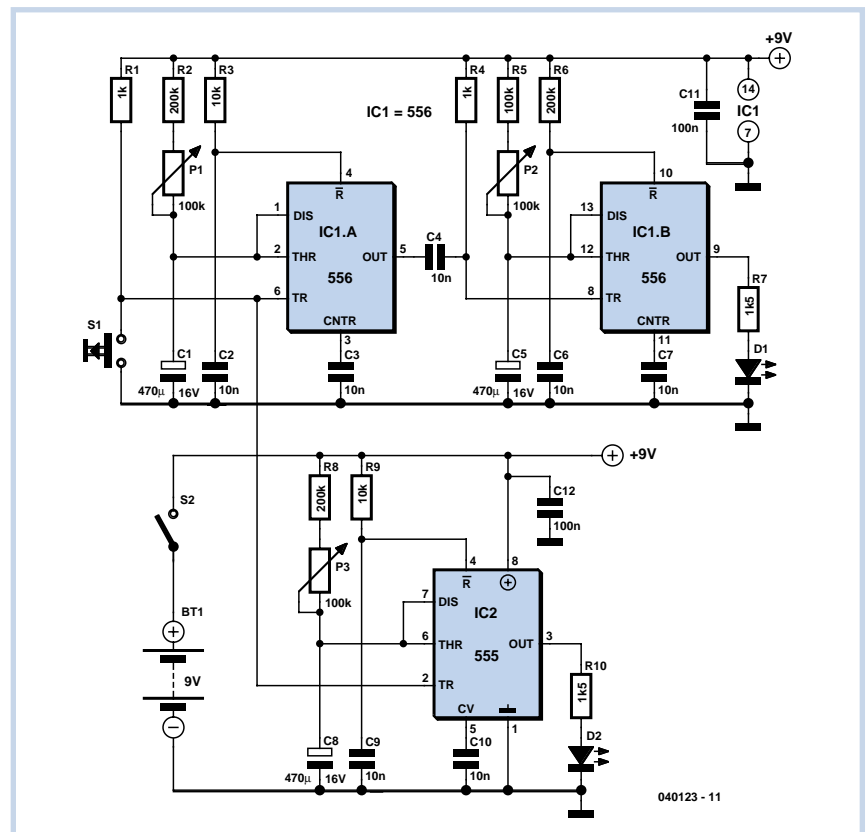
IC1b, is thus triggered. Its pulse duration is set at one minute, determined by C5, R5 and P2. D1 thus lights for one minute. Potentiometers P1, P2 and P3 allow the various time intervals to be adjusted to a certain extent. If considerably shorter or longer times are wanted, suitable changes should be made to the values of

C1, C5 and C8. The period of the monostable is given by the formula

$$T = 1.1\,RC$$

where T is the period in seconds, R the total resistance in ohms, and C the capacitance in farads.

(040123-1)

Negative-Output Switching Regulator

02

Gregor Kleine

There are only a limited number of switching regulators designed to generate negative output voltages. In many cases, it's thus necessary to use a switching regulator that was actually designed for a positive voltage in a modified circuit configuration that makes it suitable for generating a negative output voltage.

The circuit shown in **Figure 1** uses the familiar LM2575 step-down regulator
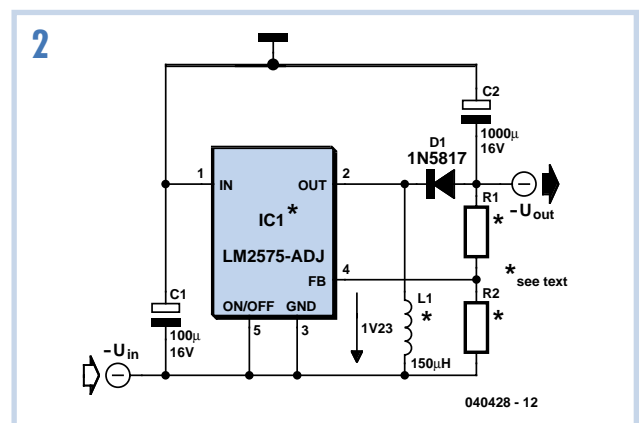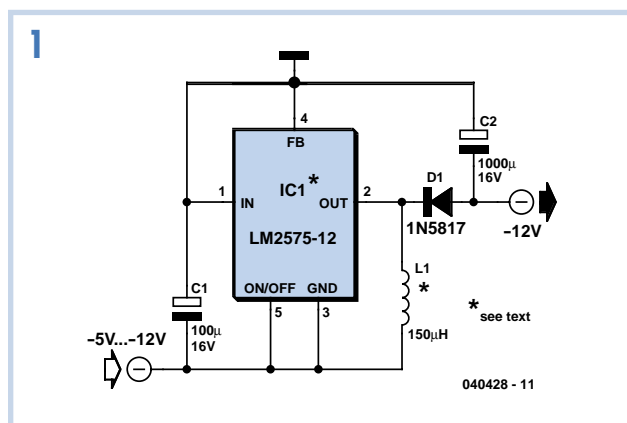
from National Semiconductor (www.national.com). This circuit converts a positive-voltage step-down regulator into a negative-voltage step-up regulator. It converts an input voltage between −5 V and −12 V into a regulated −12-V output voltage. Note that the output capacitor must be larger than in the standard circuit for a positive output voltage. The switched current through the storage choke is also somewhat higher. Some examples of suitable storage chokes for this circuit are the PE-53113 from Pulse (www.pulseeng.com) and the DO3308P-153 from Coilcraft (www.coilcraft.com). The LM2575-xx is available in versions for output voltages of 3.3V, 5 V, 12 V and 15 V, so various negative output volt-

ages are also possible. However, you must pay attention to the input voltage of the regulator circuit. If the input voltage is more negative than −12 V (i.e., V_{in} < −12 V), the output voltage will not be regulated and will be lower than the desired −12 V. The LM2575 IC will not be damaged by such operating conditions as long as its maximum rated input voltage of 40 V is not exceeded. High-voltage (HV) types that can withstand up to 60 V are also available.

Although the standard LM2575 application circuit includes circuit limiting, in this circuit the output current flows via the diode and choke if the output is shorted, so the circuit is not short-circuit proof. This can be remedied by using a Multifuse

(PTC) or a normal fuse.

There is also an adjustable version of the regulator with the type designation LM2575-ADJ (**Figure 2**). This version lacks the internal voltage divider of the fixed-voltage versions, so an external voltage divider must be connected to the feedback (FB) pin. The voltage divider must be dimensioned to produce a voltage of 1.23 V at the FB pin with the desired output voltage. The formula for calculating the output voltage is:

$$V_{out} = 1.23 \text{ V} \times (1 + [R1 \div R2])$$

The electrolytic capacitors at the input and output must be rated for the voltages present at these locations.

(040428-1)

Converting a DCM Motor

Karel Walraven

We recently bought a train set made by a renowned company and just couldn't resist looking inside the locomotive. Although it did have an electronic decoder, the DCM motor was already available 35 (!) years ago. It is most likely that this motor is used due to financial constraints, because Märklin (as you probably guessed) also has a modern 5-pole motor as part of its range. Incidentally, they have recently introduced a brushless model.

The DCM motor used in our locomotive is still an old-fashioned 3-pole series motor with an electromagnet to provide motive power. The new 5-pole motor has a permanent magnet. We therefore wondered if we couldn't improve the driving characteristics if we powered the field winding separately, using a bridge rectifier and a 27 Ω current limiting resistor. This would effectively create a permanent magnet.

The result was that the driving characteristics improved at lower speeds, but the initial acceleration remained the same. But a constant 0.5 A flows through the winding, which seems wasteful of the (limited) track power. A small circuit can reduce this current to less than half, making this technique more acceptable.

The field winding has to be disconnected from the rest (3 wires). A freewheeling diode (D1, Schottky) is then connected across the whole winding. The centre tap of the winding is no longer used. When FET T1 turns on, the current through the

054007 - 11
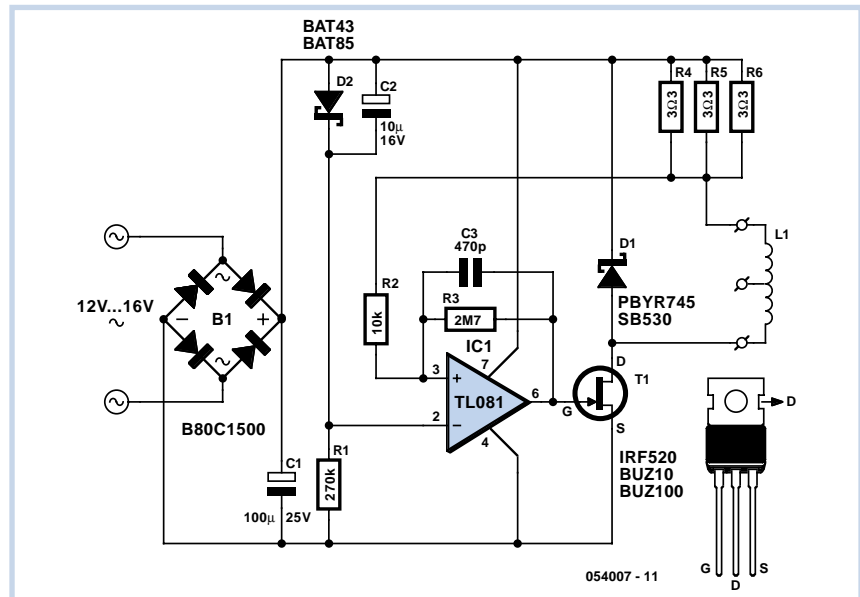
winding increases from zero until it reaches about 0.5 A. At this current the voltage drop across R4-R7 becomes greater than the reference voltage across D2 and the opamp will turn off the FET. The current through the winding continues flowing via D1, gradually reducing in strength. When the current has fallen about 10% (due to hysteresis caused by R3), IC1 will turn on T1 again. The current will increase again to 0.5 A and the FET is turned off again. This goes on continuously.

The current through the field winding is fairly constant, creating a good imitation of a permanent magnet. The nice thing about this circuit is that the total current

consumption is only about 0.2 A, whereas the current flow through the winding is a continuous 0.5 A.

We made this modification because we wanted to convert the locomotive for use with a DCC decoder. A new controller is needed in any case, because the polarity on the rotor winding has to be reversed to change its direction of rotation. In the original motor this was done by using the other half of the winding.

There is also a good non-electrical alternative: put a permanent magnet in the motor. But we didn't have a suitable magnet, whereas all electronic parts could be picked straight from the spares box.

(054007-1)

Phantom Supply from Batteries

Ton Giesberts

Professional (directional) microphones often require a phantom supply of 48 V. This is fed via the signal lines to the microphone and has to be of a high quality. A portable supply can be made with 32 AA-cells in series, but that isn't very user friendly. This circuit requires just four AA-cells (or five rechargeable 1.2 V cells).

We decided to use a standard push-pull converter, which is easy to drive and which has a predictable output voltage. Another advantage is that no complex feedback mechanism is required.

For the design of the circuit we start with the assumption that we have a fresh set of batteries. We then induce a voltage in the secondary winding that is a bit higher than we need, so that we'll still have a high enough voltage to drive the linear voltage regulator when the battery voltage starts to drop (refer to the circuit in **Figure 1**).

T1 are T2 are turned on and off by an astable multivibrator. We've used a 4047 low-power multivibrator for this, which has been configured to run in an astable free-running mode. The complementary Q outputs have a guaranteed duty-cycle of 50%, thereby preventing a DC current from flowing through the transformer. The core could otherwise become saturated, which results in a short-circuit between 6 V and ground. This could be fatal for the FETs.

The oscillator is set by R1/C1 to run at a frequency of about 80 kHz. R2/R3 and D1/D2 make T1 and T2 conduct a little later and turn off a little faster, guaranteeing a dead-time and avoiding a short-cir-

cuit situation. We measured the on-resistance of the BS170 and found it was only 0.5 Ω, which isn't bad for this type of FET. You can of course use other FETs, as long as they have a low on-resistance.

For the transformer we used a somewhat larger toroidal core with a high A_L factor. This not only reduces the leakage inductance, but it also keeps the number of windings small. Our final choice was a TX25/15/10-3E5 made by Ferroxcube, which has dimensions of about 25x10 mm. This makes the construction of the transformer a lot easier. The secondary winding is wound first: 77 turns of a 0.5 mm dia. enamelled copper wire (ECW). If you wind this carefully you'll find that it fits on one layer and that 3 meters is more than enough. The best way to keep the two primary windings identical

is to wind them at the same time. You should take two 30 cm lengths of 0.8 mm dia. ECW and wind these seven times round the core, on the opposite side to the secondary connections. The centre tap is made by connecting the inner two wires together. In this way we get two primary windings of seven turns each.

The output voltage of TR1 is rectified by a full-wave rectifier, which is made with fast diodes due to the high frequency involved. C4 suppresses the worst of the RF noise and this is followed by an extra filter (L1/C5/C6) that reduces the remaining ripple. The output provides a clean voltage to regulator IC2. It is best to use an LM317HV for the regulator, since it has been designed to cope with a higher voltage between the input and output. The LM317 that we used in our prototype

1

054024 - 11
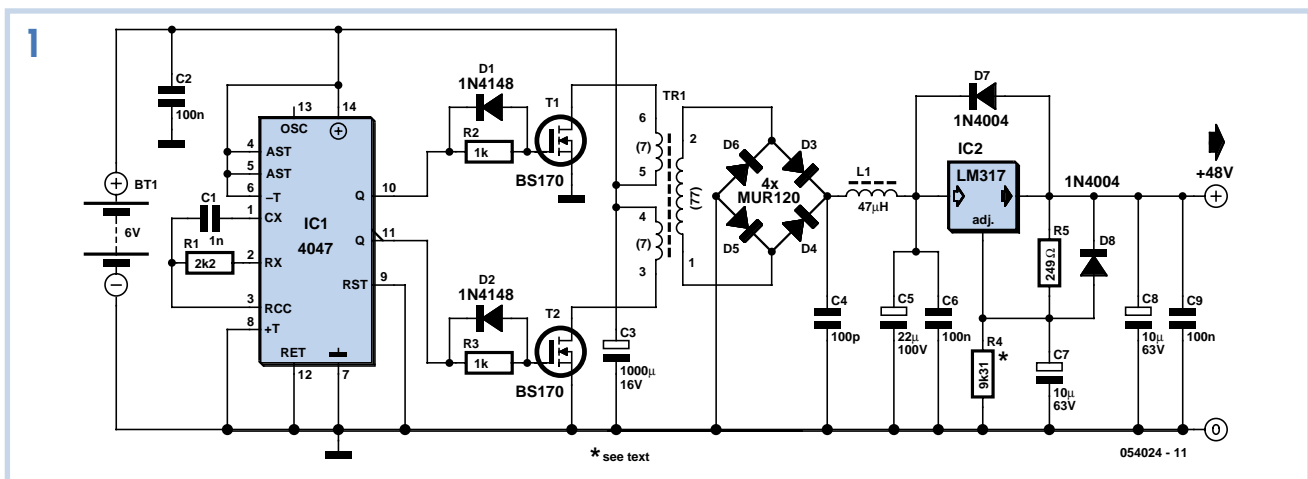
worked all right, but it wouldn't have been happy with a short at the output since the voltage drop would then be greater than the permitted 40 V. If you ensure that a short cannot occur, through the use of the usual 6k81 resistors in the signal lines, then the current drawn per microphone will never exceed 14 mA and you can still use an ordinary LM317. D7 and D8 protect the LM317 from a short at the input.

There is virtually no ripple to speak of. Any remaining noise lies above 160 kHz, and this won't be a problem in most applications.

The circuit can provide enough current to power three microphones at the same time (although that may depend on the types used). When the input voltage dropped to 5.1 V the current consumption was about 270 mA. The reference volt-

age sometimes deviates a little from its correct value. In that case you should adjust R4 to make the output voltage equal to 48 V. The equation for this is: R4 = (48–V_{ref}) / (V_{ref} / R5+50µA).

To minimise interference (remember that we're dealing with a switched-mode supply) this circuit should be housed in an earthed metal enclosure.

(054024-1)

Simple Short-Circuit Detection

024

Karel Walraven

This circuit is suitable in every situation where over-current protection is required. Here we give an example from the model train world.

Every seasoned model train enthusiast knows that there is nothing worse than having to find the cause of a short-circuit. On a small model railway with one locomotive it is obviously fairly easy, but on large layouts all locomotives stand still when there is a short and then you have to check each one in turn to find the culprit. If the track is divided into sections then we can use this super simple circuit to make our lives a lot easier.
A multifuse is inserted into one of the supply lines for each of the sections. (A multifuse is also called a multiswitch, polyfuse or polyswitch, depending on the manufacturer). This is a type of fuse that cools down and conducts normally again once the short has been removed.
The advantage is that only the section with the short becomes isolated. All the other locomotives in the other sections continue to move. The stationary locomotive is in principle the culprit, but it's quite likely that several locomotives aren't moving since not all of them would be travelling in the first place. For this reason we connect an LED indicator across each multifuse, making it clear which section caused the problem. You can choose any colour LED, but we recommend that you use low-current types that emit a lot of light at only a few mA. The value of the current limiting resistor may be changed to give an acceptable LED brightness.
As long as the current is small, the resistance of the multifuse is also low and there will barely be a voltage drop. At high cur-

054002 - 11
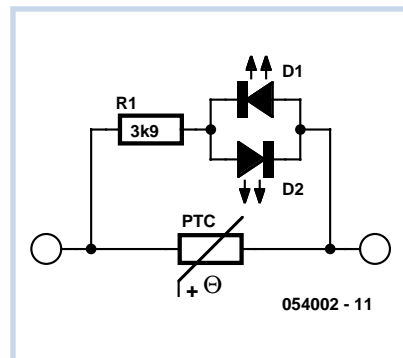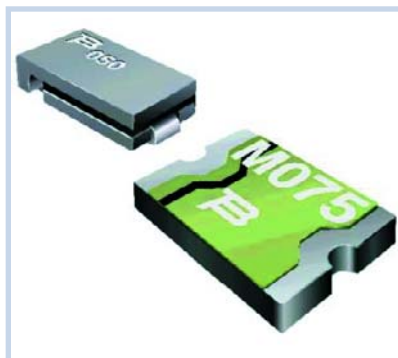
Model	V_{max} (V)	I_{hold}	I_{trip}	Initial resistance (Ω)		Max. time to trip	
				Min.	Max.	I (A)	t (s)
MF-R005	60	0.05	0.10	7.3	11.1	0.5	5.0
MF-R010	60	0.10	0.20	2.50	4.50	0.5	4.0
MF-R017	60	0.17	0.34	2.00	3.20	0.85	3.0
MF-R020	60	0.20	0.40	1.50	2.84	1.0	2.2
MF-R025	60	0.25	0.50	1.00	1.95	1.25	2.5
MF-R030	60	0.30	0.60	0.76	1.36	1.5	3.0
MF-R040	60	0.40	0.80	0.52	0.86	2.0	3.8
MF-R050	60	0.50	1.00	0.41	0.77	2.5	4.0
MF-R065	60	0.65	1.30	0.27	0.48	3.25	5.3
MF-R075	60	0.75	1.50	0.18	0.40	3.75	6.3
MF-R090	60	0.90	1.80	0.14	0.31	4.5	7.2
MF-R090-0-9	30	0.90	1.80	0.07	0.12	4.5	5.9
MF-R110	30	1.10	2.20	0.10	0.18	5.5	6.6
MF-R135	30	1.35	2.70	0.065	0.115	6.75	7.3
MF-R160	30	1.60	3.20	0.055	0.105	8.0	8.0
MF-R185	30	1.85	3.70	0.040	0.07	9.25	8.7
MF-R250	30	2.50	5.00	0.025	0.048	12.5	10.3

rents the resistance increases, which causes a voltage drop across the multifuse that is large enough to light up the LED. As we don't know the direction of the current flow (the train could be moving either forwards or backwards and digital controls use an alternating current) we connected two LEDs in parallel with opposite polarities.

Multifuses are available for many different trip currents. Choose a value that is slightly higher than the maximum current consumption of a locomotive in a section. The table below shows the characteristics of several types from the MF-R series made by Bourns. (Raychem is another well-known manufacturer of polyswitches.) I_{hold} is the current at which the multifuse still conducts normally, I_{trip} is the short-circuit current.

025

Reflection Light Barrier with Delay

Goswin Visschers

This circuit can be used to check, for example, whether the door of a refrigerator has been properly closed. An LED sends out a beam of light, which, if the door is closed, is reflected. An optical sensor (CNY70) then detects the amount of light. If the sensor does not receive the right amount of light, the buzzer will sound after about a minute. When the door is closed (and the CNY70 receives enough light again), the buzzer turns off.

The power supply for the circuit requires about 12 mA at 12 V. Potentiometer P1 adjusts the sensitivity of the sensor. The sensor works reliably from a distance of one centimetre. If the current through the LED is increased, the distance can be increased a little. The delay can be adjusted with C3. C4 provides extra filtering for the reference voltage. The
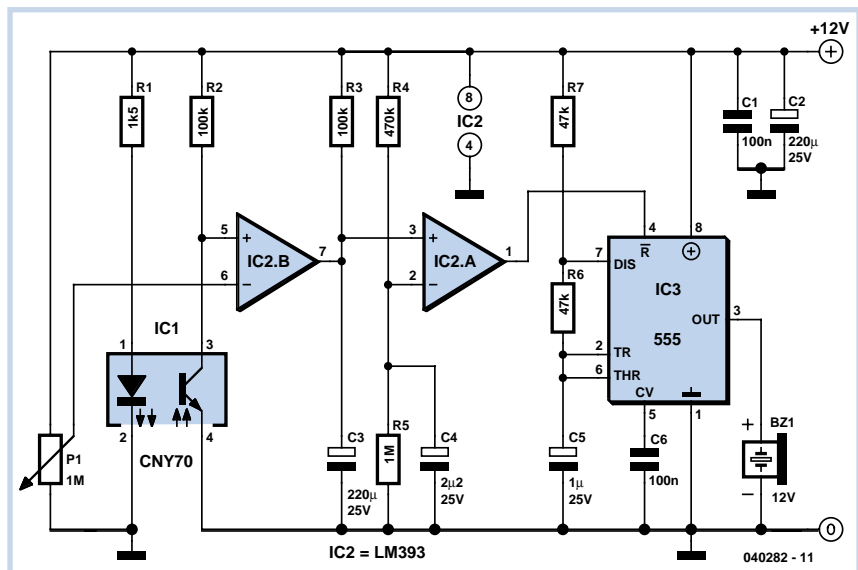
buzzer would otherwise switch on with a 'chirping' sound. The well-known NE555 is used to drive the buzzer. The buzzer is driven with a duty cycle of 2:1, which improves the audibility.

026

Swapping Without a Buffer

Paul Goossens

Most programmers will have their own library of commonly used snippets of code. One task that appears very often is the exchange of the contents of two variables. The code for this usually looks as follows:

```
int c;

c=a;
a=b;
b=c;
```

Table 1.

	A	B
initial state ⟹	10101010	11001100
A = A ^ B ⟹	01100110	11001100
B = A ^ B ⟹	01100110	10101010
A = A ^ B ⟹	11001100	10101010

There doesn't appear to be anything wrong with this, but it does make use of a third variable and this takes up more memory. In general, modern processors tend to have enough memory on board, but it never harms being economical with the available memory.

Another way in which the variables can be exchanged is shown below:

```
a=a^b;
b=a^b;
a=a^b;
```

It isn't immediately obvious that the contents of the two variables are exchanged.

However, the operation of this code is really quite simple.

We make use of the Boolean law that a^b^a = b, where the '^' symbol stands for a bitwise exclusive-or (XOR).

One consequence of this law is that when we know that the content of register A is the XOR of two variables, where the value of one is known, we can recover the value of the unknown variable by XORing register A with the known value. It shouldn't come of much of a surprise that many encryption systems make use

of this technique.

We can imagine that it may still not be clear how the XOR routine works, so we've shown in the **Table** what each step of the program does. It should now be clear that at the end of the code the contents of variables a and b have been exchanged. You could try this yourself with pen and paper. You'll find that it works with any values for a and b.

(054019-1)

Cable Tester

027

Uwe Reiser

Microcontroller-based circuits for testing cables, sometimes in conjunction with a PC, are easy to use and very flexible. For the hobbyist, however, the complication of such devices is not justified. The circuit described here is an economical, but nevertheless easy-to-understand tester for cables with up to ten conductors.

The basic idea for the cable tester is to apply a different voltage to each conductor in the cable at one end. The voltage seen at the other end of the cable is indicated by light-emitting diodes. The eight reference voltages are generated using a row of nine LEDs connected in series (D1 to D9). The first and and the tenth conductors are connected to the positive and negative terminals of the power supply respectively. The LEDs are powered from a constant current source, which allows us to dispense with the current-limiting series resistor that would otherwise be necessary. For the constant current source we use a type LM317 voltage regulator. R1 is selected using the formula

$$I_{const} = 1.25 \text{ V} / R1$$

to produce a current of 5 mA. This part of the circuit forms the transmitter end of the cable tester. The conductors of the cable under test can be connected to the transmitter in any order. The receiver consists of five LEDs whose connections are taken directly from terminal block X3. If the corresponding points in the two parts of the circuit are wired to one another using a working cable, all the LEDs on both receiver and transmitter sides will light. If there is a fault in the cable, the following situations are possible.

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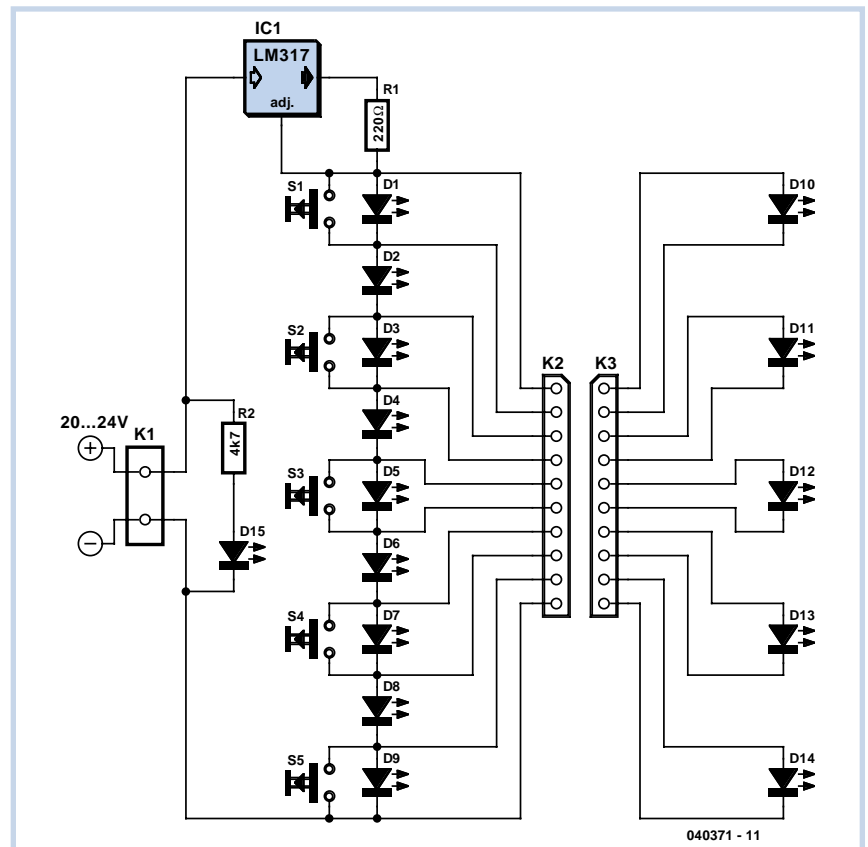
● Two LEDs opposite one another fail to light: two conductors are crossed or shorted.

● Only the LED on the transmitter side lights: one or both of the conductors in the pair is broken.

● One of the even-numbered LEDs on the transmitter side (D2, D4, D6 or D8) fails to light: there is a short between the outer conductors of the neighbouring pairs.

● Several neighbouring LEDs fail to light:

the conductor corresponding to the first unlit LED is crossed with the one corresponding to the last unlit LED, or they are shorted.

● If all LEDs light on both sides, there is still a chance that two pairs might be interchanged. Buttons S1 to S5 can be used to test this: the same LED should extinguish on each side when the button is pressed. If the wrong LED goes out on the receiver side, a pair must be swapped over.

More complicated effects can result from

combinations of these five faults.

Different colours of LED have different forward voltage drops, and so the same type of LED should be used throughout. The required current can be put into the formula to calculate R1, which can then be altered if necessary. Of course, these remarks do not apply to the power indicator LED (D15). The LM317 used for the constant current source can only deliver the calculated current if its input voltage is at least about 3 V higher than the voltage required at its output. The load voltage depends on the number of LEDs in the transmitter and on their forward voltage drop. For nine red LEDs at least 20 V is required.

(040371-1)

Burkhard Kainka

028 DRM Direct Mixer Using an EF95/6AK5

This hybrid DRM receiver with a single valve and a single transistor features good large-signal stability. The EP95 (US equivalent: 6AK5) acts as a mixer, with the oscillator signal being injected via the screen grid. The crystal oscillator is built around a single transistor. The entire circuit operates from a 6-V supply. The receiver achieves a signal-to-noise ratio of up to 24 dB for DRM signals. That means the valve can hold its own against an NE612 IC mixer.

The component values shown in the schematic have been selected for the RTL2 DRM channel at 5990 kHz. That allows an inexpensive 6-MHz crystal to be used. The input circuit is built using a fixed inductor. Two trimmer capacitors allow the antenna matching to be optimised. The operating point is set by the value of the cathode resistor. The grid bias and

input impedance can be increased by increasing the value of the cathode resistor. However, good results can also be achieved with the cathode connected directly to ground.

(050103-1)
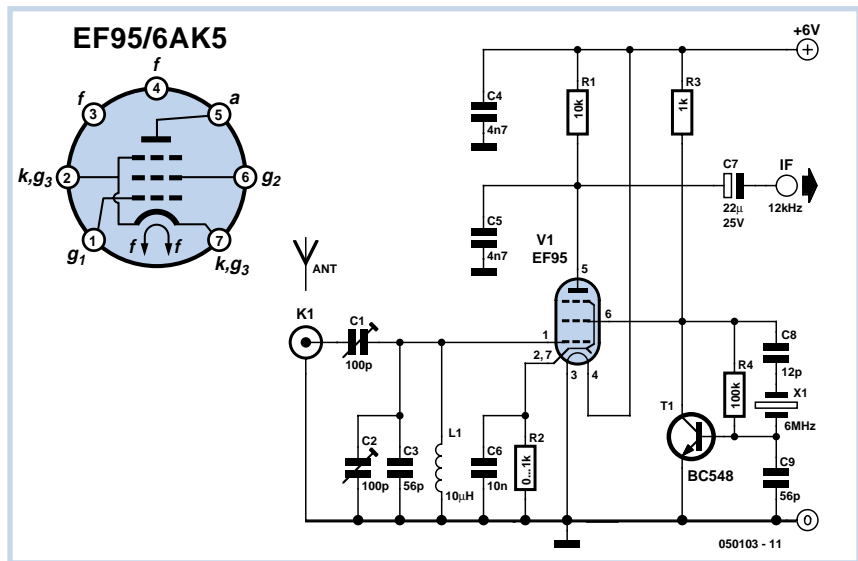
Wolfgang Zeiller

029 Two-Cell LED Torch

It sometimes comes as a bit of a shock the first time you need to replace the batteries in an LED torch and find that they are not the usual supermarket grade alkaline batteries but in fact expensive Lithium cells. The torch may have been a giveaway at an advertising promo but now you discover that the cost of a replacement battery is more than the torch is worth. Before you consign the torch to the waste bin take a look at this circuit. It uses a classic two-transistor astable multivibrator configuration to drive the LEDs via a transformer from two standard 1.5 V alka-

line batteries. The operating principle of the multivibrator has been well documented and with the components specified here it produces a square wave output with a frequency of around 800 Hz. This signal is used to drive a small transformer with its output across two LEDs connected in series. Conrad Electronics supplied the transformer used in the original circuit. The windings have a 1:5 ratio. The complete specification is available on the (German) company website at www.conrad.de part no. 516236. It isn't essential to use the same transformer so any similar model with the same specification will be acceptable.
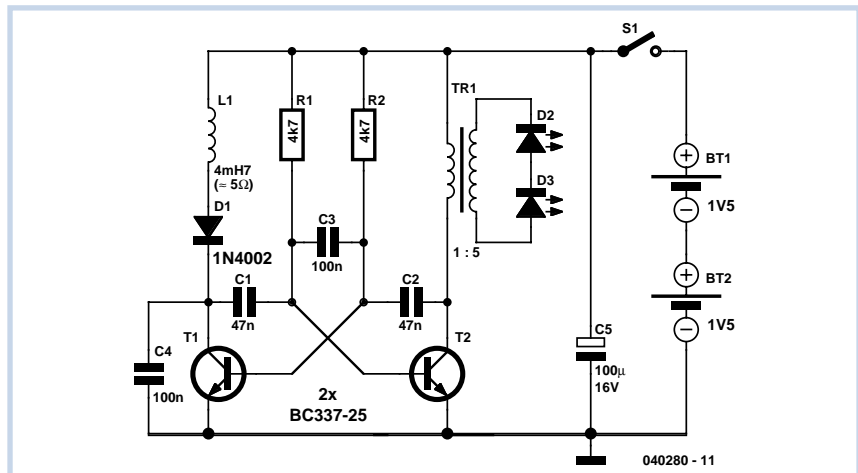
The LEDs are driven by an alternating voltage and they will only conduct in the half of the waveform when they are forward biased. Try reversing both LEDs to see if they light more brightly. Make sure that the transformer is fitted correctly; use an ohmmeter to check the resistance of the primary and secondary windings if you are unsure which is which. The load impedance for the left hand transistor is formed by L in series with the 1N4002 diode. The inductance of L isn't critical and can be reduced to 3.3 mH if necessary. The impedance of the transformer secondary winding ensures that a resistor is not required in series with the LEDs. Unlike fil-

ament type light sources, white LEDs are manufactured with a built-in reflector that directs the light forward so an additional external reflector or lens glass is not required. The LEDs can be mounted so that both beams point at the same spot or they can be angled to give a wider area of illumination depending on your needs. Current consumption of the circuit is approximately 50 mA and the design is even capable of producing a useful light output when the battery voltage has fallen to 1 V. The circuit can be powered either by two AAA or AA size alkaline cells connected in series or alternatively with two rechargeable NiMH cells.

(040280-1)

Hard Drive Switch (030)

Dieter Brunow

Readers of *Elektor Electronics* who have both a PC and children face a particular problem. Since the young tend not to be too circumspect in their surfing habits, parents' files are in permanent danger of being infected with viruses or deleted. There is also the risk of children or their friends gaining unauthorised access to files not intended for their eyes.

Perhaps a separate PC for the children would take up too much space or is ruled out for pedagogical reasons; in that case, the solution is to install two separate hard drives in the PC, one for the children and one for the adults. Ideally the two hard drives will each carry their own operating system and have their own software installed. As long as things are arranged so that the children can only boot their own drive, the parents' data will remain secure. All that is required, besides a second drive, is a specially-designed hard drive switch. This can be achieved, as has already been described in *Elektor Electronics*, by switching the two drives between master and slave modes using the IDE cable, and only activating the master drive in the BIOS. However, the IT skills of children should not be underestimated: the BIOS is easily changed back. The solution described here is a bit more secure.

Both drives are bootable and configured as masters. One is connected to IDE bus 1, and the other to IDE bus 2. The power supply voltages (+12 V and +5 V) are, however, only applied to one drive at a time. In principle, a simple double-pole

040485 - 11

changeover switch would do the job, but that has the disadvantage that it is possible to forget to reset the switch to child mode after use, especially if the switch is hidden. A better solution is to have to press a (hidden) button during boot to put the machine into parent mode. We will now see how this is done.

If the button is not pressed when the PC is switched on, then, after a short delay of about 0.7 s (determined by R1, C1, D2 and the base-emitter junction threshold voltage of the Darlington pair formed by T1 and T2) RE2 pulls in. RE1 remains unenergised and hence the children's drive connected to K2 is active. Subsequently press-

ing S1 has no effect since RE1 has been isolated by the contacts of RE2.

If the secret button is pressed, either briefly or continuously, during the 0.7 s sensitive period after the computer is switched on, RE1 pulls in immediately and holds itself in this state. D3 now prevents RE2 being subsequently activated. Since the contacts of RE1 have changed over, the PC now boots from the parents' drive. It is impossible to forget to return the computer to child mode, since the computer will always start up in this mode if the secret button is not pressed.

A 12 V miniature relay with contacts rated for 100 mA is suitable for RE2. The
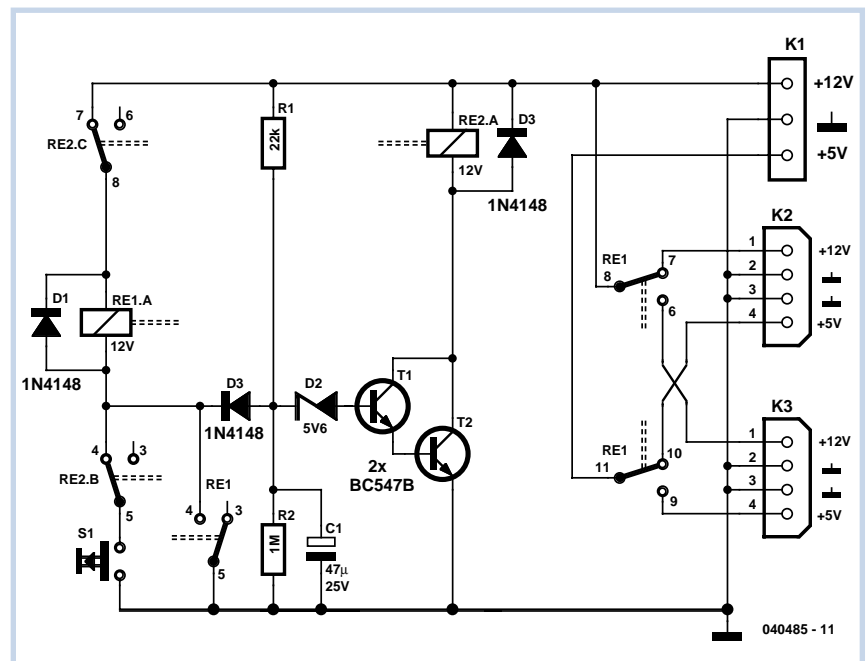
contacts of RE1 should be rated for the currents taken by a typical hard disk drive (say 2 A to 3 A). A key switch can be used instead of a secret button as a last resort against resourceful children, since the circuit will continue to operate cor-rectly if S1 is left in parent mode perma-nently while the computer is on.

031 Remote Control Blocker

Paul Goossens

This circuit was designed to block signals from infrared remote controls. This will prove very useful if your children have the tendency to switch channels all the time. It is also effective when your children aren't permitted to watch TV as a punish-ment. Putting the TV on standby and put-ting the remote control out of action can be enough in this case.

The way in which we do this is very straightforward. Two IR LEDs continuously transmit infrared light with a frequency that can be set between 32 and 41 kHz. Most remote controls work at a frequency of 36 kHz or 38 kHz.

The disruption of the remote control occurs as follows. The 'automatic gain' of the IR receiver in TVs, CD players, home cinema systems, etc. reduces the gain of the receiver due to the strong signal from the IR LEDs. Any IR signals from a remote control are then too weak to be detected by the receiver. Hence the equipment no

054023 - 11
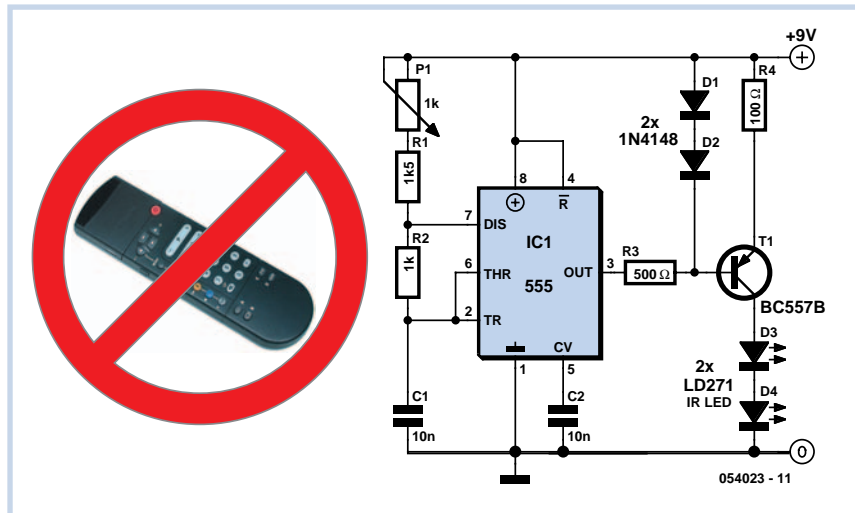
longer 'sees' the remote control!

The oscillator is built around a standard NE555. This drives a buffer stage, which provides the current to the two LEDs.

Setting up this circuit is very easy. Point the IR LEDs towards the device that needs its remote control blocked. Then pick up the remote control and try it out. If it still functions you should adjust the frequency of the circuit until the remote control stops working.

This circuit is obviously only effective against remote controls that use IR light!

032 Converter IC with Integrated Schottky Diode

L1
LQH32CN470K
47µH
044017 - 12

044017 - 11
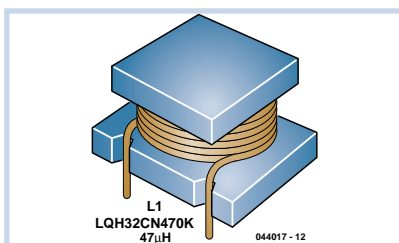
Gregor Kleine

Conventional step-up switching regulator ICs need at least one external Schottky diode and have the disadvantage that there is no effective output short-circuit cur-rent limiting. This means that very large currents can flow via coil L and Schottky diode D. Such currents can overload upstream components or destroy circuit board tracks.
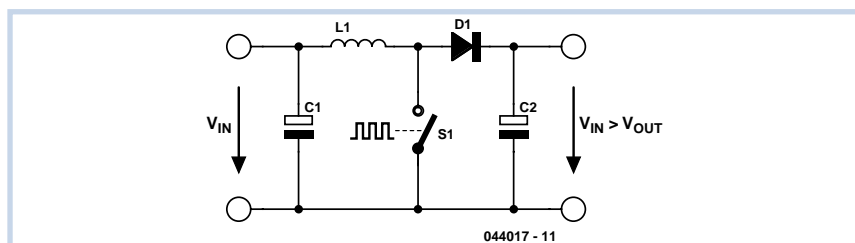
This situation is now remedied by the new LT3464 step-up switching regulator from Linear Technology (www.linear.com) in an 8-pin SOT23 package. Not only does it have an integrated Schottky diode, it also has an internal switching transistor that isolates the output from the input voltage in

the shutdown mode. The switching transistor also has short-circuit current limiting that becomes effective at around 25 mA. The IC operates with input voltages between +2.3 V and +10 V and can supply an output voltage as high as +34 V. The amount of output current that can be drawn increases as the input voltage increases. For example, the maximum output current is 15 mA with an input voltage of +9 V and an output voltage of +20 V. A quite common application is generating +12 V from a +5-V source, for which the maximum output current is 20 mA.

The output voltage is regulated via the Feedback pin (pin 2), with the voltage being determined by resistors R1 and R2 according to the formulas

$$V_{OUT} = 1.25\ V \times (1 + [R2 \div R1])$$

$$R2 = R1 \times ([V_{OUT} \div 1.25\ V] - 1)$$

Voltage divider R1/R2 can also be connected to the CAP pin (pin 5) ahead of the switching transistor. This avoids hav-

ing an open-loop condition when the output is switched off, but it reduces the accuracy of the output voltage setting. The circuit shown here generates a voltage spike when the IC is switched back on, since the feedback loop drives up the voltage on the CAP pin when the loop is open.
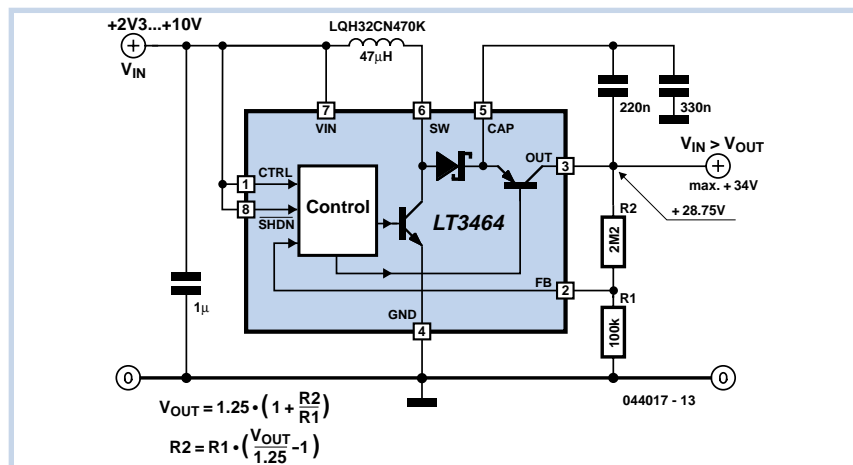
A Murata type LQH32CN470K coil (47 µH) is used here as a storage choke

due to its very compact construction. Other types of storage chokes in the range of 10–100 µH can also be used. The input capacitor, the capacitor connected to the CAP pin (pin 5), and the capacitor connected to the OUT pin (pin 3) are multilayer ceramic types (X5R and X7R).

(044017-1)

Virtual Prototyping Board

Paul Goossens

It is often very useful to test a small circuit before designing the printed circuit board. Often a small piece of prototyping board, also known as breadboard, perfboard or veroboard, is used for this. An alternative approach is to use simulation software. This is usually faster and more convenient. If the circuit doesn't work as expected, then such software makes it very easy to try something different.

Most of the software available for this purpose is pretty expensive. However, there are fortunately also a number of freeware programs available.

On of those is 'Virtual Breadboard'. This program can be downloaded from www.muvium.com.

This software allows for the simulation of digital circuits. A library with a number of standard parts is also provided. A small disadvantage is that the ICs are shown as they appear in reality, instead of a schematic block that indicates which functions each IC has.

What is very practical however is that the simulator can also simulate PIC-microcontrollers and the BASIC-stamp. This allows
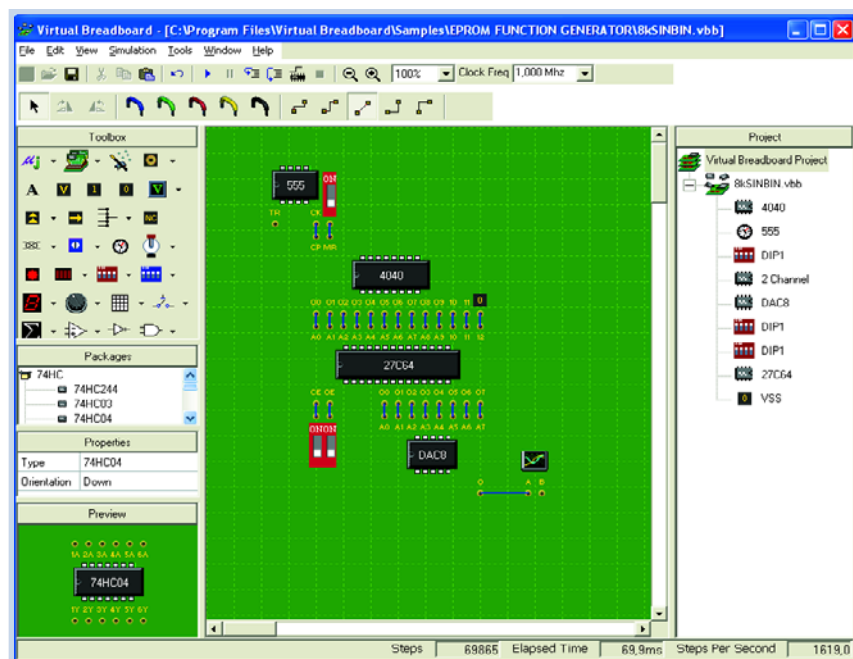
not only the hardware to be tested, but the software as well. Reprogramming is done in no time. You only need to load the new HEX file and can test immediately.

This program is not as extensive as the expensive, professional software pack-

ages, of course, but if you would like to test some small circuits (possibly including a PIC microcontroller or BASIC Stamp) then it is certainly worth it to check this program out!

(054003-1)

Compact 200 W Output Stage

Ton Giesberts

There is no doubt that this small power amp packs a punch. It is capable of delivering a healthy 200 W into 4 Ω. Into 8 Ω it can still output 125 W (see **Figure 2**). These large power outputs are made possible through the use of Darlington transistors made by Sanken, the SAP16N and its opposite number, the SAP16P (in our prototype we used their predecessors, the SAP15N and P, because the SAP16 versions were not available at that time). These power transistors have an emitter resistor built in, as well as a diode for temperature compensation. Because of this, the whole emitter follower stage has just two components (and a preset for setting the quiescent current, shown in the circuit in **Figure 1**).

One small disadvantage is that the transistors have to operate at a relatively low

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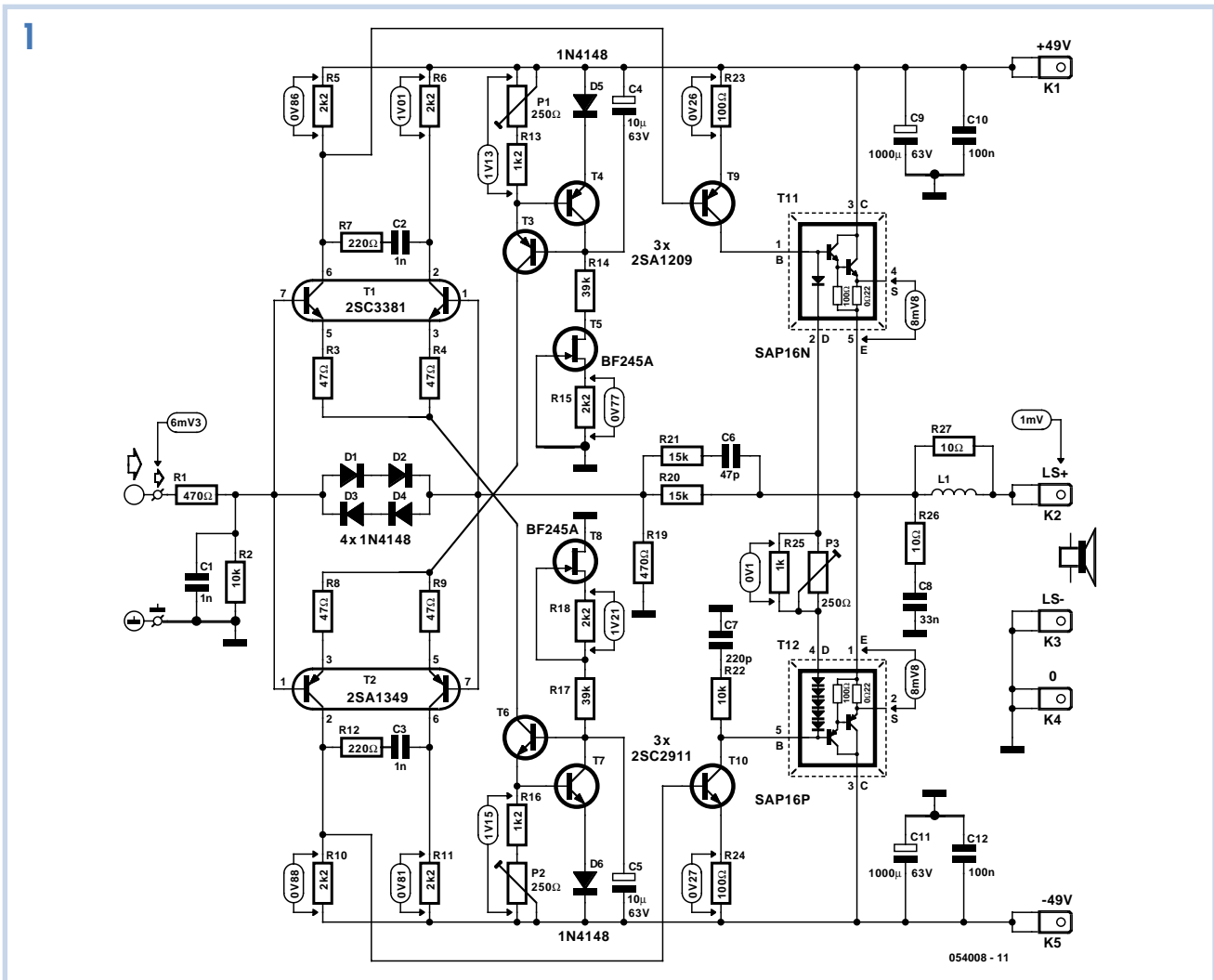
quiescent current, according to the datasheet. This causes an increase in distortion and a reduction in bandwidth. The current through the diodes has to be set to 2.5 mA, when the quiescent current will be 40 mA. This has the advantage that the driver transistors (T9, T10) do not need heat sinks, which helps to keep the circuit small.

The amplifier is of a standard design and doesn't require much explanation. The input is formed by two differential amplifiers (T1, T2), which are each followed by a buffer transistor (T9, T10). T9 and T10 together make a push-pull stage that drives the output transistors.

For T1 and T2 we've used special complementary dual transistors made by Toshiba. These, along with the driver transistors, have been used previously in the *High-End Power Amp* in the March 2005 issue. The driver transistors are a complementary pair made by Sanyo, which have been designed specifically for these applications.

Compensation in the amplifier is provided by R7/C2, R12/C3, R21/C6, R22/C7 and R26/C8. The dual transistors are protected by D1 to D4. The output inductor consists of 8 turns of 1.5 mm diameter enamelled copper wire (ECW).

Since the current through the diodes is just 2.5 mA, the operating point of T9 and T10 has to be set precisely. This operating point is determined purely by the operating point of the differential input amplifiers. Since the ambient temperature affects the operating point, any potential drift in the operating point of T9 and T10 is compensated for by the current sources of the differential amplifiers.

The voltage drop across D5 (D6) and the base-emitter voltage of T4 (T7) determine the current through P1 (P2) and R13 (R16). T4 (T7) controls the voltage at the base of T3 (T6) and creates a constant current that is independent from the sup-

Specifications

Input sensitivity		1 V_{eff}
Input impedance		10 kΩ
Sine-wave power	8Ω	125 W, THD+N = 1 %
	4Ω	200 W, THD+N = 1 %
Bandwidth		135 kHz (1 W/8Ω)
Slew rate		20 V/µs
Signal/noise ratio		101 dB (1 W/8 Ω, 22 Hz to 22 kHz)
		104 dBA
THD+noise		0.014 % at 1 kHz (60 W/8Ω)
Damping factor		>700 (1 kHz)
		>400 (20 kHz)

054008 - 12
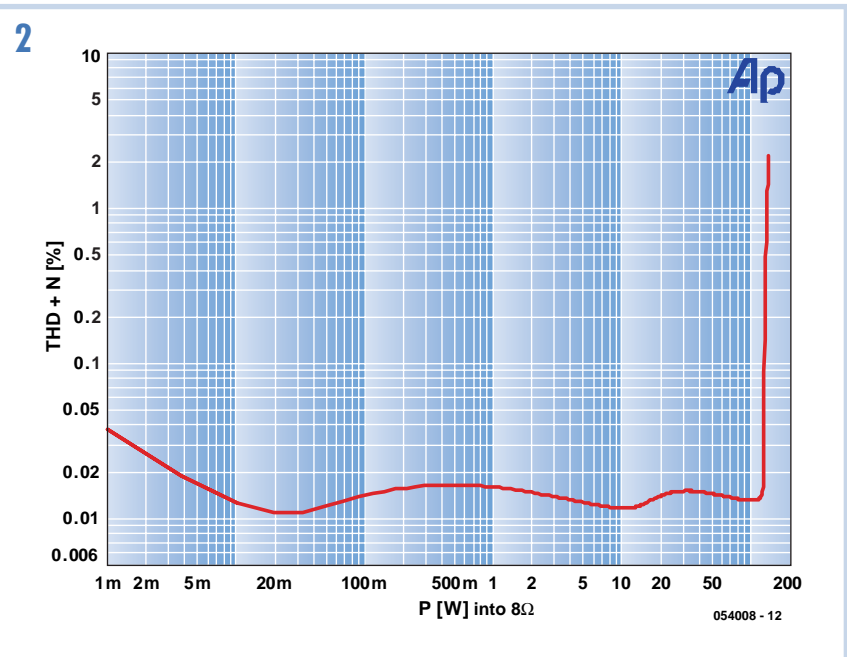
ply voltage. Since the voltage across D5 (D6) and T4 (T7) depends on the temperature, the voltage at the base of T10 (T9) has been temperature-compensated as well as possible. T3 and T4 (T6 and T7) are fed by a simple constant current source built around JFET T5 (T8), which makes the differential amplifier around T2

(T1) even less dependent on the supply voltage. R14 (R17) restricts the maximum voltage across T5 (T8), which may not exceed 30 V. According to the datasheet the JFET current should be about 0.5 mA, but in practice a deviation of up to 50% is possible. The actual value is not critical, but the voltage across the JFET must

COMPONENTS LIST

Resistors:
R1, R19 = 470Ω
R2, R22 = 10kΩ
R3, R4, R8, R9 = 47Ω
R5, R6, R10, R11, R15, R18 = 2kΩ2
R7, R12 = 220Ω
R13, R16 = 1kΩ2
R14, R17 = 39kΩ
R20, R21 = 15kΩ
R23, R24 = 100Ω
R25 = 1kΩ
R26, R27 = 10Ω 1W
P1,P2,P3 = 250Ω preset

Capacitors:
C1,C2,C3 = 1nF

C4, C5 = 10µF 63V radial
C6 = 47pF
C7 = 220pF
C8 = 33nF
C9, C11 = 1000µF 63V radial
C10, C12 = 100nF

Inductors:
L1 = 8 turns 1.5mm dia. ECW, inside diameter 10mm.

Semiconductors:
D1-D6 = 1N4148
T1 = 2SC3381 (Toshiba) (Huijzer; Segor Electronics)
T2 = 2SA1349 (Toshiba) (Huijzer; Segor Electronics)
T3,T4,T9 = 2SA1209 (Sanyo) (Farnell # 410-3841)

T5, T8 = BF245A
T6, T7, T10 = 2SC2911 (Sanyo) (Farnell # 410-3853)
T11 = SAP16N (Sanken) or SAP15N (Farnell # 410-3749)
T12 = SAP16P (Sanken) or SAP15P (Farnell # 410-3750)

Miscellaneous:
K1-K5 = 2-way spade terminal, PCB mount, vertical
Heatsink <0.5 K/W
Mica washers for T11 en T12, e.g., Conrad Electronics # 189049.
4 wire links on PCB
PCB, ref. 054008-1 from The PCBShop

3

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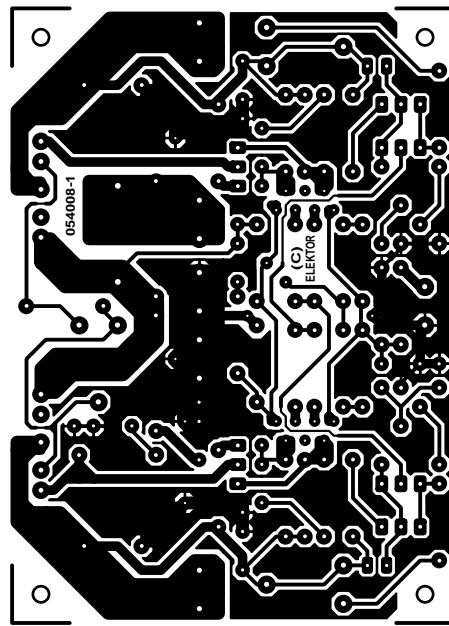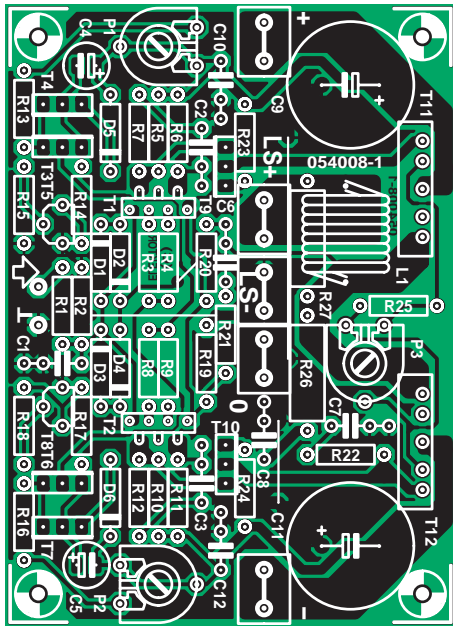
always stay below the maximum value (also take into account any possible mains voltage variations). If you do need to reduce the voltage, that should be done by **lowering** the value of R15 (R18). This causes the voltage across R14 (R17) to increase and hence the voltage across the JFET will drop.

P1 and P2 are required to compensate for various tolerances. With the input open circuit you should set the output to zero, while keeping the current through T9 and T10 as close as possible to 2.5 mA. This can be measured across R23 and R24. It is not a problem if the current is a few tenths of a mA more than this.

The quiescent current is set by P3. In the reference design a 200 Ω preset is used. We have put this together using a (standard) preset of 250 Ω in parallel with a 1 kΩ resistor. An incidental advantage of this parallel resistor is that it limits any possible current spikes when the wiper of the potentiometer makes a bad contact during the adjustment of the quiescent current.

This amplifier provides a good opportunity to experiment with the Sanken transistors. If you want to use the output stage in a complete power amplifier (refer to the print layout in **Figure 3**), you will need to add an input decoupling capacitor, a power-on delay with a relay for the loud-

speaker and a beefy power supply. The input decoupling capacitor is certainly a necessity, since the offset is determined by the various tolerances and differences between the complementary transistors. In our prototype the input offset was 6.3 mV for a 0 V output voltage. This is amplified by a factor of 33, which would result in an output offset of over 200 mV if the input was shorted by, for example, a volume control.

Elsewhere in this issue is a design for a small board, which contains an input decoupling capacitor (MKT or MKP) and a relay with a power-on delay.

(054008-1)

035 Protection for Voltage Regulators

Ton Giesberts

People often forget that many voltage regulator ICs have an upper limit (usually 35 V) on the input voltage they can handle. That applies primarily to types with a fixed output voltage. Adjustable voltage regulators also have a maximum voltage specification, in that case between the input and output (commonly 40 V). The input voltage must thus be limited to that level in a fault situation in which the output is shorted.

This circuit shows a way to allow such regulators to be used in situations with higher input voltages. Although the solu-

tion consists of an additional three components, it is simple and can be built using commonly available components. The voltage across the regulator is limited by the combination of T1 and zener diode D1 to a value that allows the regulator to work properly with loads up to the maximum rated load. R1 provides an adequate operating current for D1 and the bias current for T1. It's a good idea to use a Darlington type for T1 in order to keep the value of R1 reasonably high. The current through D1 is only 10 mA with an input voltage of 60 V. Naturally, we also measured what the circuit does when no load is connected. Surprisingly
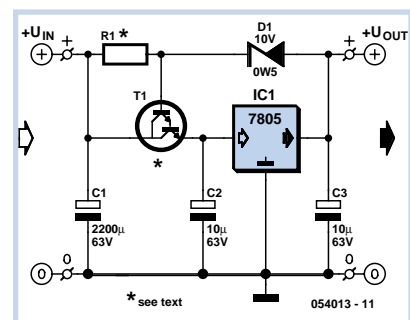
enough, the nominal output voltage of 5.02 V increased to only 5.10 V (with a 60-V input voltage).

In our experiments, we used a BDV65B

for T1 and a value of 4.7 kΩ for R1. If you want to ensure that the circuit is truly short-circuit proof with an input voltage of 60 V, you must use a transistor that remains within its safe operating area at the maximum input voltage with the short-circuit current of the regulator (which can exceed 2 A). The BDV65B and TIP142 do not meet this requirement. The maximum voltage for the BDV65B is actually 40 V, and for the TIP142 is 50 V. If the transistor breaks down, the regulator will also break down. We verified that experimentally.

One possibility is to add SOA protection for T1, but that amounts to protecting the protection. Another option is to relax the requirements. For that purpose, R1 must provide enough current to ensure that T1 receives sufficient current in the event of a short circuit to keep the voltage across T1 lower, but that doesn't make a lot of difference in practice, and it also increases the minimum load. Besides that, it should be evident that adequate cooling for T1 and IC1 must be provided according to the load.

Ripple suppression is only marginally

affected by the protection circuit, since the input is already well stabilised by T1, but the current through D1 does flow through the output. The presence of C2 must also be taken into account. In this circuit, with an adjustable voltage regulator such as the LM317 and an output voltage greater than 40 V, C2 will cause the voltage to be briefly higher than 40 V in the event of a short circuit, which can also cause the IC to be damaged. In that case, it will be necessary to find a different solution or use a different type of voltage regulator.

(054031-1)

Video Sync Generator

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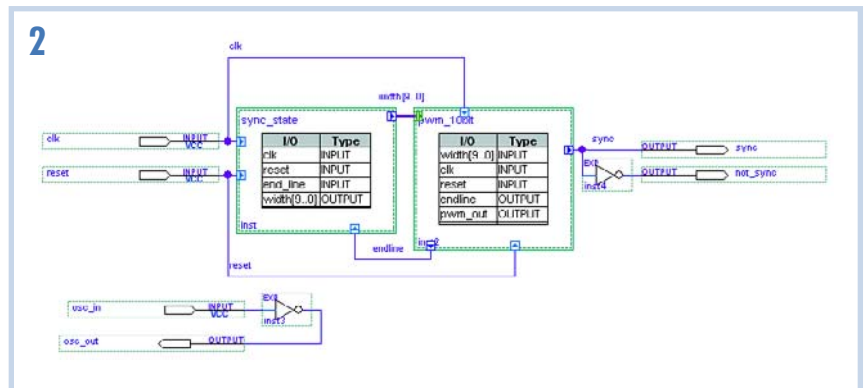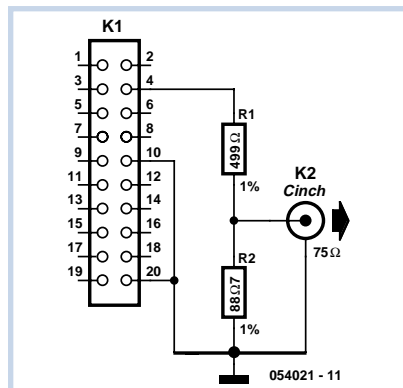
Paul Goossens

All video signals include synchronisation signals, which help the television set keep the horizontal and vertical deflection synchronous with the picture. For experimental purposes, it can be handy to build a generator for these synchronisation signals.

Synchronisation signals have a rather complicated structure. It's not easy to generate them accurately using analogue circuitry. By contrast, a design based on a CPLD is a lot easier. This design uses the experimenter's board described in the May 2004 issue ('Design Your Own IC'). The hardware extension for this generator is shown in Figure 1. The extension could hardly be simpler. The 20-way connector must be connected to connector K3 of the experimenter's board by a flat cable. The synchronisation signals on pin 4 are routed to the output connector via voltage divider R1/R2.

R1 and R2 perform two tasks in this circuit. First, they provide the correct output impedance of 75 Ω. Second, they reduce

the signal amplitude from around 4 V to 0.6 V. If the circuit is connected to a television set with an input impedance of 75 Ω, the maximum output voltage will be only 0.3 V, which complies with the specifications for the CVBS signal.

As you've surely guessed by now, the majority of the design is contained in the CPLD. We generated this design in Quartus 4.2. The top-level schematic is shown in Figure 2. As can clearly be seen from that diagram, the design consists of three separate sections. In combination with the crystal on the circuit board, the inverter at the bottom provides the clock signal. The crystal must generate a frequency of 10 MHz for this circuit. If a different crystal is already fitted, it must be replaced by a 10-MHz type.

The clock signal finds its way back into the circuit via another input at the top left. It ensures that both parts of the circuit operate synchronously.

The section named 'sync_state' keeps track of which part of the video signal is being generated. Here it should be remarked that each video line is divided

into two parts in this circuit. That is done because the synchronisation signal occurs at twice the normal rate during the vertical retrace interval.

The 'width' output indicated how long the output signal should remain low. Assertion of the 'endline' input indicates to the subcircuit that the current portion of the video signal is ready and the next portion of the video signal can be processed. The 'sync_state' block then produces the associated value at the output.

The final block bears the revealing name 'pwm_10bit'. As its name suggests, this section (which is actually implemented as part of the program code) generates a pulse on the output whose width is equal to the value of 'width'. This PWM counts from 0 to 319, which corresponds to a total duration of 32 µs (half of one video line) at a clock frequency of 10 MHz. This period is divided into 320 intervals of 0.1 µs each. The PWM sets the 'endline' output high during the next-to-last interval. You might expect that this signal would be active during the final interval of the period, but making it active one interval earlier gives the

'sync_state' block at least one clock cycle to generate a new 'width' value.

Naturally, the design files for the IC can be downloaded from the *Elektor Electronics* website (www.elektor-electronics.co.uk). The file number is **054021-11.zip**. After compilation, the final result uses 65 macrocells. The number of macrocells can be reduced by optimising the overall code. For instance, there are several obvious places where the design can be made more efficient, but a few somewhat less optimisations are also possible. Try it for yourself, and see how much you can optimise the design. Your efforts might just spark an interesting discussion on our website Forum!

037 Bidirectional I²C Level Shifter

Luc Lemmens

In some cases I²C signals need to be level-converted if they are exchanged between (sections of) logic systems operating at different supply voltages. For example, one section of a circuit may work at 5 V while a newly added I²C device is happy at just 3.3 V. Without a suitable bidirectional level converter, signals from the 5-V system may disrupt or even damage the SDA/SCL inputs of the 3.3-V device, while the other way around signals emitted by the lower voltage device may not be properly detected.

As shown in the diagram, two n-channel enhancement MOSFETs inserted in the SDA and SCL lines do the trick. Note that each voltage section has its own pull-up resistors Rp connected between the respective supply rail (+3.3 V or +5 V) and the MOSFET source or drain terminals. Both gates (g) are connected to the lowest supply voltage, the sources (s) to the bus lines

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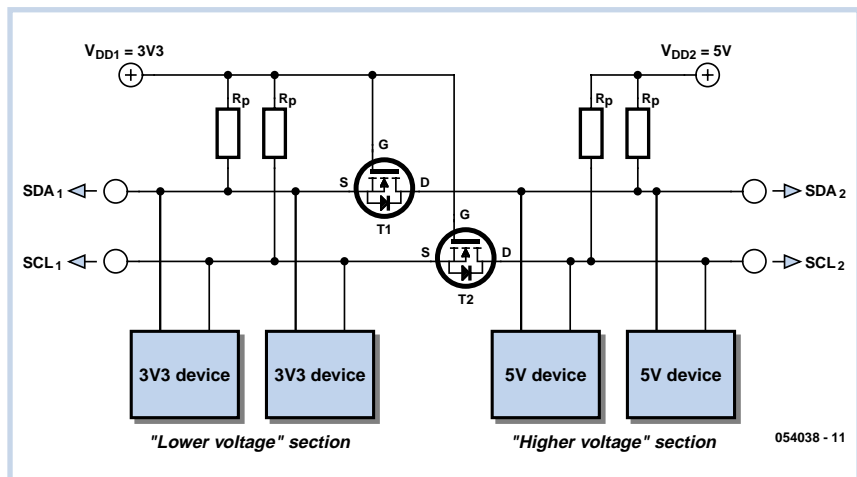
of the lower voltage section, and the drains (d) to the same of the higher voltage section. The MOSFETs should have their source connected to the substrate — when in doubt check the datasheet.

Other supply voltages than 3.3 V and 5 V may be applied, for example, 2 V and 10 V is perfectly feasible. In normal operation VDD2 must be higher than or equal to VDD1.

Source:

Philips Semiconductors
Application Note AN97055.

038 Luxeon LEDs

Karel Walraven

It won't be very long before your new sitting room lamp will last forever. While our parents had to replace the lamp at least once a year, these days the energy-efficient lamps last five to ten times as long. Our children will buy an LED lamp once, which will keep working until their grave. Granted, what is written here is possibly a slight exaggeration, but that the development is in the direction of increased lifespan and higher efficiency is beyond dispute.

The company Lumileds (from Agilent and Philips) has as its goal the development of LEDs that are suitable for lighting. That is why they are available in various shades of white: 3200 K (warm white), 4100 K (commercial white) and 5500 K (cool white). By combining multiple LEDs of different brightness in one fitting, the different fittings will have equal brightness, even if you buy another new one years later.

With respect to power output, there are models rated 1 W and 5 W, and when you read this, the range is quite likely to have grown. Because the light output and life expectancy are strongly related to temperature, not only unmounted LEDs are available but also types integrated with a heatsink. This series has the beautiful name of Luxeon Star LED, because the

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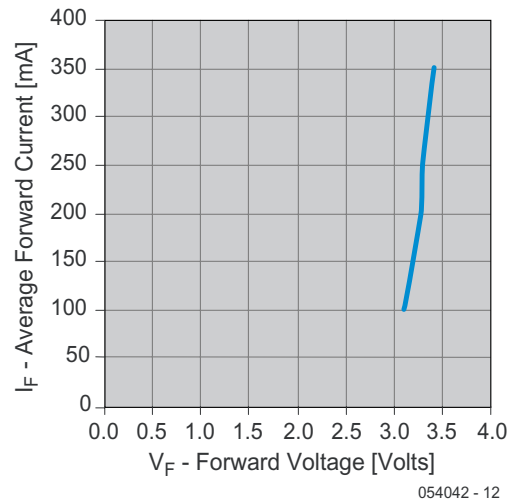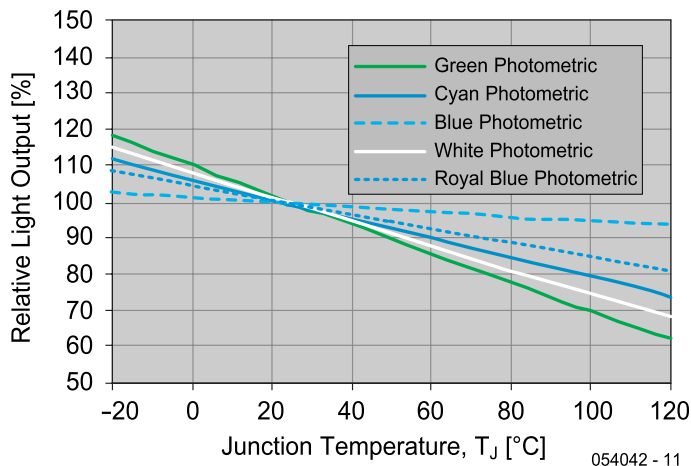
heatsink has somewhat of a star shape. Because of the heatsink it is possible to use the Luxeon Star LED at the rated current without any additional measures. For the 1-watt type that is 350 mA DC. The current may be as high as 500 mA of the LED is multiplexed, however the average value may not be higher than 350 mA. Don't use a switching frequency of less than 1 kHz, otherwise the temperature of the chip varies too much. The 3-watt type can be driven with a maximum of 1 A, also when multiplexing.

If you are going to use the LEDs at these limits it is advisable to drive them with an electronically controlled current source, so

that you can be sure that the limits are not exceeded. In general this is not necessary, since a slightly lower current does not reduce the brightness much. This is because the brightness reduces significantly when the temperature of the chip increases. This can be as much as 10 % per 20 degrees of junction temperature! It is therefore always a good idea to provide the LED with as much additional cooling as is practicable, for example by mounting the heatsink on a thermally conducting part of the fitting. We recommend that you choose a current which is a little less than the maximum value. A simple current lim-

iting resistor is then all you need and additional electronics is not required. For examples and calculations see:

www.luxeonstar.com/
resistor-calculator.php

Note that the LED, in contrast to a halogen lamp, requires DC. So in the event of an AC power supply, apart from the resistor, it is also necessary to add a bridge rectifier between transformer and LED! More information can be found in the *Custom Luxeon Design Guide*, which can be downloaded from:

www.lumileds.com/pdfs/AB12.PDF

(054042-1)

Extended Timer Range for the 555

039

Ton Giesberts

Anyone who has designed circuits using the *555* timer chip will, at some time have wished that it could be programmed for longer timing periods. Timing periods greater than a few minutes are difficult to achieve because component leakage currents in large timing capacitors become significant. There is however no reason to opt for a purely digital solution just yet. The circuit shown here uses a *555* timer in the design but nevertheless achieves a timing interval of up to an hour!

The trick here is to feed the timing capacitor not with a constant voltage but with a pulsed dc voltage. The pulses are derived from the unsmoothed low voltage output of the power supply bridge rectifier. The power supply output is not refer-

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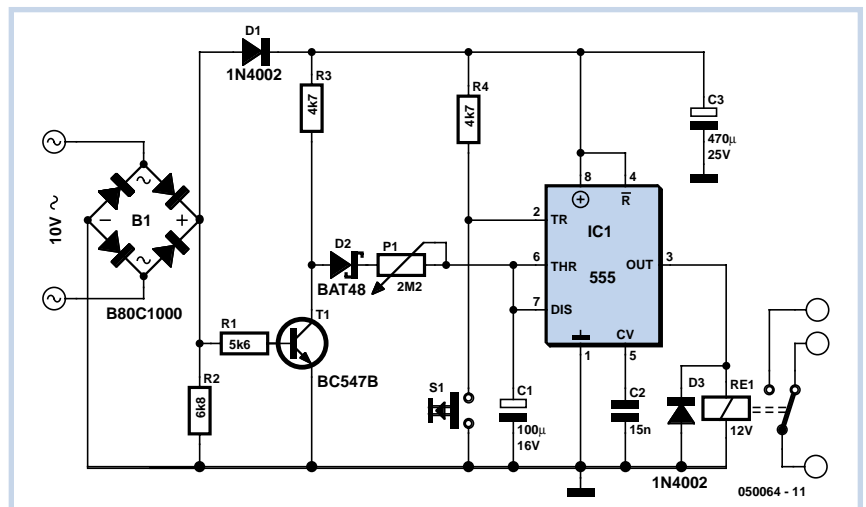
enced to earth potential and the pulsing full wave rectified signal is fed to the base of T1 via resistor R1. A 100-Hz

square wave signal is produced on the collector of T1 as the transistor switches. The positive half of this waveform

charges up the timing capacitor C1 via D2 and P1. Diode D2 prevents the charge on C1 from discharging through T1 when the square wave signal goes low. Pushbutton S1 is used to start the timing period. This method of charging uses relatively low component values for P1 (2.2 MΩ) and C1 (100 to 200 µF) but achieves timing periods of up to an hour which is much longer than a standard 555 circuit configuration.

040 Fridge Thermostat
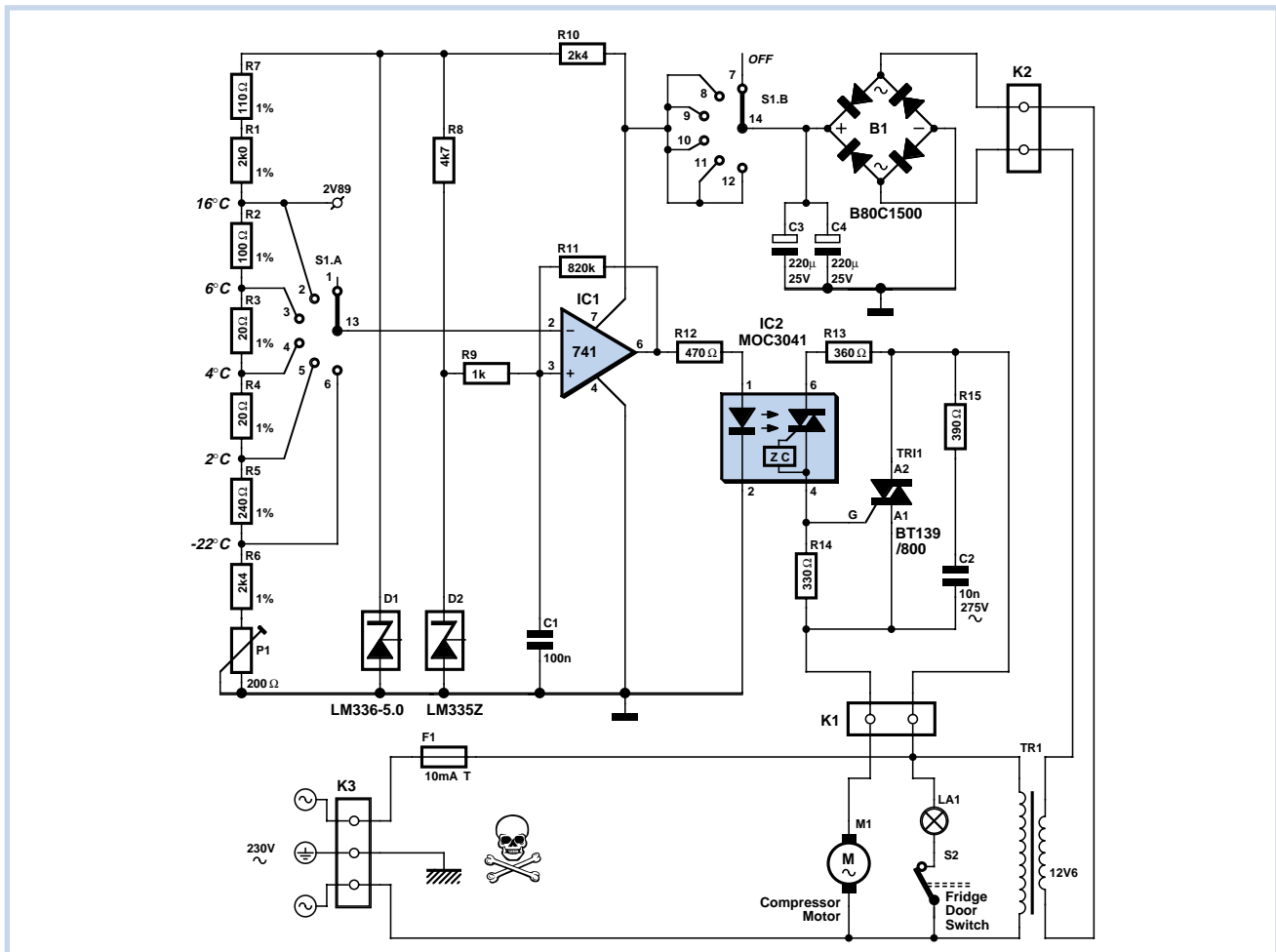
Tony Beekman

What to do when the thermostat in your fridge doesn't work any more? Get it repaired at (too) much expense or just buy a new one? It is relatively simple to make an electronic variation of a thermostat yourself, while saving a considerable amount of money at the same time. However, be careful when working with mains voltages. This voltage remains invisible and can sometimes be fatal!

This design allows for five temperatures to be selected with a rotary switch. By selecting suitable values for the resistors (R1 to R7), the temperatures at the various switch positions can be defined at construction time. With the resistance values shown here, the temperature can be adjusted to 16, 6, 4, 2 and –22 °C. 16° C is an ideal temperature for the storage of wine, while 6, 4, and 2 degrees are interesting for beer connoisseurs and the minus 22°degrees position transforms the fridge into a large freezer. Note for wine connoisseurs: to prevent mould on the labels, it is necessary to place a moisture absorber or bag of silica gel in the fridge. The circuit is built around an old workhorse among opamps, the 741. D1 provides a stable reference voltage of 5 V across the entire resistor divider. P1 allows adjustment of the voltage at the node of R1 and R2. To use the above-mentioned temperatures as setpoints this voltage needs to be adjusted to 2.89 V.

D2 is a precision temperature sensor, which can be used from –40 to +100 °C. The voltage across this diode varies by 10 mV per Kelvin. In this way D2 keeps an eye on the temperature in the fridge. The reference voltage derived from the voltage divider (selected with S1) is compared by IC1 with the voltage across the temperature sensor. Based on this, the 741 switches, via the zero voltage crossing driver (IC2), a triac that provides voltage to the compressor motor. The zero voltage crossing IC switches only at the zero crossings of the mains voltage, so that interference from the compressor motor is avoided when turning on.

The power supply for the circuit is provided by a simple bridge rectifier and fil-

tered with two electrolytic capacitors of 220 μF each.

The design can also be used for countless other uses. You can, for example, make a thermostat for heating by swapping the inputs of the opamp.

Keep in mind the safety requirements when building and mounting the circuit.

(050025-1)

USB for the Xbox

Paul Goossens

The Xbox is the well-known Microsoft game computer. The fact that the Xbox is based on PC technology should hardly be surprising, since Microsoft specialises in this computer architecture.

It's also not especially remarkable that if you open up an Xbox, you'll find several well-known ICs from the PC world. In fact, the Xbox is actually a PC. The major difference between the Xbox and a normal PC is that the operating system is stored entirely in Flash memory and users cannot add any functionality to the system. There is also a protection system that prevents any software from being accepted if it does not have a digital signature from Microsoft.

At least, that was the intention. Naturally, there are people who have cracked the Xbox protection system and use the Xbox as a PC to run Linux. We plan to publish more information about this in *Elektor Electronics* in the near future. The biggest problem with running Linux on an Xbox is that there is no keyboard for the Xbox. That's what we want to remedy here.

As usual with game computers, the Xbox has connectors for controllers (enhanced joysticks) for playing the games. The Xbox has four such connecters on the front of the enclosure. They have a form that is totally new to us. After a bit of detective work, it turns out that the signals on these connectors are actually quite familiar: they're USB signals.

Once you know that, it's easy to connect a keyboard to the Xbox. If you fit a standard USB connector somewhere on the enclosure and wire it to the signal lines for one of the connectors, you can then connect a USB keyboard. Another benefit of this is that most types of USB memory sticks can be used by the Xbox as Xbox memory cards. USB memory sticks are a lot less expensive than 'genuine' Xbox memory cards.

The wires to the connector at the front can be clearly seen in **Figure 1**. The yellow wire is not important for our purposes.

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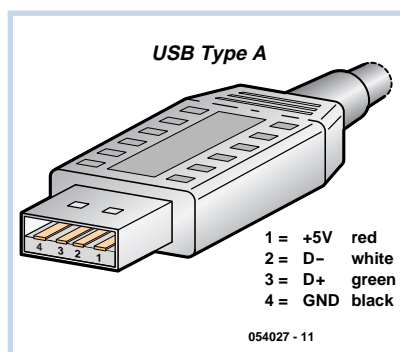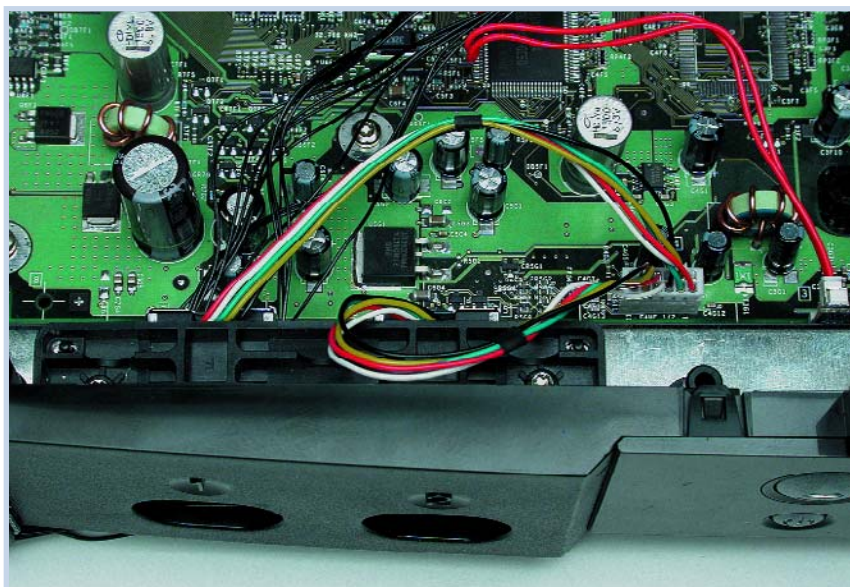
Table 1. USB connections

Pin 1 (red) : +5 V

Pin 2 (white) : D–

Pin 3 (green) : D+

Pin 4 (black) : GND

The other wires are used for the actual USB signals. A nice detail is that Microsoft uses exactly the same colours for these wires as those specified in the USB standard, which makes them much easier to recognise.

For the installation, you will some wire and a USB connector (Type A). That's the same type of connector as the USB connectors in a PC. **Figure 2** shows an example of such a connector, along with the proper pin numbers.

Find a place on the Xbox where the connector can be fitted. It's easy to make a hole in the case with a small hand-held router or a drill and a small file. Next, make connections between the four wires leading to the Xbox connector and the

four terminals of the USB connector, as shown in **Table 1**.

It's a good idea to check the connections before using the modified unit, in order to ensure that there aren't any shorts between the lines. As a second test, we recommend checking whether a voltage can be measured between pin 1 of the USB connector (+3.6 to 5 V) and pin 4 (ground) after the Xbox power has been switched on. If the test results are all OK, the USB connector is ready for use.

USB keyboards (and USB mice) are supported by Xbox Linux, and some Xbox games also use a USB keyboard to make it easier to control the game and/or chat with other players.

(054027-1)

12-V Dimmer

030141 - 11
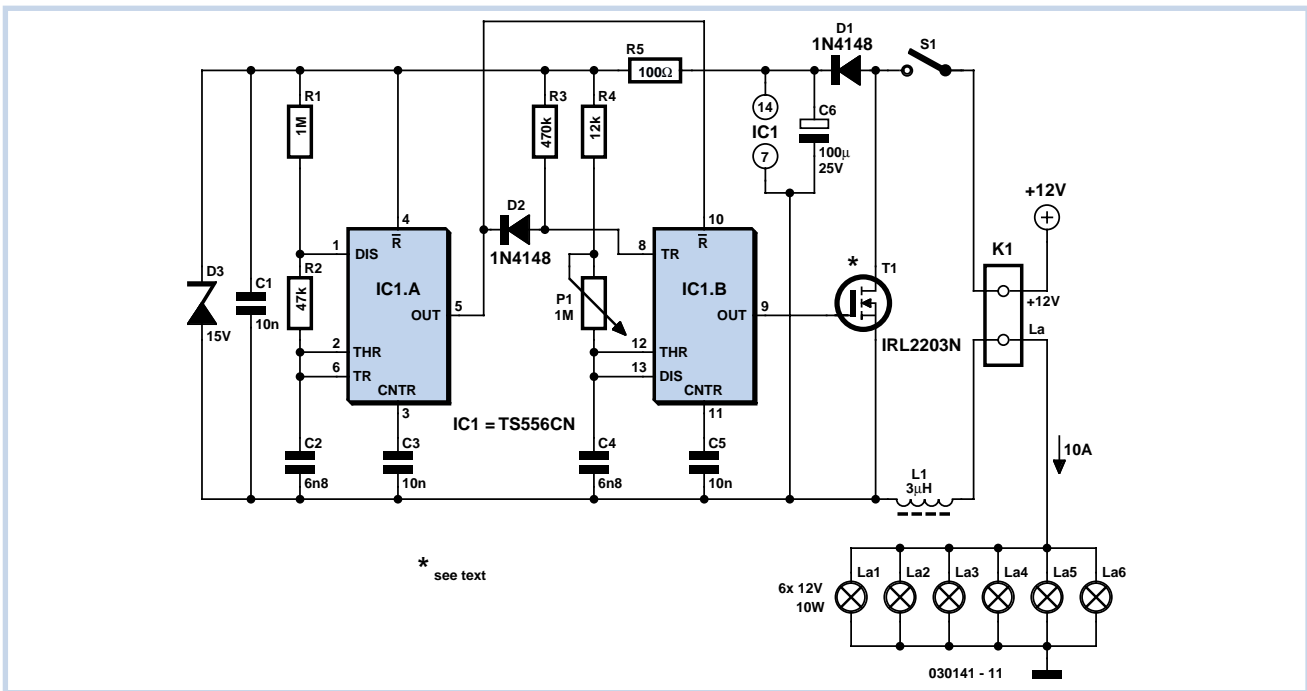
John Dakin

A dimmer is quite unusual in a caravan or on a boat. Here we describe how you can make one. So if you would like to be able to adjust the mood when you're entertaining friends and acquaintances, then this circuit enables you to do so.

Designing a dimmer for 12 V is tricky business. The dimmers you find in your home are designed to operate from an AC voltage and use this AC voltage as a fundamental characteristic for their operation. Because we now have to start with 12 V DC, we have to generate the AC voltage ourselves. We also have to keep in mind that we're dealing with battery-powered equipment and have to be frugal with energy.

The circuit that we finally arrived at can easily drive 6 lamps of 10 W each. Fewer are also possible, of course. In any case, the total current has to be smaller than 10 A. L1 and S1 can be adapted to suit a smaller current, if required. Note that the whole circuit will also work from 6 V.

IC1 is a dual timer. You could also use the old faithful NE556, but it draws a little more current. IC1a is wired as an astable multivibrator with a frequency of 180 Hz. IC1b is configured as a mono-stable and is triggered, via D2, from the positive edge at the output of IC1a. The length of the pulse that now appears at

the output of IC1b is dependant on the position of P1. IC1b will be reset when-

ever the output of IC1a goes low, inde-pendent of the pulse duration, set with
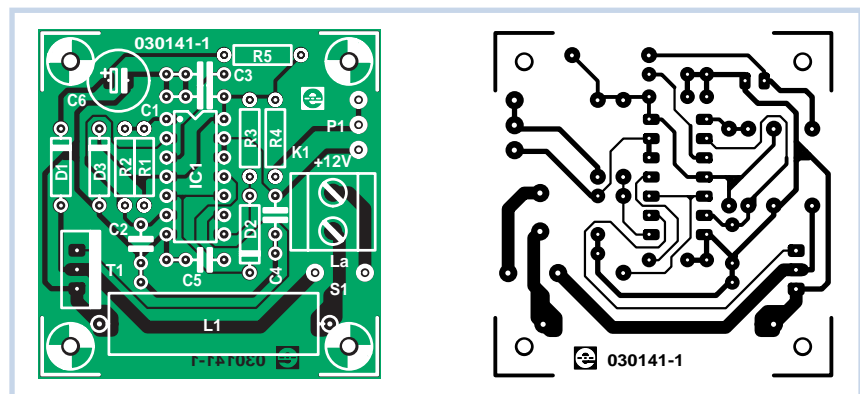
COMPONENTS LIST

Resistors:
R1 = 1MΩ
R2 = 47kΩ
R3 = 470kΩ
R4 = 12kΩ
R5 = 100Ω
P1 = 1MΩ preset

Capacitors:
C1,C3,C5 = 10nF
C2,C4 = 6nF8
C6 = 100µF 25V radial

Semiconductors:
D1,D2 = 1N4148
D3 = zener diode 15V /1.3W

T1 = IRL2203, BUZ10, BUZ11, BUZ100
   or BUK455 *
IC1 = TS556CN (CMOS) or NE556N
   (not CMOS)

Miscellaneous:
L1 = 3µH 9A suppressor coil * (e.g.,
   Farnell # 976-416)
K1 = 2-way PCB terminal block, lead
   pitch 5mm
S1 = on/off switch, 10A
PCB, ref. 030141-1 from The PCBShop

* see text

P1, R4 and C4. This guarantees that the dimming is smooth, even when the brightness is set to maximum.

The output of IC1b (pin 9) drives the gate of MOSFET T1. When the duration of the pulses at the gate increases, the average time that the MOSFET is in conduction will also increase. In this way the brightness of the lamps is controlled. T1 conducts about 96 % of the time when the brightness is set to maximum. In this configuration, this can never be 100 %, because the 4 % of the time that the FET does not conduct is necessary to charge C6. If the FET were to conduct with 100 % duty cycle, the power supply for the circuit would be effectively short-circuited. C6 allows the circuit to ride through the conduction period of the FET. D1 ensures that the charge cannot leak away via the FET during the 'on' period.

In the schematic, an IRL2203N is indicated for T1, but in principle you could use just about any power transistor (for example, BUK455, BUZ10, BUZ11 or BUZ100). The IRL2203 does however, have a very low 'on' resistance ($R_{DS\,ON}$) of only 7 mΩ and can switch 12-V loads up to 5 A without a heatsink. If you choose a different MOSFET (with higher $R_{DS\,ON}$) or use the circuit in a 6-V system then you will likely need a heatsink. Using the IRL2203N with six lamps rated 12 V / 10 W, T1 dissipates only 170 mW. At 6 V and 10 A this becomes 680 mW. The circuit itself consumes about 0.35 mA

at maximum brightness and about 1.25 mA at minimum.

The power supply is derived from the power system via D1 and C6. Zener diode D3 provides protection against voltage surges. The main purpose of R5 is to limit the current through D3, in the event it becomes active. L1 reduces interference that could be caused by the fast switching of the transistor.

We have designed a small printed circuit board for the circuit. The construction is very simple. The PCB is quite compact in order to facilitate the replacement of existing switches. Keep in mind that the CMOS-parts, IC1 and T1, are sensitive to static electricity.

(030141-1)

Low-cost LiPo Charger

043

The charging of Lithium-Polymer (LiPo) cells takes place very differently to that of the well known NiCd and NiMH cells. This aspect has previously been covered in *Elektor Electronics*. And this isn't the first LiPo charger that we've published, but it is undoubtedly the smallest!

Chip manufacturer Intersil has designed a LiPo charger IC that requires a minimum of external components. Since the IC itself is also extremely small (2×3 mm), the complete charger can be kept very small as well. This lets us design a charger that can easily be built into various pieces of equipment, especially when we use SMDs for all external components.

For those of you who don't know how a LiPo cell should be charged, we'll give a short explanation. When the cell voltage is very low (<2.5 V), it should be charged using a small current (see **Figure 1**). This current is typically less than 0.1*C* (where *C* is the nominal battery capacity). When the voltage has risen sufficiently, but is still below 4.2 V, the cell is charged with a constant current. Most LiPo manufacturers specify a current of 1*C* for this stage. The voltage across the cell may not exceed 4.2 V, so the charger has to keep an eye on this as well. At this constant voltage the current through the cell will slowly reduce while the charge in the cell increases.

At the point when the cell voltage is 4.2 V and the charging current has dropped to 0.1*C*, the cell is about 80-90% charged, depending on the manufacturer. Most chargers decide at this point that the cell
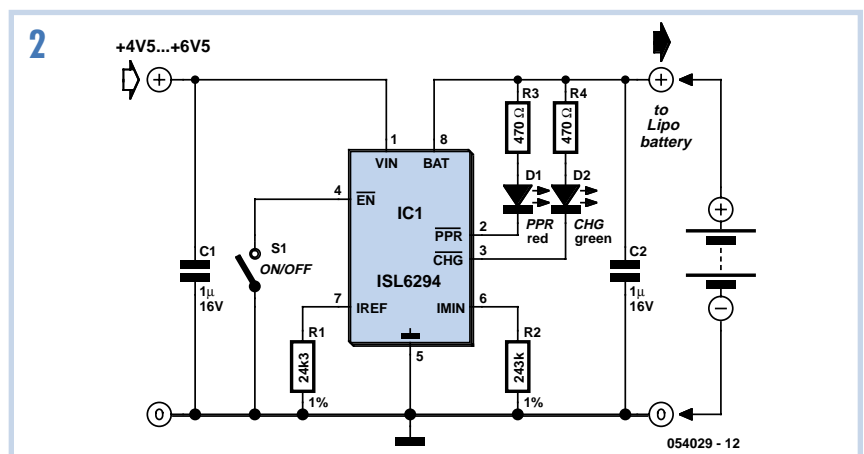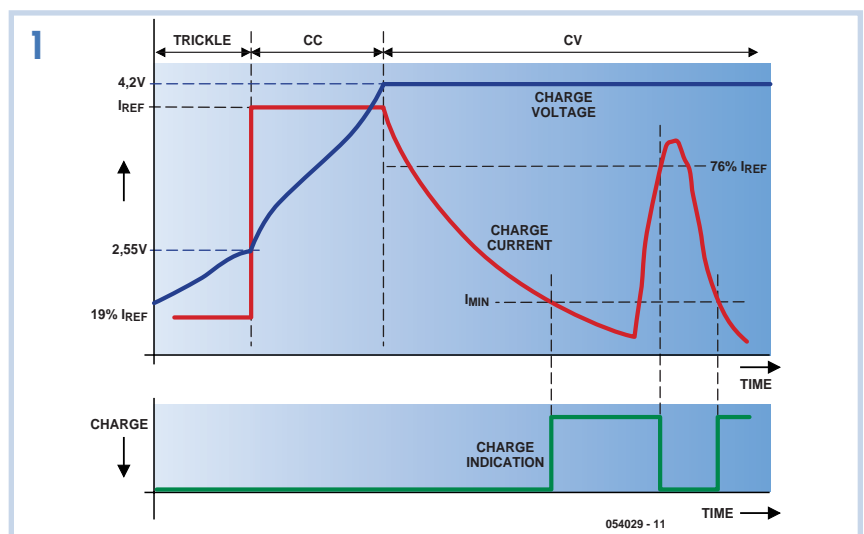
is fully charged and switch to trickle charging the cell.

Our charger works in exactly the same way. There are two parameters that can

1

054029 - 11

2

054029 - 12

be adjusted in this charger, which are the normal charging current and the trickle charge that flows when the cell is 'full'. In the circuit of **Figure 2** resistor R1 sets the charging current to about 500 mA, and resistor R2 sets the trickle charge current to about 45 mA.

R3, R4, D1 and D2 are optional in this design and provide the user with status information. D1 shows when the charging process is busy and D2 indicates that the correct input voltage is present.

If you want to use different maximum and minimum charge currents you should use the following formulae for R1 and R2:

$R1 = 12 \times 10^3 / I_{ref}$
$R2 = 11 \times 10^3 / I_{min}$

Keep in mind that the accuracy of the current source at 500 mA is about 10%; this drops to about 30% at 50 mA. You should therefore be conservative in your choice of charging current so that you keep below the manufacturer's maximum recommended charging current.

(054029)-1

044 DIL/SOIC/TSSOP Experimenting Boards
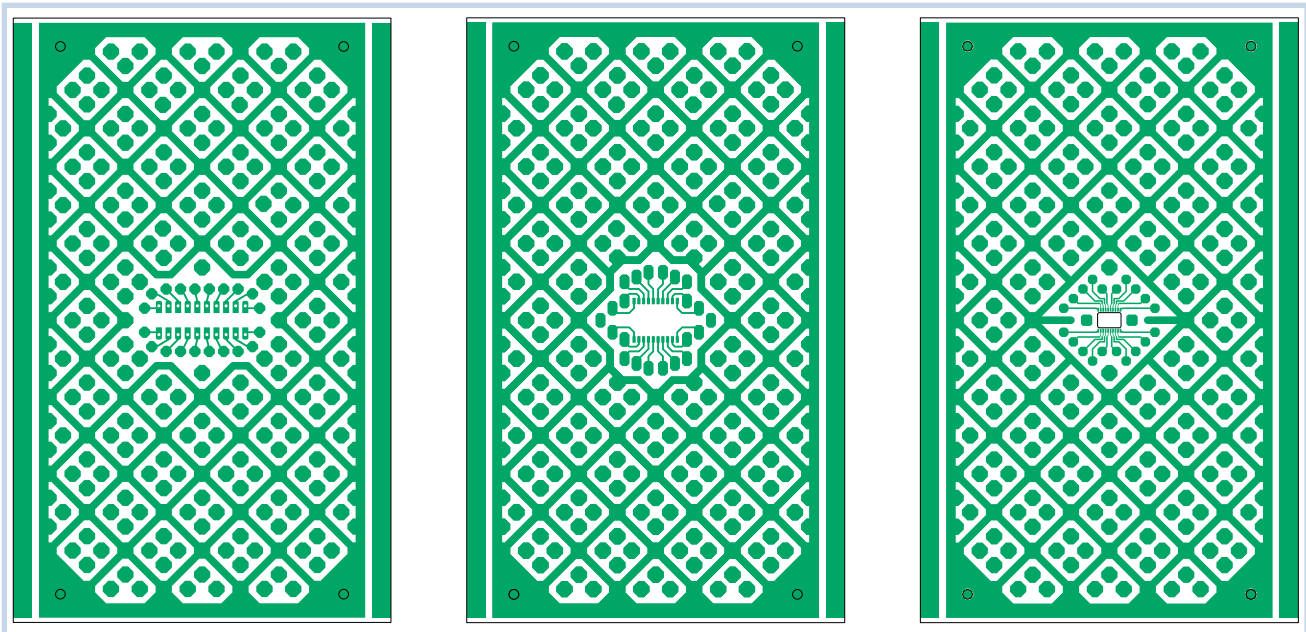
Wolfgang Steimle

Whenever you want to put a circuit together quickly, it will take too long to design a PCB for it first. In that case, the experimenting PCBs shown here are eminently suitable.

Three variations are available: 20-pin DIL package, 20-pin SOIC package and a 20-pin TSSOP package. If you use an IC with fewer pins, then you simply don't use some of the solder pads.

The remaining part of each PCB is filled with solder pads, which are arranged in groups of four. In between is a continuous copper pattern. By connecting this copper grid to ground, the boards are also suitable for RF designs.

The layouts for the various PCBs are shown here at a reduced scale. You can download the true scale layouts from the *Elektor Electronics* website (in pdf format). The file number is **040289-1.zip**. They are also available ready-made from *Elektor Electronics* (refer to SHOP pages or website), the part numbers are **040289-1**, **-2** and **-3**.

(040289-1)

045 Digital VU Meter

Robin van Arem

The circuit presented here has the same functionality as the renowned LM3914, an LED driver that can control 10 LEDs. The circuit shown here can even drive 12 of them, with only 4 outputs. A necessary requirement is that low-current LEDs are used.
The audio signal is amplified by (half of) an LM358 opamp. P1 allows adjustment of the gain and therefore the sensitivity.

One input of the opamp is connected to ground so that only the positive half of the input signal is amplified and is effectively rectified at the same time. The combination of R2/C4 then performs an averaging function after which the signal is converted to a digital value by the 8-bit ADC in the Attiny15L microcontroller. Subsequently, the 12 LEDs are then controlled through a method called 'charlieplexing'. Switch S1 selects between dot and bar mode. The power supply is regulated with the usual 7805. The maximum current consumption amounts to 20 mA at 13.8 V. Power supply voltages of up to 30 V are not a problem, since the LM358 can deal with a maximum of 33 V at least (a 7805 can typically deal with 35 V). The minimum voltage at which the circuit will operate is around 7 V.

The software can be downloaded in the form of a hex file from our website at www.elektor-electronics.co.uk, The file number is **050118-1.zip**. After the code has been programmed into the ATtiny, it is necessary the disable the external reset with the appropriate fuse,
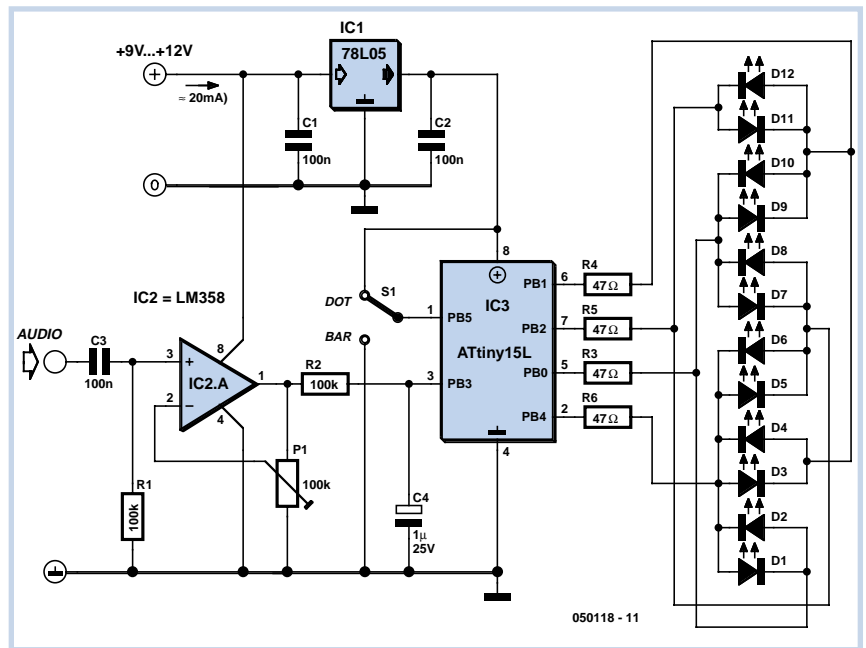
050118 - 11

since the reset pin in this circuit is used as an output.

Those among you who would like to know more on the subject of charlieplex-

ing are referred to www.maxim-ic.com.

(050118-1)

The chip is also available ready-programmed as no. 050118-41.

3 V Headphone Amplifier

046

Ton Giesberts

Many new devices require a headphone connection, but due to the high level of integration and miniaturisation there is usually little room left. The low supply voltage and/or battery voltage also causes problems. If no special techniques are used, the output power and headroom are severely limited.

The MAX4410 made by Maxim overcomes these problems not just by virtue of its small size, but also by including an internal supply inverter (charge-pump). This requires only two small external ceramic SMD capacitors (C6 and C7). The supply voltage to the output stage is now symmetrical and the outputs are therefore relative to ground (no DC offset). This gets round the need for large output capacitors to stop a DC voltage from reaching the headphones. A DC-coupled output can also be implemented using two bridge amplifiers, but virtually all plugs for stereo headphones are asymmetric and use 3-pole connectors (common ground), which can't be connected to a bridge output.

054022 - 11
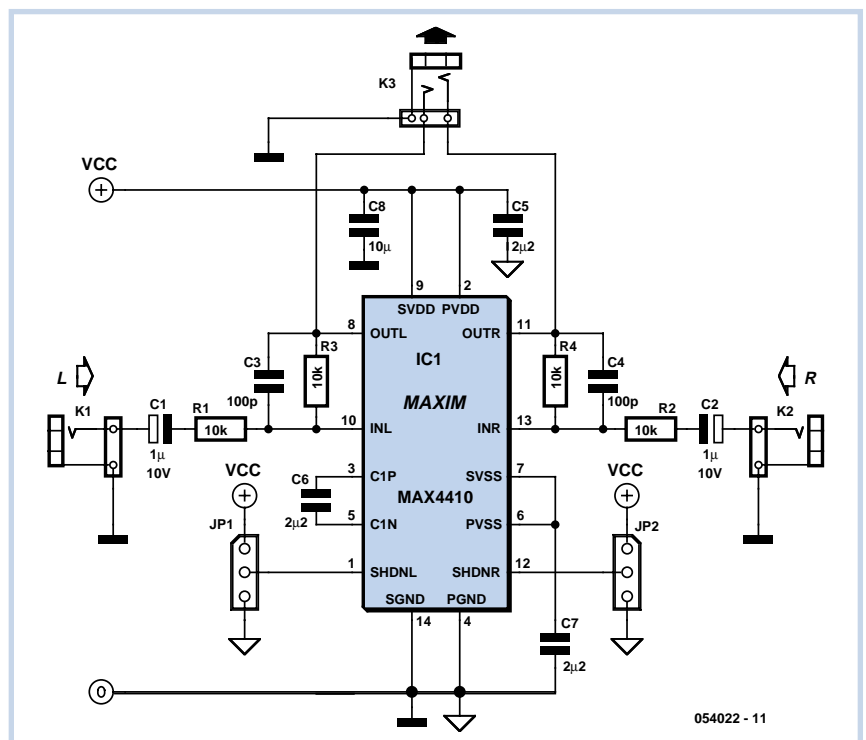
Each channel can be individually turned off (SHDNL and SHDNR) by jumpers JP1

and JP2. During normal operation these two inputs should be connected to the

positive supply. When both channels are turned off the charge pump is also switched off and the current consumption drops to about 6 µA.

The IC also has thermal and short-circuit protection built in. The IC switches to standby mode when the supply voltage is too low and it has a circuit that prevents power-on and off plops at the outputs. The recommended supply voltage is between 1.8 V and 3.6 V. The IC can deliver about 80 mW per channel into a 16 Ω load. The power supply should be able to output at least 200 mA. In practice this means that when you use a power supply that also powers other circuits, it should

have at least 300 mA in reserve.

The amplifiers are configured in inverting mode with a gain set by the ratio of two resistors (R3/R1 or R4/R2); the input impedance is determined by R1 and R2. C1 and C2 are required to decouple any possible DC-offset from the inputs. In the MAX4410 evaluation kit these are small tantalum capacitors, but we don't recommend these for use in audio applications. Plastic film types would be much better, although they take up much more room. HF decoupling is provided by 100 pF capacitors connected in parallel with R3 and R4. These set the bandwidth of the amplifiers to just over 150 kHz. The typi-

cal distortion is 0.003%. For more details you should refer to the MAX4410 datasheet. It is also worth looking at the datasheet for the associated evaluation kit. The choice of capacitors for decoupling etc., their positioning on the board and the overall layout are very critical and demand a lot of attention. Furthermore, the 14-pin TSSOP package (with a pin spacing of 0.65 mm) and SMDs in 0402 packages make it very difficult to construct this circuit yourself. The IC is also available in a (much more difficult to solder) UCSP 16 package (ball grid array, only 2.02 by 2.02 mm).

(054022-1)

047 Servo Points Actuator
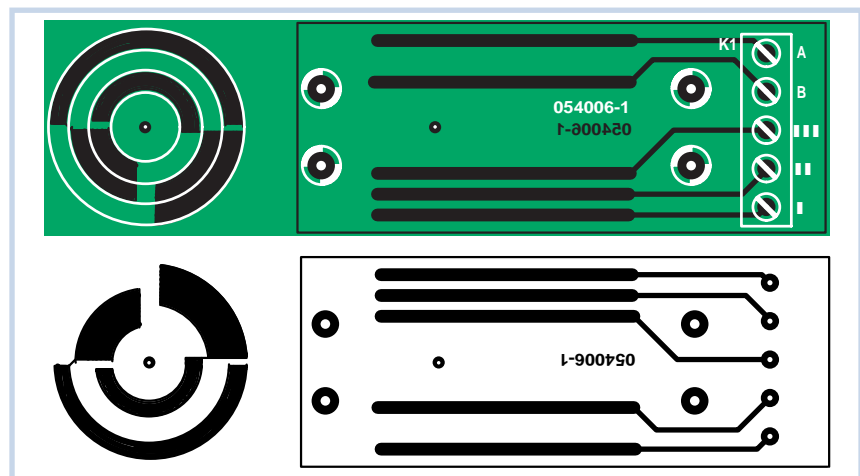
Karel Walraven

Servos for model making can also be used for completely different purposes besides model airplanes, boats and cars. As an example, here a servo is used to operate a set of points for a model railway system. The points are directly actuated by a length of steel wire connected to the servo arm, and they move quietly and smoothly, so the illusion is no longer spoiled by that irritating click-clack sound. The voltage on the point tongues and nose is also switched over by the servo.

As an example for DIY construction, we have designed two small PCBs that can be attached to a servo with a bit of glue. The larger board should be glued to the case of the servo, while the smaller (round) board should be glued to the arm. Several contact strips made from phosphor bronze must be soldered to the larger board.

054006 - 11
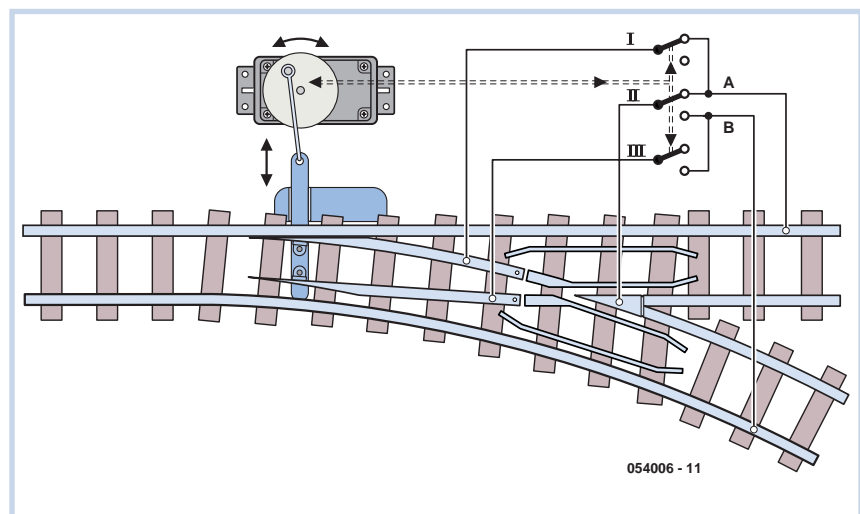
Phosphor bronze is a copper alloy with good spring characteristics. Almost all relay contacts arms are made from this material. It can be obtained from Conrad,

among other sources, in the form of small sheets that can be cut or sawn into strips. Any desired switching scheme can be created by devising a suitable pattern of cop-

per tracks. The actuator works as follows: in the straight-through state, one tongue and the nose are connected to rail B. When the points are moving, both

tongues and the nose are floating, since there is a gap between the segments with no copper. Just before the points reach the turn-out state, the other tongue and the

nose pick up the voltage from rail A. Te PCB shown here is available through The PCBShop.

(054006-1)

Searching for Components

Karel Walraven

This is a tip we think you'll appreciate: the large mail-order firms have a lot of information on their sites that can be quite handy even if you never order anything from them. As an example we can mention www.Farnell.com. If you're looking for a certain component, you can simply use the search menu to retrieve its most important characteristics and immediately see whether it is still generally available and approximately what it costs. The full data sheet is also usually available.

If the component is no longer available or you're looking for an alternative for some reason, you can use the 'find similar products by attributes' function to find several similar products. You can refine your choice in several steps until you finally end up with the components with the desired properties. You can't get the same type of results on a manufacturer's site, because such sites are usually limited to the manufacturer's own products, while a dealer also shows
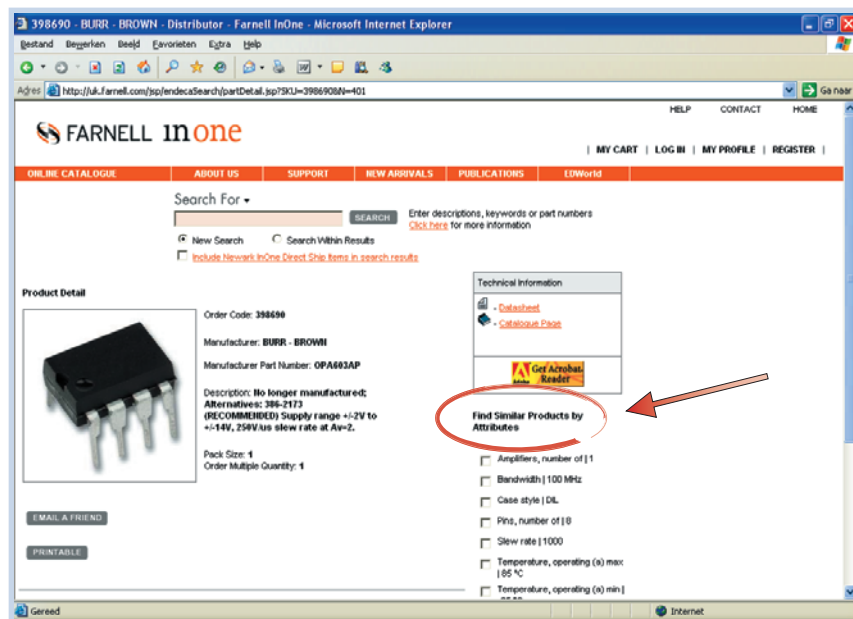
competitive products and you can directly compare their availability and prices. That means you can make things a lot easier for yourself, since it takes time to check out all the manufacturer

sites, with the added risk that even if you find a suitable component it may turn out to not be available unless you plan to buy 100,000 at the same time.

(054039-1)

Short-Wave Superregenerative Receiver

Burkhard Kainka

Superregenerative receivers are characterised by their high sensitivity. The purpose of this experiment is to determine whether they are also suitable for short-wave radio.
Superregenerative receivers are relatively easy to build. You start by building a RF oscillator for the desired frequency. The only difference between a superregenerative receiver and an oscillator is in the base circuit. Instead of using a voltage

divider, here we use a single, relatively high-resistance base resistor (100 kΩ to 1 MΩ). Superregenerative oscillation occurs when the amplitude of the oscillation is sufficient to cause a strong negative charge to be applied repeatedly to the base. If the regeneration frequency is audible, adjust the values of the resistors and capacitors until it lies somewhere above 20 kHz. The optimum setting is when you hear a strong hissing sound. The subsequent audio amplifier should have a low upper cutoff frequency to

strongly attenuate the regeneration signal at its output while allowing signals in the audio band to pass through.
This experimental circuit uses two transistors. A Walkman headphone with two 32-Ω earphones forms a suitable output device. The component values shown in the schematic diagram have proven to be suitable for the 10–20 MHz region. The coil consists of 27 turns wound on an AA battery serving as a winding form. The circuit produces a strong hissing sound, which diminishes when a sta-

tion is received. The radio is so sensitive that it does not require any antenna to be connected. The tuned circuit by itself is enough to receive a large number of European stations. The circuit is usable with a supply voltage of 3 V or more, although the audio volume is greater at 9 V. One of the major advantages of a superregenerative receiver is that weak and strong stations generate the same audio level, with the only difference being in the signal to noise ratio. That makes a volume control entirely unnecessary. However, there is also a specific drawback in the short-wave bands: interference occurs fairly often if there is an adjacent station separated from the desired station by something close to the regeneration frequency. The sound quality is often worse than with a simple
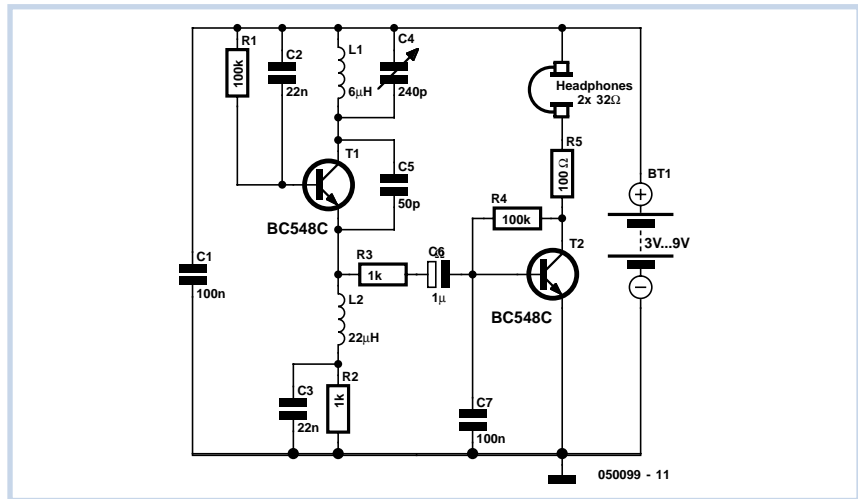
050099 - 11

regenerative receiver. However, this is offset by the absence of the need for manual feedback adjustment, which can be difficult.

(050099-1)

050 Medium-Wave Modulator

Burkhard Kainka

If you insist on using a valve radio and listening to medium-wave stations, you have a problem: the existing broadcasters have only a limited number of records. Here there's only one remedy, which is to build your own medium-wave transmitter. After that, you can play your own CDs via the radio.

The transmitter frequency is stabilised using a 976-kHz ceramic resonator taken from a TV remote control unit. Fine tuning is provided by the trimmer capacitor. If there's another station in the background, which will probably be weak, you can tune it to a heterodyne null, such as 981 kHz. As an operator of a medium-wave transmitter, that's your obligation with respect to the frequency allocations. And that's despite the fact that the range of the transmitter is quite modest. The small ferrite coil in the transmitter couples directly into the ferrite rod antenna in the radio.

The modulator is designed as an emitter follower that modulates the supply voltage of the output amplifier. As the medium-wave band is still mono, the two input channels are merged. The potentiometer can be adjusted to obtain the least distortion and the best sound. The RF amplifier stage has intentionally been kept modest to prevent any undesired radiation. The quality of the output signal

050100 - 11
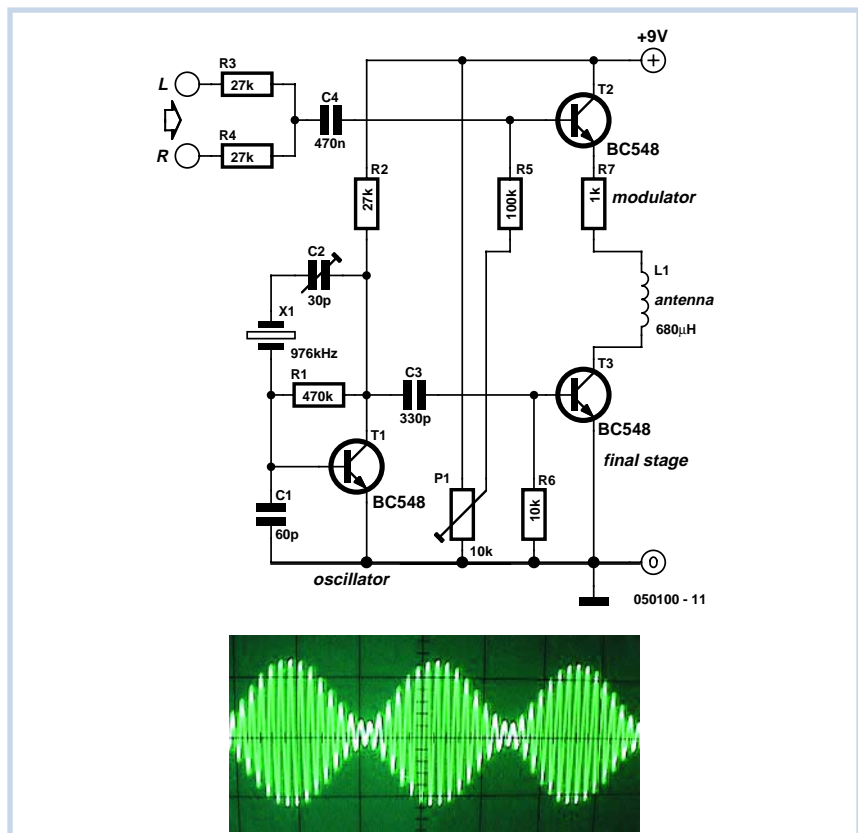
can also be checked using an oscilloscope. Clean amplitude modulation should be clearly visible.

The medium-wave modulator can simply be placed on top of the radio. A signal from a CD player or other source can be fed in via a cable. Now you have a new, strong station on the radio in the medium-wave band, which is distinguished by good sound quality and the fact that it always plays what you want to hear.

(050100-1)

Filter-based 50 Hz Sinewave Generator

Myo Min

When it comes to designing a reliable 50-Hz oscillator, the disadvantage of the good old Wien Bridge oscillator is the difficulty to adjust its own gain. If the gain is higher or lower than the optimum value, the Wien Bridge often fails to work properly.

The circuit shown here combines the functions of a low-pass filter and an integrator, presenting a novel approach to creating a precision 50-Hz source with relatively low distortion.

The circuit is free from any kind of gain setting network. Opamp IC.1B and R3/C4/C5 act as an inverting integrator effectively converting the incoming sine wave (from IC.1A) into a square wave with a good amount of harmonics. R4, D1 and D2 divide the square wave to the desired level. For optimum switching speed, a matching number of series-connected low-power switching diodes like the ubiquitous 1N4148 may be used instead of the zener diodes. The output voltage is directly proportional to the zener diode values. The second opamp, IC.1A and its surrounding components R1, C1 acts as a two-pole low-pass filter supplying the 50-Hz output signal via R5. Theoretically, the filter roll-off is at 24 Hz, which means the base frequency of 50 Hz is also attenuated to some degree. That is not too serious as long as higher harmonics are properly attenuated. The design with the component values shown here will supply an output voltage of 1.24 V at a frequency of 49.6 Hz. Current consumption was measured at less than 5 mA, while the distortion was 3.7% when using an LF353 opamp.

We performed an FFT (fast Fourier Transform) analysis on the generator's output signal. Even-numbered harmonics were found clearly less in level than their odd-numbered counterparts. This is caused by a slight asymmetry in the generator's internal square wave. In our prototype, the FFT graph showed the 3rd harmonic at a relatively high level of –29.2 dB; the 2nd harmonic did much better at just –67.7 dB.

(040093-1)
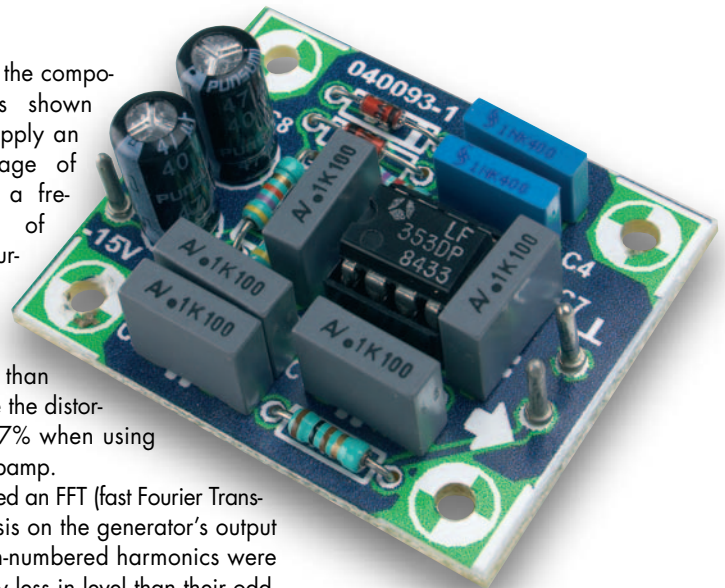
COMPONENTS LIST

Resistors:
R1,R2,R3 = 47kΩ
R4 = 4kΩ7
R5 = 100Ω

Capacitors:
C1,C2,C3,C6,C7 = 100nF

C4,C5 = 1nF
C8,C9 = 47µF 25V radial

Semiconductors:
D1,D2 = zener diode 5.6V 400mW
IC1 = LF353DP

Miscellaneous:
PCB, ref. 040093-1 from The PCBShop

052

Long-Delay Stop Switch

TLE4905L

UA UB
GND

track

track interruptions

040058 - 11
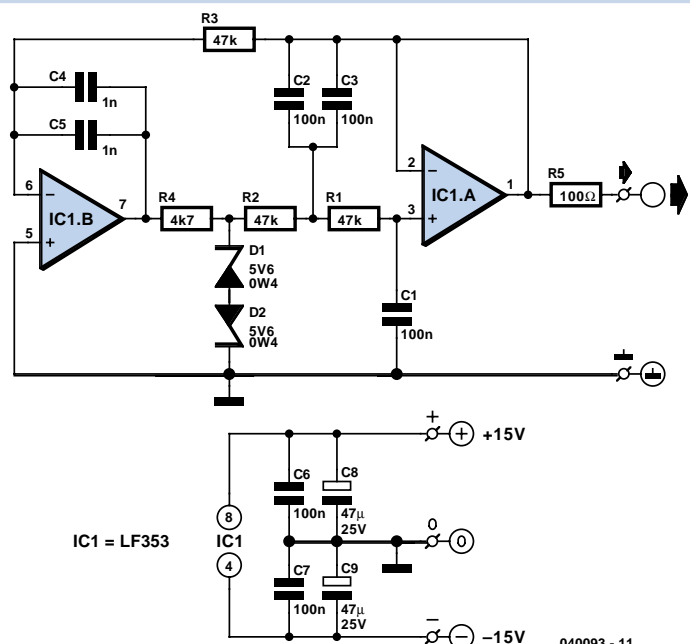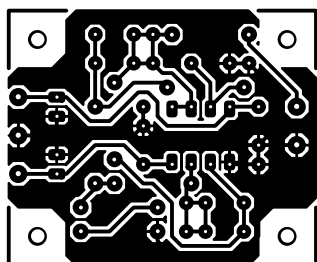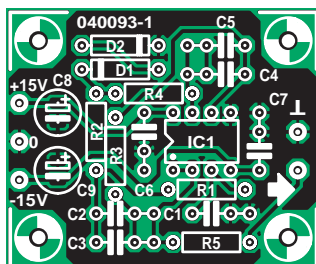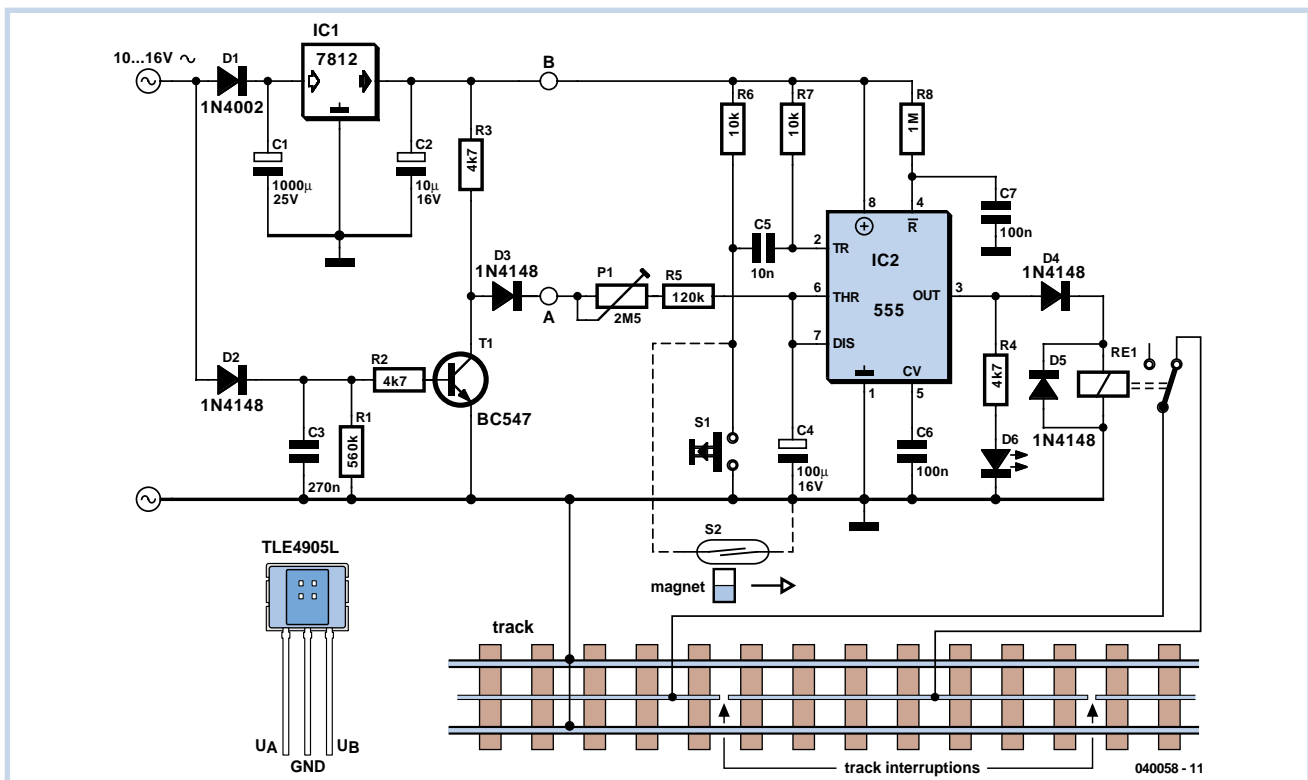
Robert Edlinger

Presettable times for train stops in stations are indispensable if you want to operate your model railway more or less realistically according to a timetable. This circuit shows how a 555 timer can be used with a relatively small timing capacitor to generate very long delay times as necessary by using a little trick (scarcely known among model railway electronic technicians): pulsed charging of the timing network. Such long delays can be used in hidden yards with through tracks, for instance.

As the timer is designed for half-wave operation, it requires only a single lead to the transformer and one to the switching track or reed contact when used with a Märklin AC system (H0 or H1). The other lead can be connected to any desired grounding point for the common ground of the track and lighting circuits.

As seen from the outside, the timer acts as a monostable flip-flop. The output (pin 3) is low in the quiescent state. If a negative signal is applied to the trigger input (pin 2), the output goes high and C4 starts charging via R3 and R4. When the voltage on C4 reaches 2/3 of the supply voltage, it discharges via an internal transistor connected to pin 7 to 1/3

of the supply voltage and the output (pin 3) goes low. The two threshold values (1/3 and 2/3) are directly proportional to the supply voltage. The duration of the output signal is independent of the supply voltage:

$$t = 1.1(R4 + R5) \times C4$$

if the potentiometer is connected directly to the supply line (A and B joined). The maximum delay time that can be generated using the component values shown in the schematic diagram is 4.8 minutes. However, it can be increased by a factor of approximately 10 if the timing network is charged using positive half-waves of the AC supply voltage (reduced to the 10–16-V level) instead of a constant DC voltage.

The positive half-waves of the AC voltage reach the timing network via D2, the transistor, and D3. Diode D3 prevents C4 from being discharged between the pulses. The total resistance of R4 and R5 should not be too high (no more than 10 MΩ if possible), since electrolytic capacitors (such as are needed for C4) have significant leakage currents. Incidentally, the leakage current of aluminium electrolytic capacitors can be considerably reduced by using a supply voltage

well below the rated voltage. Capacitor C6 is intended to suppress noise. It forms a filter network in combination with an internal voltage-divider resistor.

If a vehicle happens to remain standing over the reed switch so the magnet holds the contacts constantly closed, the timer will automatically be retriggered when the preset delay times out. In this case the relay armature will not release and the locomotive will come to the 'end of the line' in violation of the timetable. This problem can be reliably eliminated using R6, R7 and C5. This trigger circuit ensures that only one trigger pulse is generated, regardless of how long the reed switch remains closed.

RC network R8/C7 on the reset pin ensures that the timer behaves properly on switch-on (which is far from being something to be taken for granted with many versions of the 555 or 556 dual timer).

Reed switches have several special characteristics that must be kept in mind when fitting them. The contact blades, which are made from a ferromagnetic material, assume opposite magnetic polarities under the influence of a magnetic field and attract each other. Here the position and orientation of the magnet, the distance between the magnet and the reed

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switch, and the direction of motion of the magnet relative to the switch are important factors. The fragility of the glass housing and the thermal stress from soldering (stay at least 3 mm away from the glass housing) require a heat sink to be used between the soldering point and the glass/metal seal. A suitable tweezers or flat-jawed pliers can be used for this purpose. If you need to bend the leads, use flat-jawed pliers to protect the glass/metal seal against mechanical stresses.

Matching magnets in various sizes are available from toy merchants and electronics mail-order firms. They should preferably be fitted underneath the locomotive or carriage. However, the magnet can also be fitted on the side of a vehicle with a plastic body. In this case the reed switch can be hidden in a mast, bridge column or similar structure or placed in a tunnel, since the distance must be kept to less than around 10 mm, even with a strong magnet. If fitting the circuit still presents problems (especially with Märklin Z-gauge Mini-Club), one remedy is to generate the trigger using a unipolar digital Hall switch, such as the Siemens TLE4905L or Allegro UGN3120. To avoid coupled-in interference, the stop timer should be fitted relatively close to the Hall sensor (use screened cable if necessary). Pay attention to the polarity of the magnet when fitting it to the bottom of the vehicle. With both types of sensors, the South pole must point toward the front face of the Hall IC (the face with the type marking). The North pole is sometimes marked by a dab of paint. Generally speaking, the polarity must be determined experimentally.

Fitting the circuit is not a problem with Z-gauge and 1-gauge tracks, since the distance between the iron parts (rails) and the Hall switch is sufficiently large. In an HO system, some modifications must be made to the track bed of the Märklin metal track. Cut a suitably sized 'window' between one wheel rail and the centre rail in order to prevent secondary magnetic circuits from interfering with the operation of the sensor. Keep the distance between the magnet and the case of the Hall switch between 5 and 10 mm, depending on the strength of the magnet, to ensure reliable actuation.

(040058-1)

Transformerless 5-volt Power Supply 053

Srdjan Jankovic and Branko Milovanovic

An increasing number of appliances draw a very small current from the power supply. If you need to design a mains-powered device, you could generally choose between a linear and a switch-mode power supply. However, what if the appliance's total power consumption is very small? Transformer-based power supplies are bulky, while the switchers are generally made to provide greater current output, with a significant increase in complexity, problems involving PCB layout and, inherently, reduced reliability.

Is it possible to create a simple, minimum-part-count mains (230 VAC primary) power supply, without transformers or coils, capable of delivering about 100 mA at, say, 5 V? A general approach could be to employ a highly inefficient stabilizer that would rectify AC and, utilizing a zener diode to provide a 5.1 V output, dissipate all the excess from 5.1 V to (230×√2) volts in a resistor. Even if the load would require only about 10 mA, the loss would be approximately 3 watts, so a significant heat dissipation would occur even for such a small power consumption. At 100 mA, the useless dissipation would go over 30 W, making this scheme completely unacceptable. Power conversion efficiency is not a major consideration here;
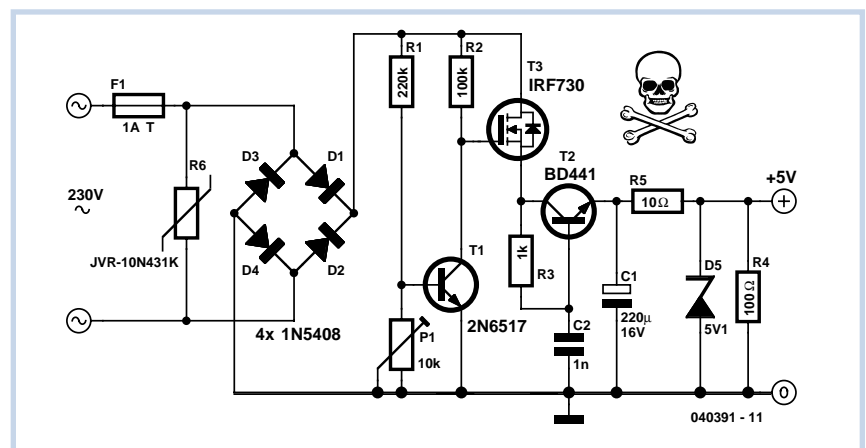
040391 - 11

instead, the basic problem is how to reduce heavy dissipation and protect the components from burning out.

The circuit shown here is one of the simplest ways to achieve the above goals in practice. A JVR varistor is used for over-voltage/surge protection. Voltage divider R1-R2 follows the rectified 230 V and, when it is high enough, T1 turns on and T3 cannot conduct. When the rectified voltage drops, T1 turns off and T3 starts to conduct current into the reservoir capacitor C1. The interception point (the moment when T1 turns off) is set by P1 (usually set to about 3k3), which controls the total output current capacity of the power supply: reducing P1 makes T1

react later, stopping T3 later, so more current is supplied, but with increased heat dissipation. Components T2, R3 and C2 form a typical 'soft start' circuit to reduce current spikes — this is necessary in order to limit C1's charging current when the power supply is initially turned on. At a given setting of P1, the output current through R5 is constant. Thus, load R4 takes as much current as it requires, while the rest goes through a zener diode, D5. Knowing the maximum current drawn by the load allows adjusting P1 to such a value as to provide a total current through R5 just 5 to 6 mA over the maximum required by the load. In this way, unnecessary dissipation is much reduced, with zener stabilization function preserved. Zener diode D5 also protects C1 from overvoltages, thus enabling te use of low-cost 16 V electrolytics. The current flow through R5 and D5, even when the load is disconnected, prevents T3's gate-source voltage from rising too much and causing damage to device. In addition, T1 need not be a high-voltage transistor, but its current gain should exceed 120 (e.g. BC546B, or even BC547C can be used).

(040391-1)

054 Telephone Line Indicator

Flemming Jensen

Many 'busy' indicators for use in telephone systems present undesirable loading of the telephone line. Some circuits are very simple indeed to the extent of only loading the line when it is not in use. The downside is that a (usually green) LED lights when the line is *not* occupied. The author feels that a LED should flash when the line is actually in use by another extension and that the circuit should present a minimal load of the line. The circuit shown here fulfills both requirements. We should, however, not forget to mention its only drawback: its needs to be powered from a battery or an energy-friendly battery eliminator (a.k.a. wall cube or mains adapter). If a high-efficiency LED is used then the current drain from the 9-volt supply will be so small that a standard (170-mAh) 9-V PP3 battery will last for months. Considering that the LED is powered at current of 2 mA by T1, theoretically some 85 hours of 'LED on' time can be obtained.

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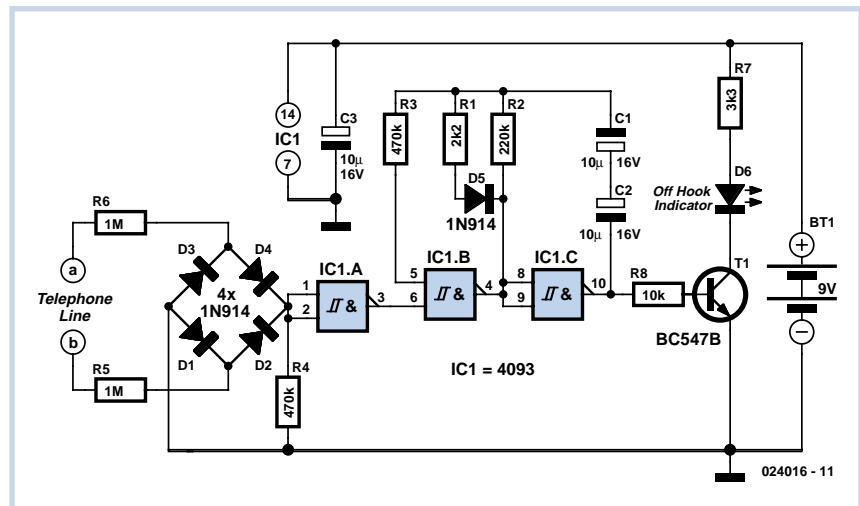
If, for some reason, you wish to change the flash frequency or on/off ratio (duty cycle) then do feel free to experiment with the values and ratio of R1 and R2. The effect will also depend on the brand of the 4093 IC, its exact logic High/Low switching thresholds and hysteresis.

The circuit is not approved to BABT standards for connection to the public switched telephone network (PSTN). Please check local/national regulations.

(024016-1)

055 PC IrDA Port

Luc Lemmens

Many PC motherboards (perhaps most of them, in fact) are fitted with a connector for an infrared communication port. That connector is generally not used, since IrDA never became truly successful and has probably already seen its best days. Still, quite a few modern devices that can use this link to communicate with a PC are available, including printers, PDAs, mobile phones, and laptops. However, the link between the above-mentioned connector on the motherboard and the outside world, the IrDA interface, is not supplied with any motherboard and is usually not available in computer shops as an accessory.

Fortunately, the necessary hardware is quite simple, and most solder artists should find it dead easy to build it as a 'point-to-point' construction. Selection of the IrDA IC is not critical, and just about any type is suitable. However, you should check the size of the module when making your purchase, because quite a few types are so small that

they're difficult to solder.

Naturally, the interface must be able to see outside, and it should preferably be fitted at the front of the computer. A cover plate for a free floppy-disk or CD drive bay is quite suitable for this purpose. It's easy to remove from the case, and it should be easy to make a neat opening in it for the interface.

The connection to the motherboard is another story. Unfortunately, the motherboard manufacturers never agreed on a standard for this. That means you'll have to consult your user's manual, and if that documentation is no longer to be found, the manufacturer's website can remedy the situation in 99% of the cases, since most manuals are available as downloads. Be careful: a mistake in the connection can cause serious damage to the motherboard, so check everything thoroughly and carefully before switching on the PC. The next step is to check the BIOS settings of the PC (to verify that the IrDA port is
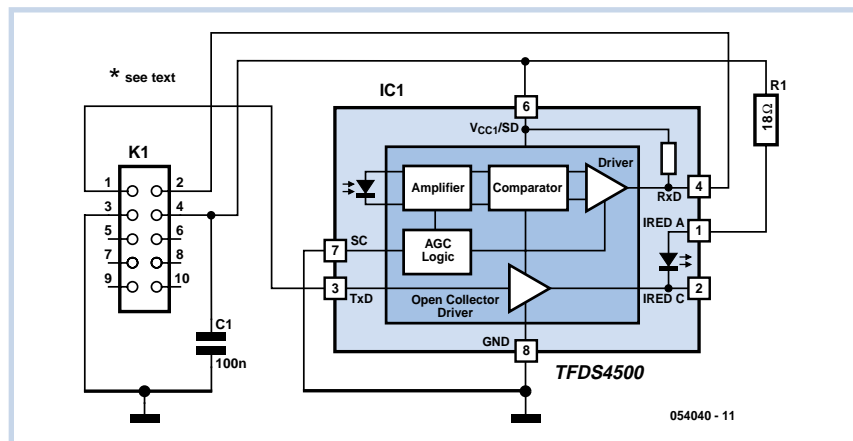
enabled) and install the drivers. What this involves varies from one PC to the next, and it also depends on the operating system, so there's no single recipe for it. If you aren't keen on figuring all this out for yourself, you can try searching the Internet. A highly suitable site is www.infrarot-port.de, which clearly explains in Ger-

man and English what you have to do and has all sorts of settings, drivers and patches, including supplementary explanations and experience with various types of motherboards. That's often what takes the most time in getting this serial interface to start talking.

(054040-1)

Carriage Detection for Model Railway

Karel Walraven

Model railway builders know all about this: it is a troublesome job to get a block system to function properly. We present here a simple, reliable and cheap solution on how to fit resistors between insulated wheels, as is used with the two-rail systems that operate a block detection system based on current consumption.

A block, in this case, is an isolated section of rail. It is considered occupied if a load is detected. The locomotive usually has at least some current consumption, even if it is just for the lights. Digital loco-

motives with a decoder always consume a few milliamps, which is also sufficient for detection. To be able to detect the rolling stock, a little more effort is required. When a single carriage is accidentally left behind in a block, the detector has to be able to sense this and indicate the block as occupied. In order to achieve this, all axles of all carriages have to be fitted with a small resistor, so that a small current can flow.

Carriages with internal lighting have additional sliding contacts (on the wheels) and a small lamp or LED as load. However, it is much too complicated to fit all carriages with additional sliding contacts. That is why it is usual for a resistor to be placed across the plastic insulating sleeve. One of the wheels is isolated with respect to the axle, otherwise the wheels would short circuit the rails. This is, of course, not the intention with a two-rail system. Axles with resistors are available read-made, but are somewhat expensive.

Usually an SMD or 1/8-W type resistor is used, with a value ranging from about 4k7 to 10k. It is mechanically mounted with a little (epoxy) glue and the actual electrical connection is made with conductive glue (often containing silver particles). This will usually last for years, but regular

inspection is required if carriages are subject to rough handling. In addition, conductive glue is expensive, not always available and dries out after a while.

We consider the following a better method: grab the axle with small pliers and carefully pull of the isolated wheel from the axle. Also remove the insulating sleeve. Cut a two cm piece of thin hook-up wire and remove the individual strands. They have to be thin, no more than about 0.1 mm. Put the wheel back on, but now with a 0.1-mm wire between axle and sleeve and opposite that a 0.1-mm wire between sleeve and wheel. You now have created two connections. With a little bit of dexterity you can

solder a resistor to those wires. First practise a little on a few old axles, the example in the pictures isn't the newest model either! Don't forget to glue the resistor down, otherwise the thin wires will certainly break after a short time.

It is also possible to first solder the wires on an SMD resistor and then re-assemble the axle. Do it whichever way you personally find the easiest.

(054017-1)

057

Short-Wave Regenerative Receiver

for AM and DRM

Burkhard Kainka

Is it possible to make a short-wave regenerative valve receiver so stable that it is even suitable for DRM? And is it possible to do this using a 6-V supply, so only a single voltage is necessary for the filament and anode supply? It looks like it might be possible with an EL95, which has good transconductance even at low anode voltages, although it is actually an output-stage pentode instead of an RF valve. Besides that, it draws only a modest 200 mA of heater current. Everything can be operated from a small battery, which eliminates any problems with 50-Hz hum. The stability depends entirely on the tuned circuit. Consequently, a robust coil with 20 turns of 1.5-mm wire was wound on a PVC pipe with a diameter of 18 mm. With short leads to the air-dielectric variable capacitor, this yields an unloaded Q factor considerably larger than 300.

The schematic shows a regenerative receiver with feedback via the cathode. The amount of feedback is adjusted using the screen grid voltage. The audio signal across the anode resistor is coupled out via a capacitor. No additional gain is
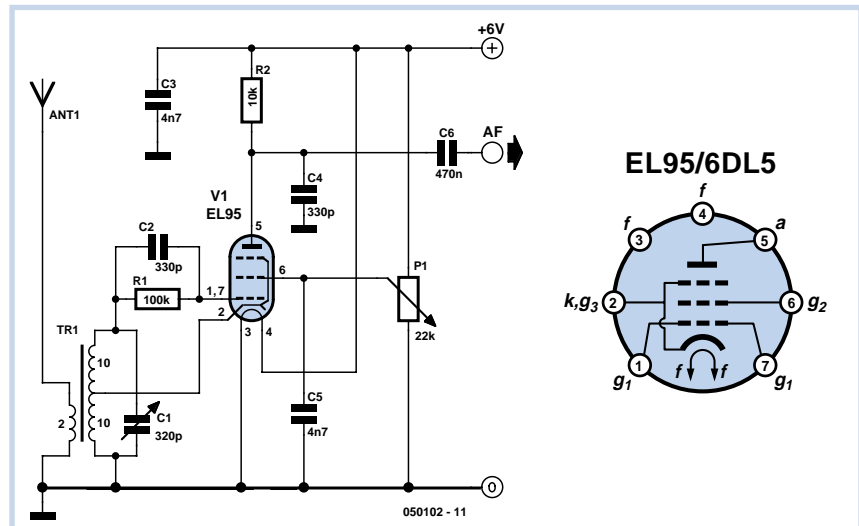
necessary, since the voltage level is sufficient for a direct connection to the Line input of a PC sound card. A screened cable should be used for this connection. A two-turn antenna coil is located at the bottom end of the tuned circuit. It provides very loose coupling to the antenna, which is important for good stability.

Now it's time to see how it works in practice. Despite the open construction, the frequency drift is less than 1 Hz per minute. That's the way it should be if you want to receive DRM. Quite strong feedback should be used, so the regenerative cir-

cuit acts like a direct mixer or a self-oscillating mixer stage.

Every strong DRM signal could be seen using DREAM and tuned to 12 kHz. A total of six different DRM frequencies could be received in the 40-m and 41-m bands. If no good DRM stations are available, the receiver can also pick up AM transmitters. In this case, the amount of feedback should be reduced. The PC can be set aside for AM reception, since all you need is a direct connection to an active PC speaker.

(050102-1)

058

Improved DECT Battery Charger

Karel Walraven

After buying a number of DECT telephones, we noticed that these became quite warm while charging. That surprised us, because the manufacturer wrote in the manual that the batteries had to be charged for 14 hours. That would lead you to conclude that the batteries are charged at $1/10$th of the nominal capacity. But we had the feeling that the batteries were getting rather warm for such a small charging current. That is why we quickly reached for a screwdriver and explored the innards of the charging station. The accompanying schematic reveals what is going on.

The batteries are 'simply' charged from a 9-V mains adapter. In series with the output are a diode and a resistor. A quick calculation shows that a current of about

160 mA will flow and this was indeed the case when measured with a multimeter. That means that, for the AAA cells used here, rated at 650 mAh, the charging current isn't $1/_{10}$ C, but $1/_4$ C! This is rather high and certainly not good for the life expectancy of the batteries. The remedy is simple: increase the value of the 25 Ω series resistor so that the charging current will be less. We chose a value of 68 Ω, resulting in a charging current of about 60 mA.

You may ask what the purpose of the remainder of the circuit it. This is all required to turn on the LED, which indicates when charging is taking place. During charging, there is a voltage drop of about 4 V across R1. T1 will then receive base current via R2 and the LED turns on. The resistor in series with the LED limits the LED current.

The fact that the batteries are charged with an unregulated supply is not such a problem. The mains voltage will vary

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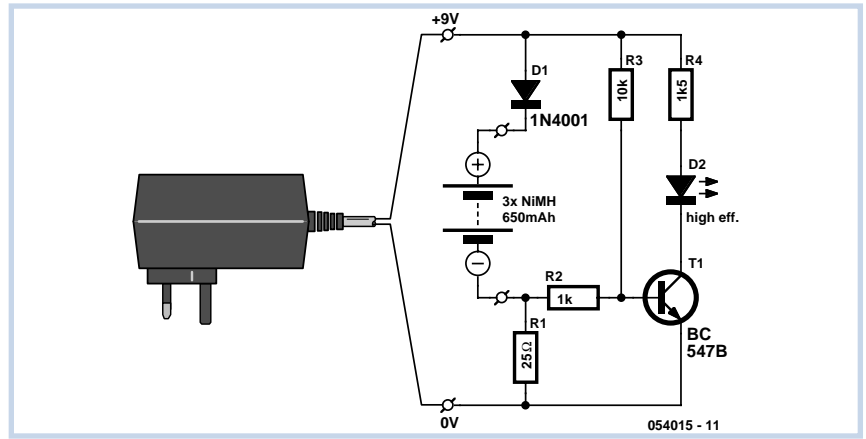
somewhat, but with a maintenance charge such as in this application it is not necessary to charge with an accurate constant current, provided that the current is not too high.

For the curious, here is the calculation for the charging resistor: three cells are being charged. The charging voltage of a

NiMH cell is about 1.4 V. The voltage drop across D1 is about 0.7 V. That leaves a voltage across the resistor of:

$9_{mains\ adapter} - 4.2_{batteries} - 0.7_{diode} = 4.1\ V$

Therefore, there flows a current of 4.1/25 = 164 mA.

(054015-1)

1:800 Oscillator

Bernd Oehlerking

040221 - 11

040221 - 12
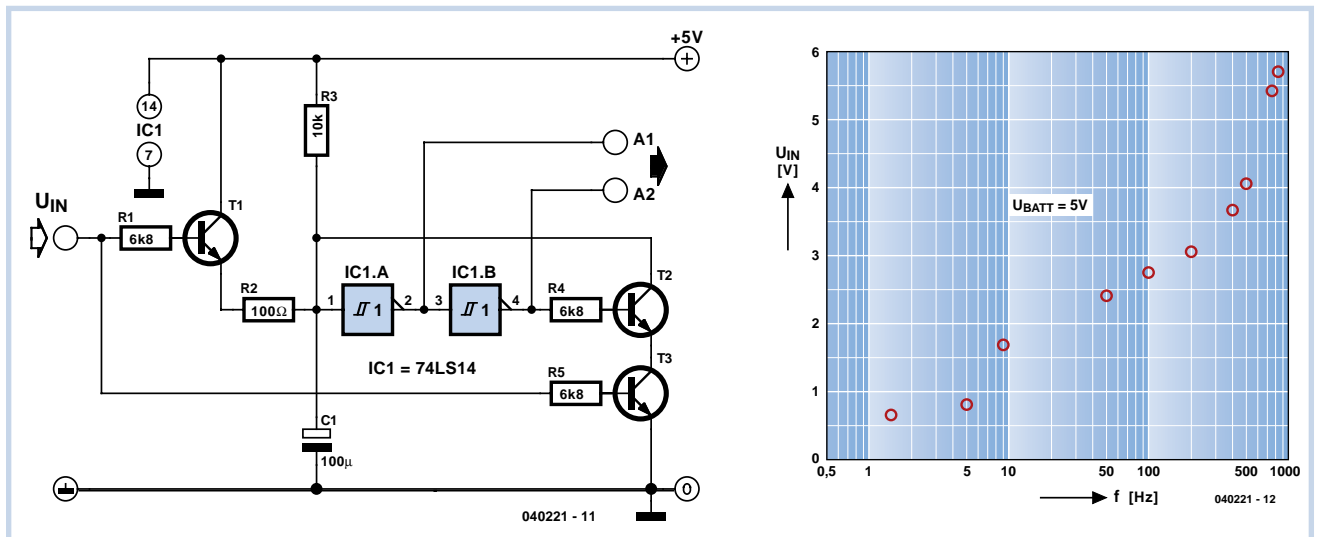
Oscillators are ten a penny, but this one has something special. Its frequency can be adjusted over a range of 800:1, it is voltage controlled, and it switches off automatically if the control voltage is less than approximately 0.6 V.

As can be seen from the chart, the characteristic curve f = f(Ue) is approximately logarithmic. If the input voltage is less than

0.7 V, T1 and T3 are cut off. The capacitor then charges via the 10-kW resistor. The combination of the capacitor, the two Schmitt triggers and T2 form the actual oscillator circuit. However, T2 cannot discharge the capacitor, because T3 is cut off. In this state, a low level is present at A1 and a high level is present at A2. If the input voltage is increased, T3 starts conducting. This allows the capacitor to be discharged via T2, and the circuit starts to

oscillate. If Ue is further increased, the capacitor receives an additional charging current via T1 and the l00-Ω resistor. That causes the oscillator frequency to increase. In situations where the duty cycle of the output signal is not important (such as when the circuit is used as a clock generator), this circuit can be used as a voltage-controlled oscillator (VCO) with a large frequency range and shutdown capability.

(040221-1)

MP3 Adapter for TV

Ton Giesberts

Nowadays there are many ways in which you can listen to music. A portable MP3 player with headphones is often used while on the move. But when you need to stay in a hotel and would like to listen without headphones to your favourite music in your hotel room, things become more difficult. Most hotel rooms have a TV, but rarely a music centre.

We have designed a fairly compact adapter that lets you connect an MP3 player (or any other portable device) to the SCART socket of a TV. It is obvious that this will only work if the TV has a SCART socket! The board directly feeds the headphone signals to the correct SCART pins. If the TV only has mono sound, then the left input signal is probably used. The connec-

tion between the adapter and TV is made with a SCART cable. It is
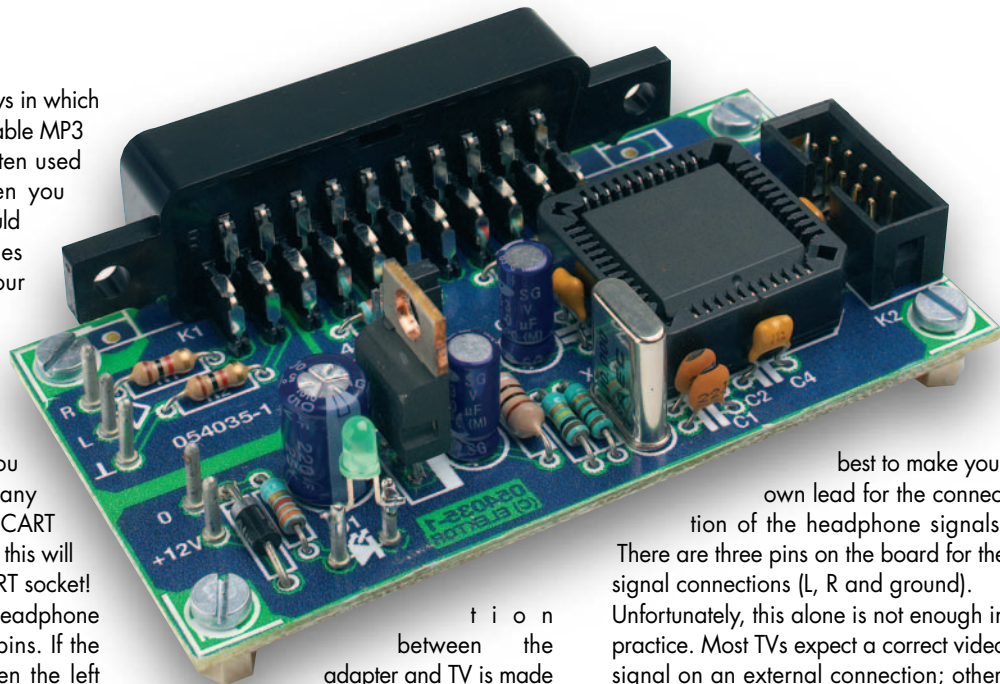
best to make your own lead for the connection of the headphone signals. There are three pins on the board for the signal connections (L, R and ground). Unfortunately, this alone is not enough in practice. Most TVs expect a correct video signal on an external connection; otherwise the input is turned off (muted). To get
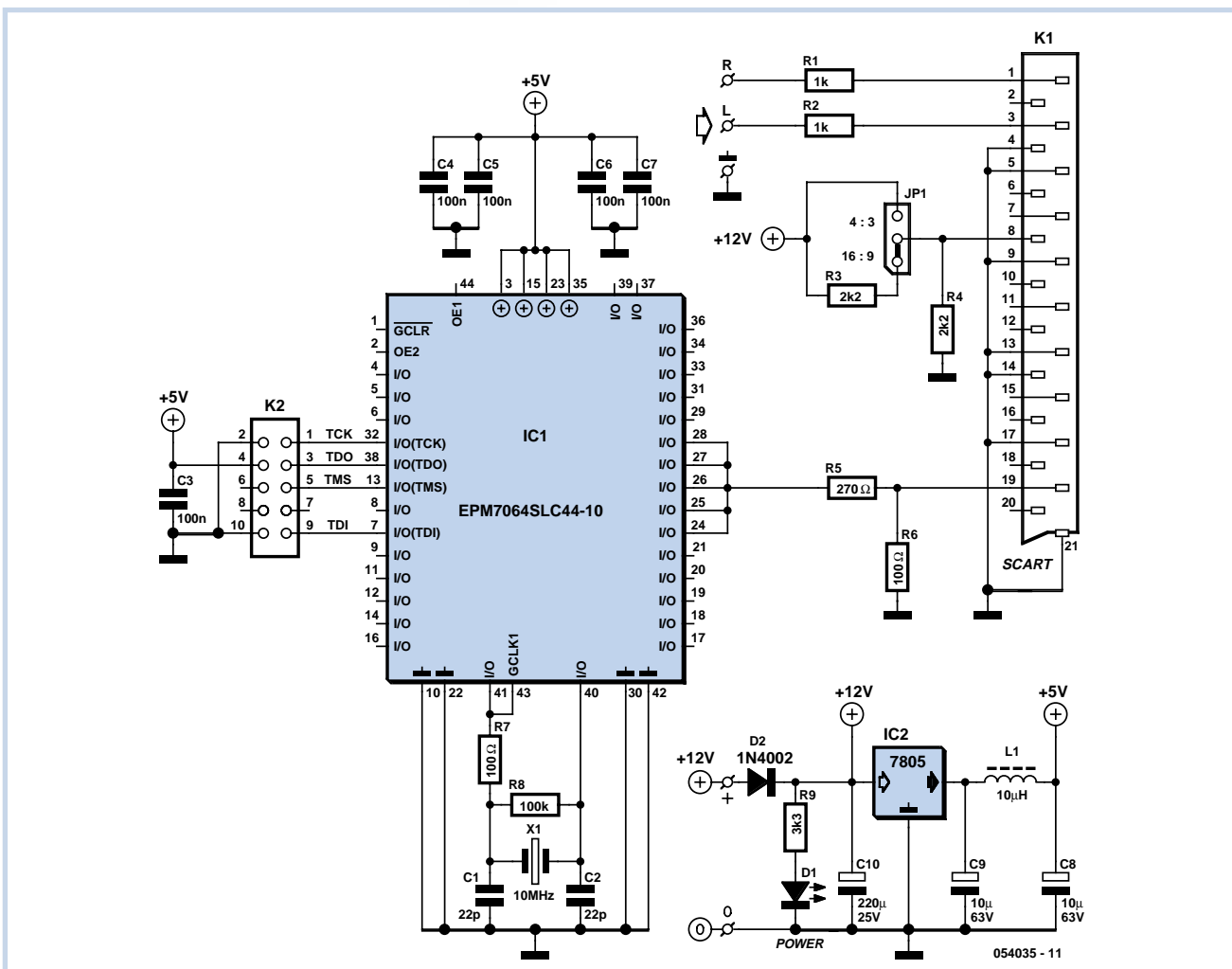
round this problem we used a programmable logic device (IC1, an EPM7064 made by Altera) to generate a video sync signal. More detailed information can be found in the sync generator article elsewhere in this issue. It is sufficient to state that this IC generates a sync signal according to the PAL/SECAM specification. Several outputs are connected in parallel to give a stronger output signal. Potential divider R5/R6 produces a signal that is slightly bigger than a normal video signal (normally 30% of 1 V_{pp} into 75 Ω). The signal is now a bit under 0.5 V_{pp} into 75 Ω. The output impedance of R5/R6 is 75 Ω, which reduces reflections should the cable be incorrectly terminated. ISP connector K2 has been included for those of you who would like to experiment with this circuit (see www.altera.com).

The TV can be automatically switched to an external source using the video-status signal (pin 8). Modern widescreen TVs use this signal to switch between two display modes. A voltage between 9.5 and 12 V results in a 4:3 display and a voltage between 4.5 and 7 V switches to a widescreen format. Jumper JP1 can be used to control this function of the TV. For older TVs the jumper should be in the 4:3 position. In all cases the display remains dark though.

A supply voltage is required for IC1 as well as the video-status signal. This is provided by a mains adapter with a stabilised 12 V output, preferably a modern switch-mode supply. Voltage regulator IC2 provides a stable 5 V to IC1 and K2. LED D1 indicates that the circuit is powered up. The current consumption is mainly determined by IC1 and is about 80 mA.

(054035-1)
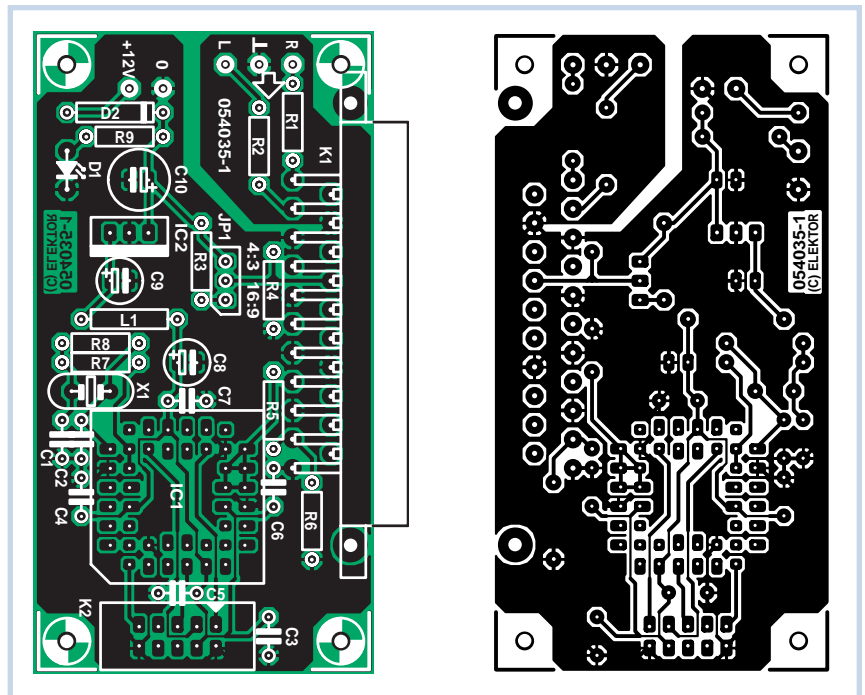
COMPONENTS LIST

Resistors:
R1,R2 = 1kΩ
R3,R4 = 2kΩ2
R5 = 270Ω
R6,R7 = 100Ω
R8 = 100kΩ
R9 = 3kΩ3

Capacitors:
C1,C2 = 22pF
C3-C7 = 100nF ceramic, lead pitch 5mm
C8,C9 = 10µF 63V radial
C10 = 220µF 25V radial

Inductor:
L1 = 10µH

Semiconductors:
D1 = LED, low-current
D2 = 1N4002
IC1 = EPM7064SLC44-10 PLC44 with socket (programmed, Publisher's order code **054035-31** *)
IC2 = 7805

Miscellaneous:
JP1 = 3-way SIL header with jumper
K1 = SCART socket (female), PCB mount, angled
K2 = 10-way boxheader
X1 = 10MHz quartz crystal
PCB, Publisher's order code **054035-1** *
Disk, EPM7064 code, Publisher's order code **054035-11** * or Free Download *

* See Elektor SHOP pages or www.elektor-electronics.co.uk

Solar-powered SLA Battery Maintenance

061

Myo Min

This circuit was designed to 'baby-sit' SLA (sealed lead-acid or 'gel') batteries using freely available solar power. SLA batteries suffer from relatively high internal energy loss which is not normally a problem until you go on holidays and disconnect them from their trickle current charger. In some cases, the absence of trickle charging current may cause SLA batteries to go completely flat within a

few weeks. The circuit shown here is intended to prevent this from happening. Two 3-volt solar panels, each shunted by a diode to bypass them when no electricity is generated, power a MAX762 step-up voltage converter IC. The '762 is the 15-volt-out version of the perhaps more familiar MAX761 (12 V out) and is used here to boost 6 V to 15 V. C1 and C2 are decoupling capacitors that suppress high and low frequency spurious components produced by the switch-

mode regulator IC. Using Schottky diode D3, energy is stored in inductor L1 in the form of a magnetic field. When pin 7 of IC1 is open-circuited by the internal switching signal, the stored energy is diverted to the 15-volt output of the circuit. The V+ (sense) input of the MAX762, pin 8, is used to maintain the output voltage at 15 V. C4 and C5 serve to keep the ripple on the output voltage as small as possible. R1, LED D4 and pushbutton S1 allow you to check the

presence of the 15-V output voltage. D5 and D6 reduce the 15-volts to about 13.6 V which is a frequently quoted nominal standby trickle charging voltage for SLA batteries. This corresponds well with the IC's maximum, internally limited, output current of about 120 mA.

The value of inductor L1 is not critical — 22 µH or 47 µH will also work fine. The coil has to be rated at 1 A though in view of the peak current through it. The switching frequency is about 300 kHz. A suggestion for a practical coil is type M from the WEPD series supplied by Würth (www.we-online.com). Remarkably, Würth supply one-off inductors to individual customers. At the time of writing, it was possible, under certain conditions,
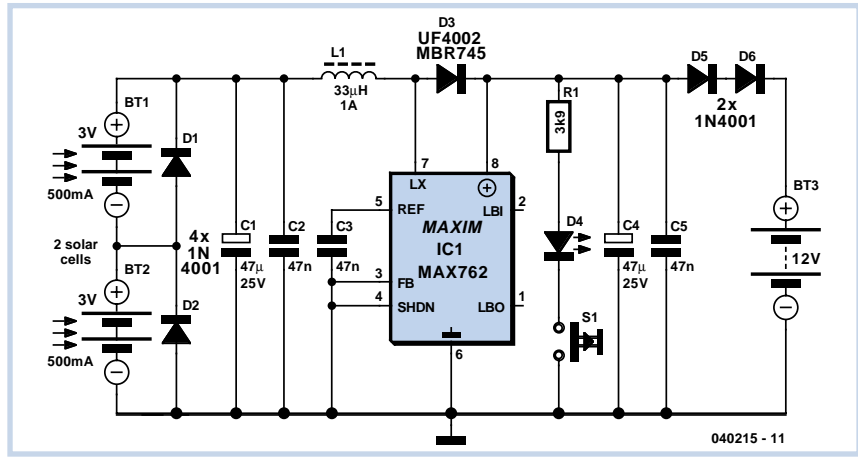
to obtain samples, or order small quantities, of the MAX762 IC through the Maxim website at www.maxim-ic.com.

(040215-1)

Simple Window Comparator

062

Gregor Kleine

A window comparator that monitors whether its input voltage Uin lies within a defined voltage window can be built using only a few components.

The circuit shown in **Figure 1** is a version that operates with complementary supply voltages. Two diode pairs are connected across the inputs of the comparator IC and supplied with bias currents via R1 and R2. If the input of the circuit is open, the current flowing through diode pair D2a and D2b (whose common terminal is connected to ground) causes the inverting input of the comparator to be at +0.7 V and the non-inverting input to be at –0.7 V. The comparator output is thus at the $-U_b$ level, since the differential voltage at the comparator input is negative. The differential voltage is equal to the voltage on the non-inverting input minus the voltage on the inverting input.

If a positive input voltage is applied, diode D1b conducts and the voltage on the non-inverting input rises. This voltage is always 0.7 V lower than the input voltage. Diode D2b is cut off if the input voltage is positive. If the voltage at the circuit input rises to somewhat more than +1.4 V, the voltage on the non-inverting input will be slightly higher than the voltage on the inverting input, which is held to 0.7 V. The differential voltage between the comparator inputs will thus be positive, and the comparator output will switch to the $+U_b$ level.

1

2
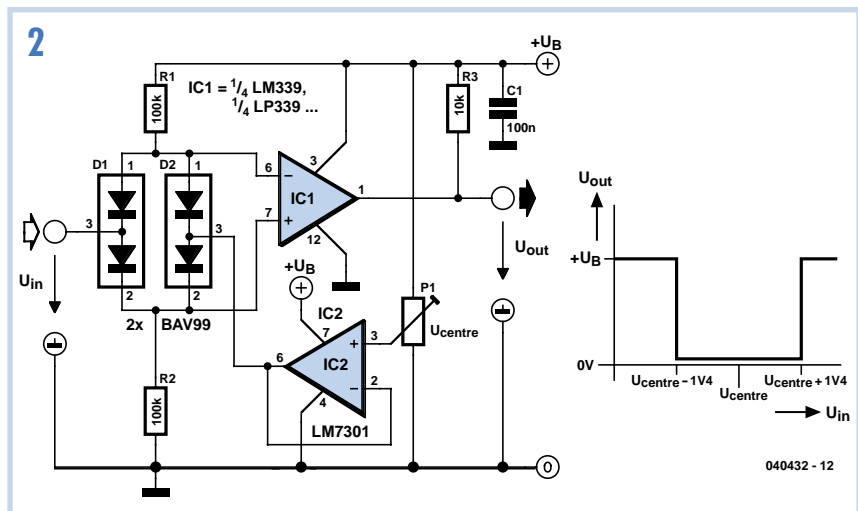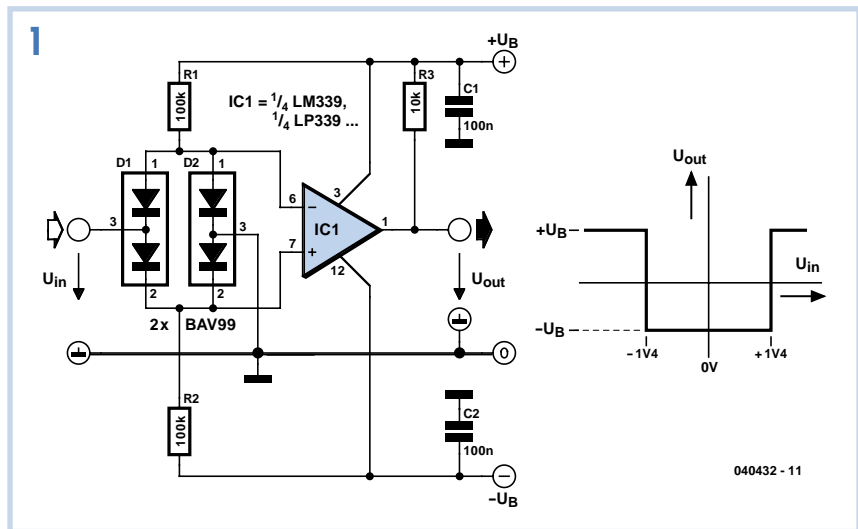
The behaviour of the circuit is similar with a negative input voltage, with the difference being that the roles of the two diodes are swapped. In this case, the non-inverting input of the comparator remains at –0.7 V. If the input voltage drops below –1.4 V, the differential voltage between the comparator inputs again becomes positive, and the comparator output again switches to the +U_b level. Note that the 'Low' output level of the window comparator is –U_b instead of ground, due to the complementary supply voltages.

A version of the window comparator that works with a single supply voltage can be implemented by tying the common terminal of the diodes to a freely selectable intermediate voltage. The schematic diagram for such an arrangement is shown in **Figure 2**, where opamp IC2 acts as a low-impedance source of reference voltage U_{center}. The voltage at the centre of the window can be adjusted to the desired value using the trimpot.

The width of the voltage window is determined by the diodes alone and amounts to twice the forward voltage drop (0.7 V) of a single diode. The width of the window can easily be enlarged by connecting additional diodes in series with D1 and D2. That can be done symmetrically, but it can also be done asymmetrically, such as by only wiring an additional diode in series with each of D1b and D2b. In the latter case, the window will not be symmetric about voltage U_{center} ($U_{center} \pm 0.7$ V), but will instead extend from $U_{center} - 0.7$ V to $U_{center} + 1.4$ V.

The circuit works with practically any type of comparator, such as the familiar LM399 or LP399 (low-power) quad comparator IC with supply voltages between ±2 V and ±18 V. IC2 in Figure 2 must be a rail-to-rail type (such as the LM7301) that is rated for the same supply voltage range as the comparator.

(040432-1)

Simple Stepper Motor Driver

(063

Paul Goossens

There is hardly any field in the world of electro-mechanics that has not found an application for the stepper motor. They are used extensively in the world of model making and as actuators in remote control equipment. In industry, picture scanners and printers are probably the most obvious devices that simply would not function without them, so no excuse is needed to include this very simple 4-phase stepper motor driver design in this collection of circuits. The circuit clock generator is formed from two exclusive OR (XOR) gates IC2A and IC2B together with C1 and P1. A logic '0' on the ENABLE input enables the clock generator and its output frequency is defined by:

$$1.4 \, P1C1$$

The output signal from the clock generator is connected to the clock inputs of the two D-type flip-flops IC1.A and IC1.B. These two flip flops are connected together in a ring to form a 2-bit shift register so that the $\overline{Q}$ output of IC1.B is fed back to the D input of IC1.A and the Q output of IC1.A is fed into the D input of IC1.B. This configuration supplies the 4 phase impulses necessary to provide motor rotation. When the DIRECTION input is changed to logic zero IC2C and IC2D operate as non-inverting gates, reversing the phase sequence of the output signals and making the motor spin in the opposite direction.

The actual rotation direction will depend on the sense of the motor windings.

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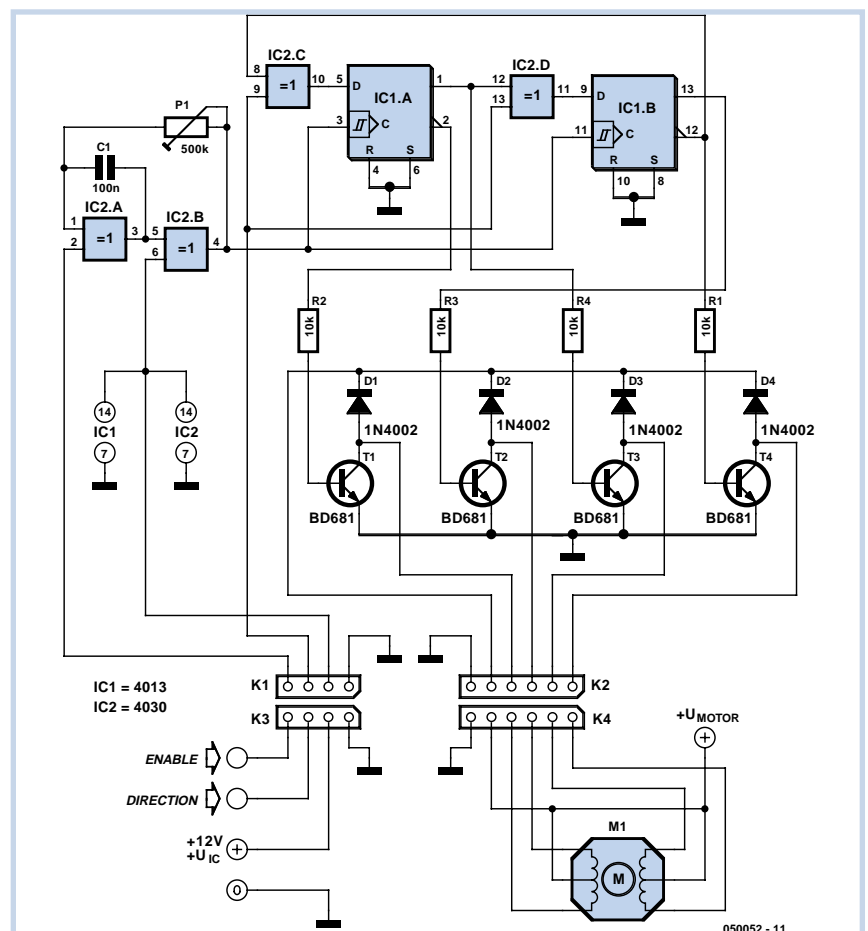
Swapping the outer two coil connections on one of the windings will reverse the direction if this is necessary.

With the components specified the circuit oscillates at a frequency of 10 Hz. The clock frequency can be adjusted between 0.2 and 100 Hz by substituting different values for P1 and C1. It is important to ensure that power drawn by the stepper motor is within the power handling capability of the driver transistors T1 to T4. Diodes D1 to D4 are necessary to conduct away the back-EMF produced each time a drive impulse to each of the motor coils is switched off.

(050052-1)

064! Extension for LiPo Charger

The 'Simple LiPo Charger' published in *Elektor Electronics* April 2005 is a small and handy circuit that allows you to quickly charge two or three LiPo cells. Especially in the model construction world are LiPo batteries used a lot these days, particularly model aeroplanes. It is usual to use a series connection of three cells with these models. Since working with these model aeroplanes usually happens in the field, it would be nice if the batteries could be charged from a car battery. We therefore designed a voltage converter for the LiPo charger concerned, which makes it possible to charge three cells in series. The voltage per cell increases while charging to a value of about 4.2 V, which gives a total voltage of 12.6 V. The converter, therefore, raises the 12-V voltage from the car battery to 16.5 V, from which the LiPo charger can be powered.

A step-up controller type MAX1771 in combination with an external FET carries out the voltage conversion. The IC operates at a moderately high switching frequency of up to 300 kHz, which means that quite a small coil can be used. Because the IC uses pulse frequency modulation (PFM) it combines the advantages
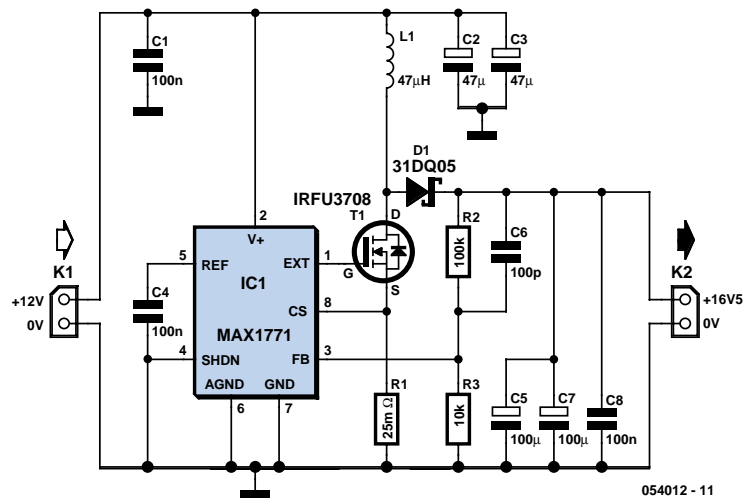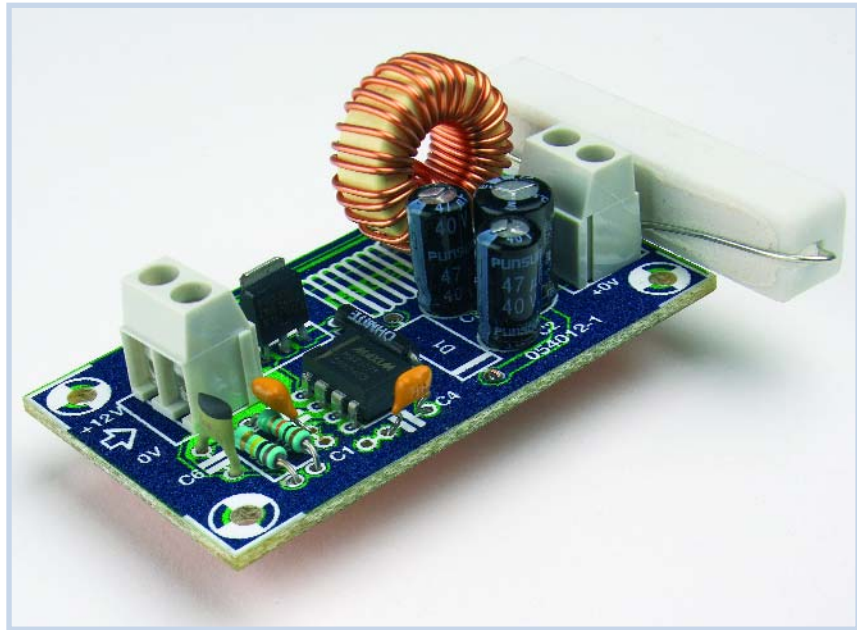
COMPONENTS LIST

Resistors:
R1 = 25mΩ (e.g., Digikey # 2FR025-ND)
R2 = 100kΩ
R3 = 10kΩ

Capacitors:
C1,C4,C8 = 100nF
C2,C3 = 47µF 25V radial
C5,C7 = 100µF 25V radial
C6 = 100pF

Semiconductors:
D1 = 31DQ05 (e.g., Digikey # 31DQ05-ND)
IC1 = MAX1771-CPA (e.g., Digikey # MAX1771EPA-ND)
T1 = IRFU3708 (e.g., Digikey # IRFU3708-ND)

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 5mm
L1 = 47µH high current suppressor coil, (e.g, Digikey # M9889-ND)
PCB.,ref. 054012-1 from The PCBShop

054012 - 11
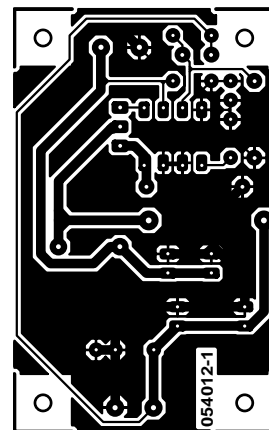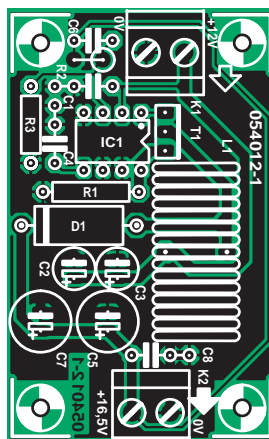
of pulsewidth modulation (high efficiency at high load) with very low internal current consumption (110 µA).

The IC is configured here in the so-called non-bootstrapped mode, which means that it is powered from the input voltage (12 V). The output voltage is adjusted with voltage divider R2/R3. This can be set to any required value, provided that the output voltage is greater than the input voltage.

Finally, sense resistor R1 determines the maximum output current that the circuit can deliver. With the 25 mΩ value as indicated, this is 2.5 A.

(045012-1)

Transistor Dip Meter

050097 - 11

Burkhard Kainka

The dip meter consists of a tunable RF oscillator whose resonant circuit is held in the vicinity of a resonant circuit to be checked. If the frequencies of the two circuits match, the circuit being measured draws energy from the oscillator circuit. This can be measured. This type of meter is also called a 'grid dip meter', since it was originally built using a valve. The amplitude of the voltage on the tuned circuit could be measured from the grid leakage current. Such meters typically have a set of interchangeable coils and several frequency scales.

A meter that can manage with a low voltage of only 1.5 V can be built using a circuit with two transistors. In addition, a coil tap is not required in this design. That makes it easy to connect many different coils to cover a large number of frequency bands.

If a sufficiently sensitive moving-coil meter is not available, an acoustic signal can be used instead of a pointer display. This involves a sound generator whose frequency increases when its input voltage rises. A resonance dip is then indicated by a falling tone. This acoustic indicator draws less current from the measurement rectifier than a moving-coil instrument. That allows the amplitude of the oscillation to be decreased slightly by reducing the emitter current. This increases the sensitivity, so the dip meter can measure resonant circuits at greater distances.

(050097-1)

T1 ... T4 = BC548C   050097 - 12
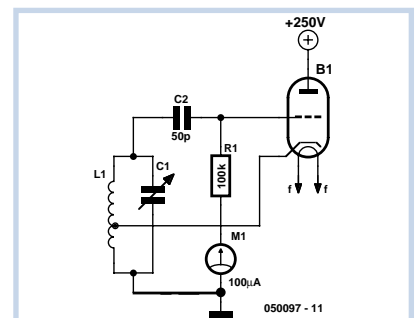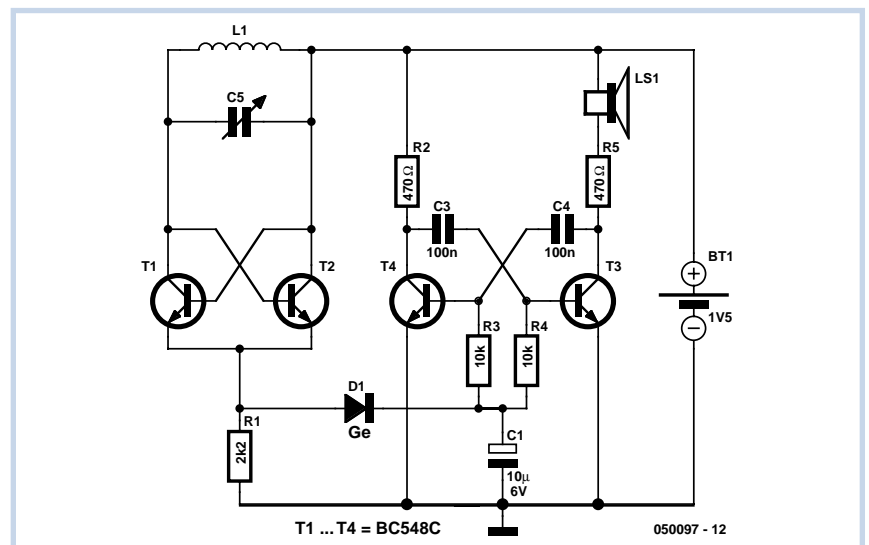
Three-component Li-ion Charger

Gregor Kleine

The LTC4054 from Linear Technology (www.linear.com) is a very simple device for charging 4.2 V Li-ion batteries. This SMD IC comes in a five-pin SOT-23 package and needs just two external components (the LED is not absolutely essential): a decoupling capacitor of at least 1 µF and a resistor connected to pin 5 (PROG) to set the charging current. The value of 1.62 kΩ shown here gives a charging current I_{CELL} of 600 mA when the device is in constant current mode. The formula

$$I_{CELL} = 1000 (V_{PROG}/R_{PROG})$$

where $V_{PROG} = 1$ V, gives the charging current in terms of R_{PROG}.

The device works from a supply voltage of between 4.25 V and 6.5 V and is therefore suitable for connection to a USB port on a computer. To avoid risk of damage to the cells, the charging process is divided into three stages. In the first stage, which is brief, a constant power is delivered to the cell. In the next stage a constant current is delivered, and the cell voltage rises linearly. Finally the devices

switches to a constant voltage mode, and the current drops off sharply.

The LTC4054 goes into a high-impedance state when the input voltage falls below a set value to ensure that the battery does not get discharged. The $\overline{CHARGE}$ pin (pin 1) indicates the charging state. It is an open drain output which is pulled down to ground via a low impedance during charging, allowing an LED to be connected. The pin sinks approximately 20 µA to ground when the Li-ion cell voltage is between 2.9 V and 4.05 V: this is the standby state. If the cell voltage falls below 2.9 V, the LTC4054 begins charging again. $\overline{CHARGE}$ goes into a high-impedance state if the input voltage is not at least 100 mV higher than the cell voltage. The under-voltage lockout circuit is then activated, with less than 2 µA being drawn from the cell.
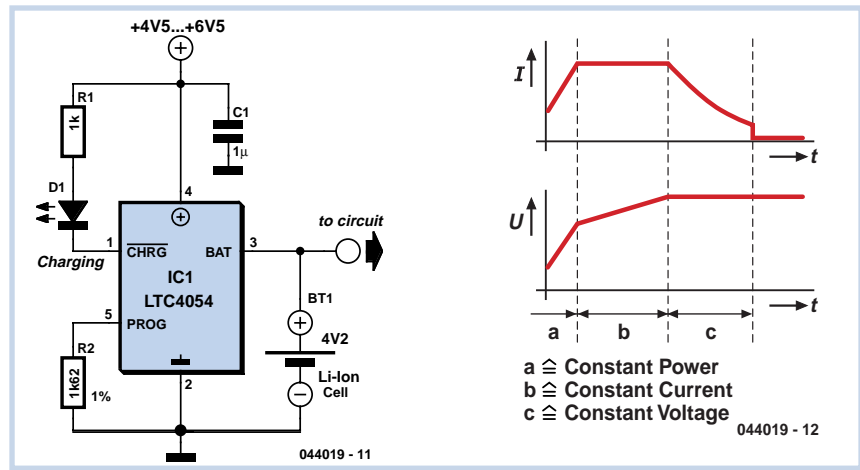
(044019-1)

067

DRM Double Superhet Receiver
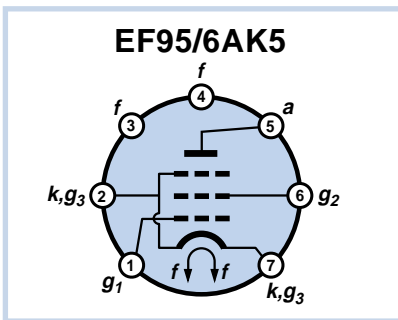
Using an EF95/6AK5

Burkhard Kainka

This receiver arose from the desire to demonstrate that valves are fully capable of holding their own against modern semiconductor devices. Valves often have better large-signal characteristics and less noise. The decisive difference is that the circuit must be designed with higher input and output impedances.

This circuit is built using four EF95 (US equivalent: 6AK5) valves, since this type of valve is small and has proved to operate well with low anode voltages. All four heaters are connected in series and operated from a 24-V supply. That makes it attractive to use the same supply for the anode voltage. The achievable gain is fully adequate.

The receiver is designed for the RTL DRM channel at 6095 kHz. It consists of two mixer stages with two crystal oscillators. A steep-edged ceramic filter (type CFW455F) with a bandwidth of 12 kHz provides good IF selectivity. Thanks to the high-impedance design of the circuit, the valves achieve a good overall gain level.
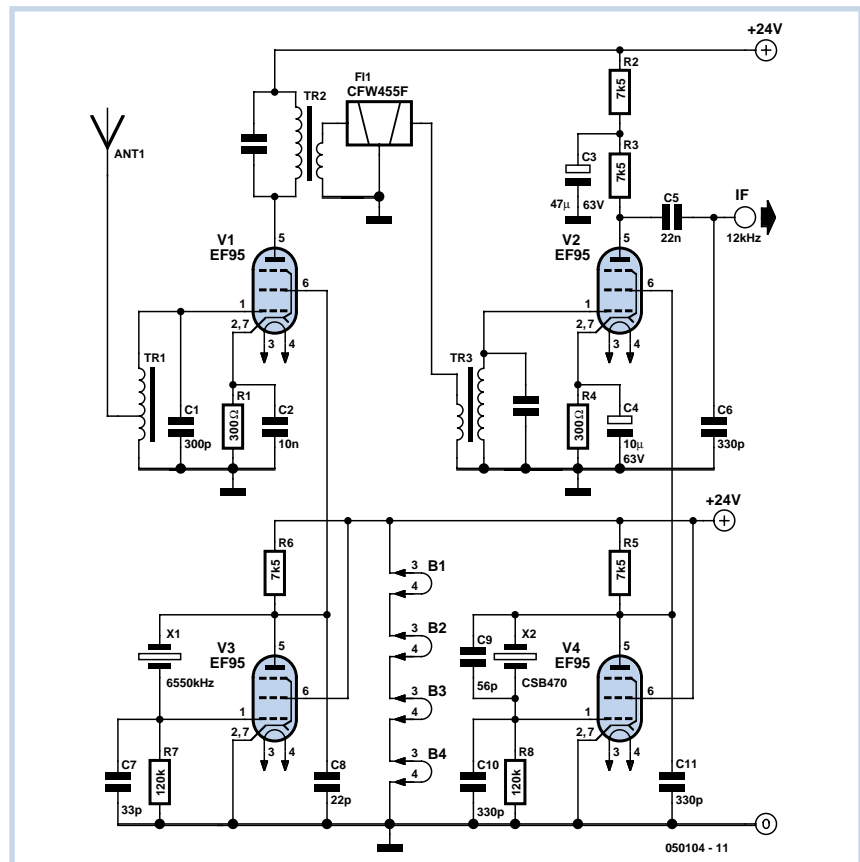
The receiver performance is comparable to that of the *Elektor Electronics* DRM receiver design published in the March 2004 issue, and it can even surpass the performance of the latter circuit with a short antenna, since the tuned input circuit

allows better matching to be obtained.

The key difficulty is obtaining a suitable crystal with a frequency of 6550 kHz. Old-style FT243 crystals with exactly this frequency are available from American army radio units. However, it takes a bit of luck to obtain a crystal with exactly the right frequency. It's also possible to use a standard crystal with a frequency of 6553.6 kHz, which yields an IF that is 3.6 kHz too high. However, that shouldn't be a problem if a relatively wide-bandwidth ceramic filter is used. One possibility is the CFW455C, which has a bandwidth of 25 kHz. If the frequency of the second crystal oscillator remains unchanged, the DRM baseband signal will appear at around 9 kHz, approximately 3 kHz below the nominal value. Nevertheless, the signal can easily be decoded by the DREAM software, since it does not depend on the signal being at 12 kHz. Another possibility would be to use the programmable crystal oscillator design published in the March 2005 issue of *Elektor Electronics*.

(050104-1)

Simulator for Bridge Measurements

Bernd Schaedler

The arrangement of resistors shown here can be used to test bridge amplifiers with differential inputs. Such amplifiers are used in conjunction with strain gauges, for example, or in measuring inductances or capacitances. Because of their symmetrical construction, bridges allow the tiniest variations in the quantity in question (for example, resistance) to be amplified without resorting to complex compensation techniques.

The circuit here simulates small variations in one of the resistors that forms the bridge, as happens in the example of strain gauges. Since only standard metal film resistors are used, it is suitable only for general testing of the connected amplifier. Strain gauges typically have a sensitivity of 2 mV/V. This means that if the supply voltage to the bridge is 10 V, the maximum variation in differential voltage taken from the bridge to the differential amplifier is 20 mV. The resistance of this circuit is rather greater than the 350 Ω typical of strain gauges, but in practice this is not important.

Calibrating the bridge simulator

Ensure that the power supply voltages connected to the positive and negative supply inputs have exactly equal magnitude (+5.000 V and –5.000 V). Now connect a voltmeter between the negative output and ground and adjust P1 so that the meter reads as close to 0 mV as possible. Now connect the voltmeter across the two outputs and set S1 to '0 %'. Adjust P2 until the voltmeter reads as close to 0 mV as possible.

Finally, switch S1 to the '25 %', '50 %', '75 %' and '100 %' positions in turn and adjust the corresponding trimmer potentiometers P4 to P7 to obtain voltages of 5 mV, 10 mV, 15 mV and 20 mV respec-

020070 - 11

020070 - 12
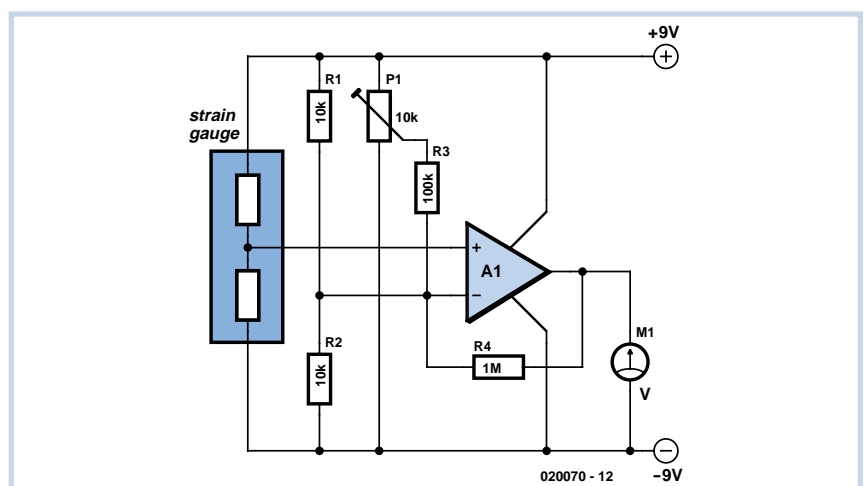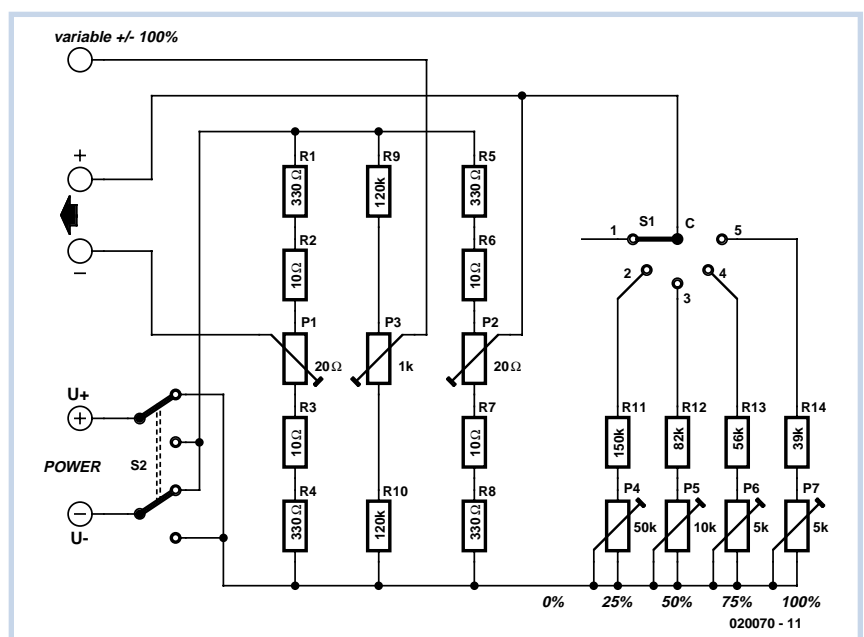
tively, with the voltmeter still connected between the positive and negative outputs. Once this calibration process has been carried out, you can now simulate a varying bridge resistance by switching S1 with a differential amplifier connected across the positive and negative outputs.

If the variable output is used instead of the positive output, the voltage can be varied continuously over the full positive and negative range using potentiometer P3. Switch S2 allows the polarity of the supply voltage to be reversed.

(020070-1)

069

Code Lock with One Button

Zorislav Miljak

The unusual feature of this code lock is that it can be operated with just one push-button. In situations where a tamper-proof solution is required this circuit has a great financial advantage: only one robust pushbutton needs to be bought. The disadvantage of this solution is that it takes a little longer to enter the code.

The operation of the code lock is as follows. After pressing the button, the PIC16F84 starts to count at a rate of one hertz. The numbers are visible on the LED display. The button is released once the correct number is displayed. This operation is repeated for the other digits in the code. The time between releasing the button and pressing it again for the next digit may not be more than 15 seconds. After the last digit, the letter 'E' (Enter) needs to be entered. If the entered code is incorrect, the display will show an 'F' (Fault) for 15 sec-
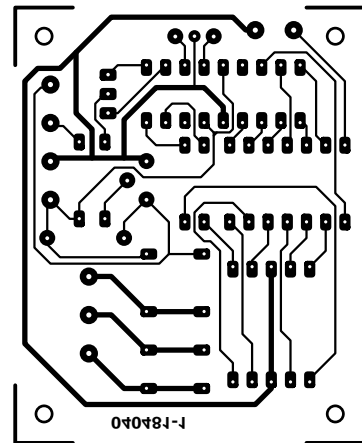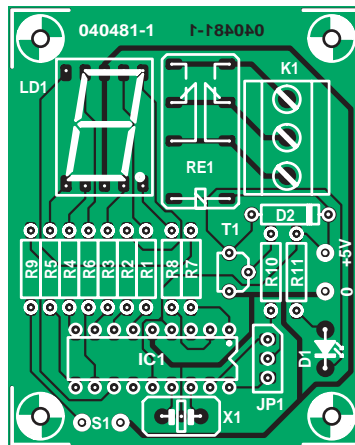
COMPONENTS LIST

Resistors:
R1-R8, R11 = 1kΩ
R9 = 100Ω
R10 = 6kΩ8

Capacitors:
C1 = 100nF

Semiconductors:
D1 = LED, green, low-current
D2 = 1N4148
IC1 = PIC16F84 (programmed, order code **040481-41***)
LD1 = 7-segment display, red, common-anode (e.g., Kingbright Sc56-11SRWA)
T1 = BC547B

Miscellaneous:
JP1 = 3-way SIL pinheader with jumper
K1 = 3-way PCB terminal block, lead pitch 5mm
Re1 = relay, 5V coil, (e.g., Omron G6A-234P-ST-US-DC5)
S1 = switch, 1 make contact, tamper proof (see text)
X1 = 4MHz ceramic resonator
PCB, ref. 040481-1 from The PCBShop Disk, source and hex code, order code **040481-11***

* see Elektor SHOP pages or www.elektor-electronics.co.uk
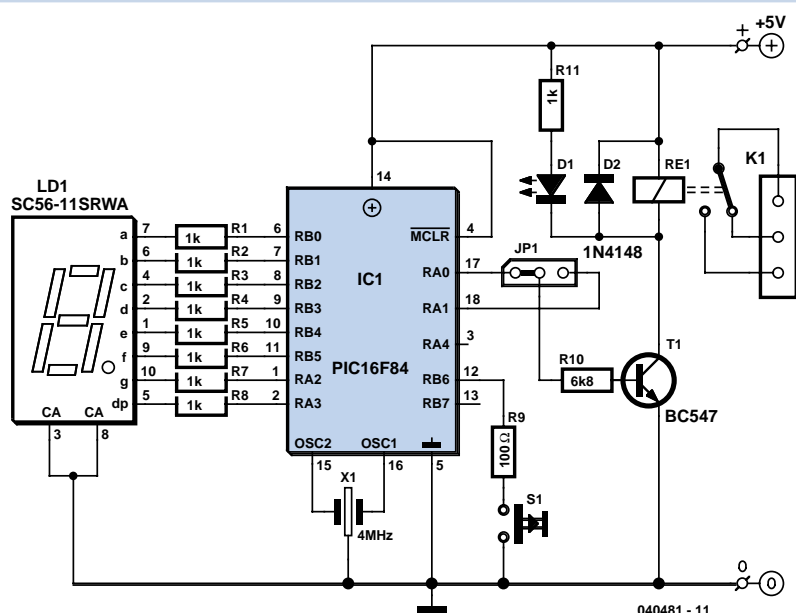
onds. If the code has been entered incorrectly three times in a row, the lock will block further input for 1 minute. During this time the display shows a flashing 'F'.

To alter the code, it is necessary to hold the button until the letter 'C' appears (Change code). The display subsequently shows an 'o' (Old code). Now enter the (valid) old code, followed by an 'E'. The PIC now asks for the new code by displaying an 'n' (New code). Now enter the new code, also followed by an 'E'. The display now shows 'c' (Confirm). Repeat entry of the new code (and once again an 'E' as confirmation). The code is now changed. A maximum of 10 digits can be used for the code.

JP1 is used to set whether the relay is energised or de-energised when the correct code has been entered. You can use a standard 5-V regulated mains adapter for the power supply.

(040481-1)

LED Flasher for 230 V

Matthias Haselberger

The small circuit shown here could act as a power indicator for the 230 V mains supply and in terms of efficiency is the equal of classical neon bulbs. Note first that the LED in this circuit flashes rather than lighting continuously, and is therefore also suitable for applications where a flashing light is wanted for decorative purposes or as a gimmick.

Diode D1 rectifies the input voltage, and C1 is charged by the rectified mains voltage via R1. When, after a number of half-cycles of the mains, the voltage on C1 exceeds the breakover voltage of the diac D2, the diac conducts and C1 discharges via R2 and light-emitting diode D3. This discharge results in a brief flash of light. A 470 µF/40 V capacitor is suitable for C1. For the diode a 1N4004 can be used, and R1 should have a value of 33 kΩ, be rated at 0.6 W and be suitable for use at 350 V. As an alternative, the value of 33 kΩ can be made up from two (or more) resistors wired in series: for

example, 15 kΩ + 18 kΩ or 2 x 10 kΩ and 1 x 12 kΩ. R2 should be 390 Ω. The firing voltage of the diac should be 30 V.

Using these values the LED flashes for 0.3 s every second.

(050015-1)
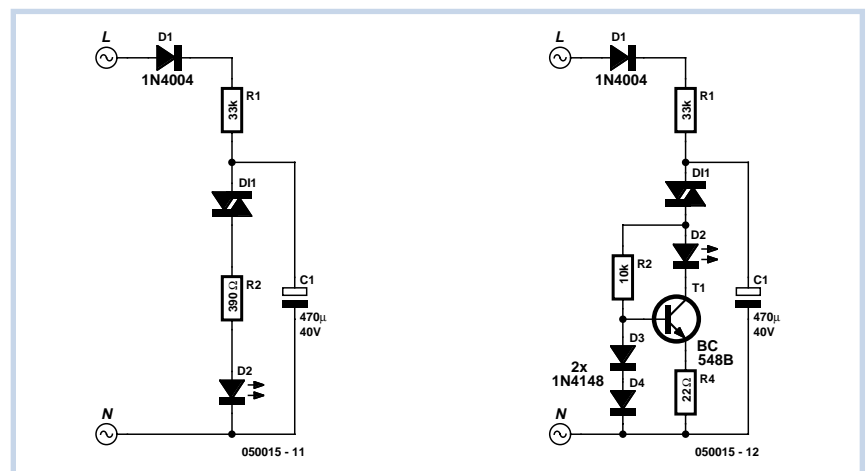
Caution: high voltage
This circuit is connected directly to the mains, and it is therefore dangerous to touch any part of it. This goes for the LED itself as well. It is absolutely essential to build the circuit in an insulating touchproof plastic enclosure; see also the safety advice pages.

On-demand WC Fan

Ton Giesberts

In most WCs with an extractor the fan is connected to the lighting circuit and is switched on and off either in sympathy with the light or with a short delay. Since toilets are sometimes used for washing the hands or just for a quick look in the mirror, it is not always necessary to change the air in the smallest room in the house. The following circuit automatically determines whether there really is any need to run the fan and reacts appropriately. No odour sensor is needed: we just employ a small contact that detects when and for how long the toilet seat lid is lifted. If the seat lid is left up for at least some presettable minimum time t_1, the fan is set run-

ning for another presettable time t_2. In the example shown the contact is made using a small magnet on the lid and a reed switch mounted on the cistern. The rest is straightforward: IC2, the familiar 555, forms a timer whose period can be adjusted up to approximately 10 to 12 minutes using P2. This determines the fan running time. There are three CMOS

NAND gates (type 4093) between the reed switch and the timer input which generate the required trigger signal.

When the lid is in the 'up' position the reed switch is closed. Capacitor C1 charges through P1 until it reaches the point where the output of IC1a switches from logic 1 to logic 0. The output of IC1b then goes to logic 1. The edge of the 0-1 transition, passed through the RC network formed by C2 and R2, results in the output of IC1c going to logic 0 for a second. This is taken to the trigger input on pin 2 of timer IC2, which in turn switches on the relay which causes the fan to run for the period of time determined by P2.

The circuit is powered from a small transformer with a secondary winding delivering between approximately 8 V and 10 V. Do not forget to include a suitable fuse on the primary side. The circuit around IC1b and IC1c ensures that the fan does not run continuously if the toilet seat lid is left up for an extended period.
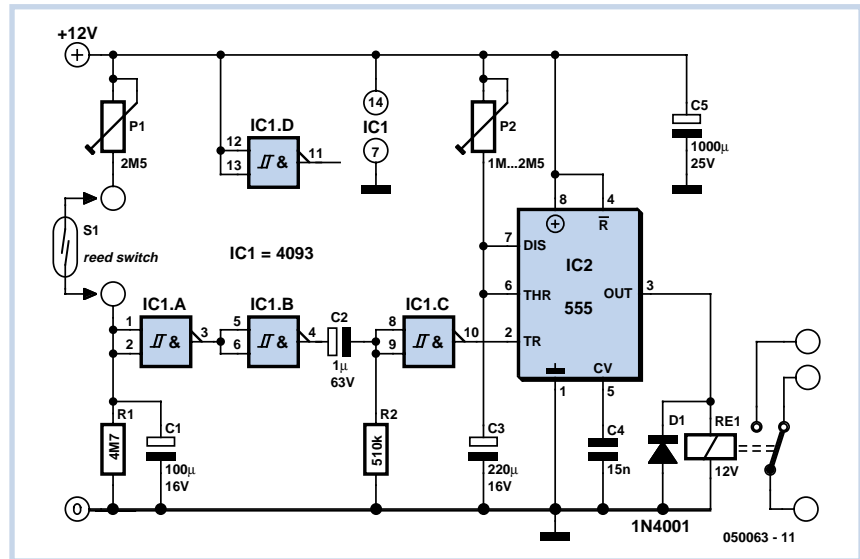
The time constant of P1 and C1 is set so that the fan does not run as a result of lavatorial transactions of a more minor nature, where the lid is opened and then closed shortly afterwards, before C1 has a chance to charge sufficiently to trigger the circuit.

(050063-1)

072 Simple Microphone Preamplifier
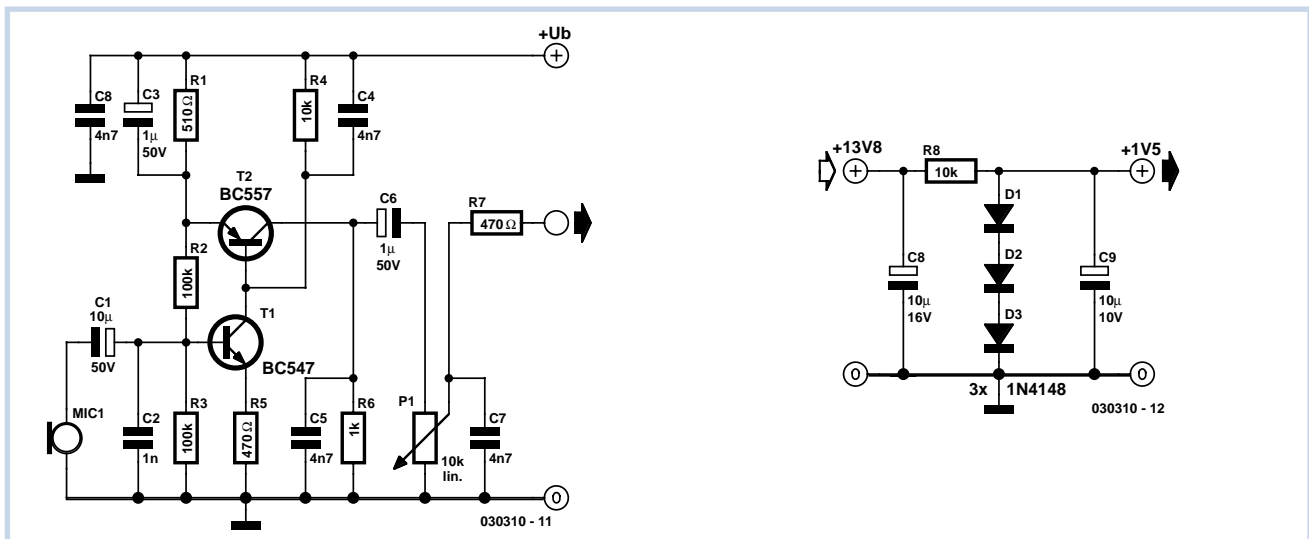
for Radio Amateurs

Ludwig Libertin

The technical demands on microphones used with radio equipment are not stringent in terms of sound quality: a frequency response from around 50 Hz to 5 kHz is entirely adequate for speech. For fixed CB use or for radio amateurs sensitivity is a more important criterion, so that good intelligibility can be achieved without always having to hold the microphone directly under your nose. Good microphones with extra built-in amplifiers can be bought, but, with the addition of a small preamplifier, an existing microphone will do just as well.

The project described here uses only a few discrete components and is very undemanding. With a supply voltage of between 1.5 V and 2 V it draws a current of only about 0.8 mA. If you prefer not to use batteries, the adaptor circuit shown, which uses a 10 kΩ resistor, three series-connected diodes and two 10 µF electrolytic smoothing capacitors, will readily generate the required voltage from the 13.8 V supply that is usually available.

There is little that need be said about the amplifier itself. Either an ordinary dynamic microphone or a cheaper electret capsule type can be connected to the input. In the latter case a 1 kΩ resistor needs to be connected between the 1.5 V supply volt-

age and the positive input connection. The impedance of the microphone and of the following stage in the radio apparatus are not of any great importance since the available gain of 32 dB (a factor of 40) is so great that only in rare cases does P1 have to be set to its maximum position.

With a frequency range from 70 Hz to about 7 kHz, low distortion, and small physical size, the preamplifier is ideal for retrofitting into the enclosure of the radio equipment or into the base of a microphone stand.

In case you are concerned about our

somewhat cavalier attitude towards distortion: for speech radio the 'fi' does not need to be 'hi'. Quite the reverse, in fact: the harmonics involved in a few percent of distortion can actually improve intelligibility — *it's not a bug, it's a feature!*

(030310-1)

9-in-1 Logic Glue / Level Translators

Dirk Gehrke

Two logic devices from revered Texas Instruments, the SN74AUP1T97 and '98 are logic glue components in tiny SOT23 cases. As shown in the diagrams, both the AUP1T97 and its inverting counterpart the AUP1T98 can be configured as voltage level translators with nine different logic functions marked by Schmitt trigger inputs. Apart from their logic function, these devices can also act as volt-

age level translators between low-voltage logic systems, as follows:

in	out	at Vcc
1.8 V	3.3 V	3.3 V
2.5 V	3.3 V	3.3 V
1.8 V	2.5 V	2.5 V
3.3 V	2.5 V	2.5 V

An example of a level translator could be one converting from 1.8 V LVCMOS to 3.3 V LVTTL or LVCMOS.

The devices, says TI, are tolerant to slow
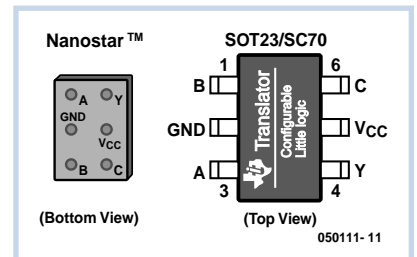
input transitions and noisy signals.

(050111-1)
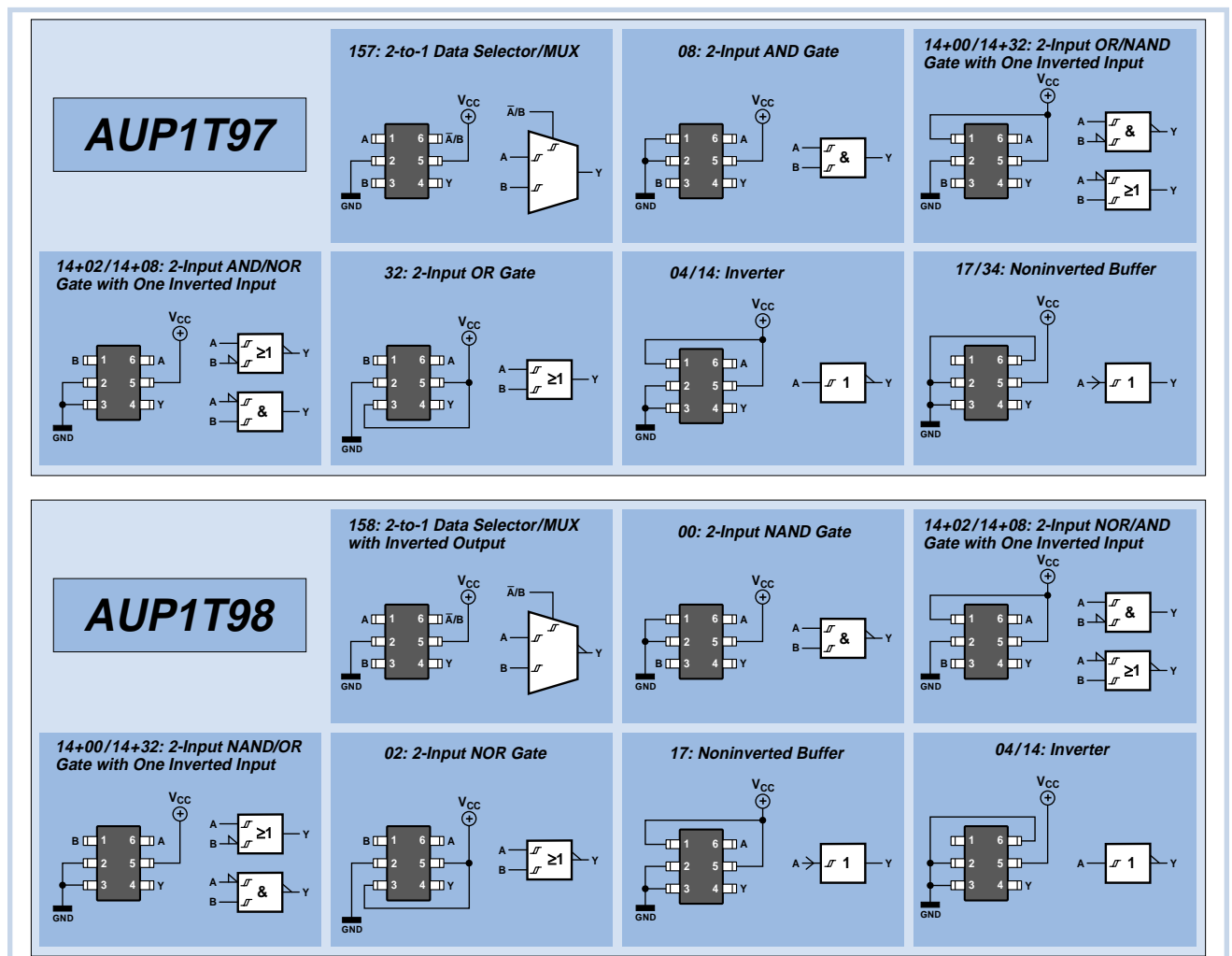
074! Universal I/O for Power Amps

Ton Giesberts

This two-part circuit was designed as an addition to the 'Compact 200 W Output Stage' in this issue. But it is also suitable for use with IC amplifiers that don't have their own power-on delay.

The circuit consists of an input stage (nothing more than a resistor and capacitor) and a power-on delay with a relay for the amplifier output.

A small PCB has been designed for the input signal. This board contains a phono socket, capacitor and a resistor that is connected directly across the input. This resistor keeps the input side of the capacitor at ground level. It prevents any offset voltage at the amplifier input from appearing at the input of this circuit when there is no connection. This would otherwise cause a loud bang from the loudspeaker when a connection was made. We have taken account of the larger size of MKP and MKT capacitors. There are several mounting holes on the board to cater for the various sizes of capacitor. The maximum size is 18×27.5×31.5 mm (WxHxL).

To protect a loudspeaker from a DC offset during the switch-on period a relay needs to be connected in series that turns on after a short delay. This circuit also makes use of the falling supply voltage of the amplifier when it is switched off. This concept also makes this circuit suitable to protect against overloads.

The circuit itself is relatively straightforward. MOSFET T1 turns on relay RE1 when the gate-source voltage rises above 2.5 V. The gate voltage is derived directly from the amplifier supply via potential divider R3/R4/P1. P1 is used to adjust the exact level at which the relay turns on.

054010 - 11
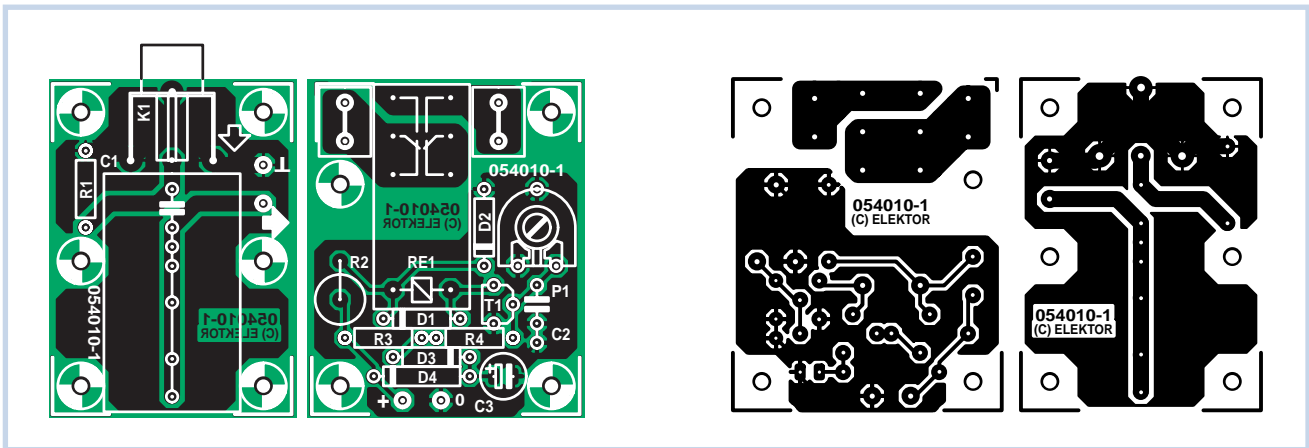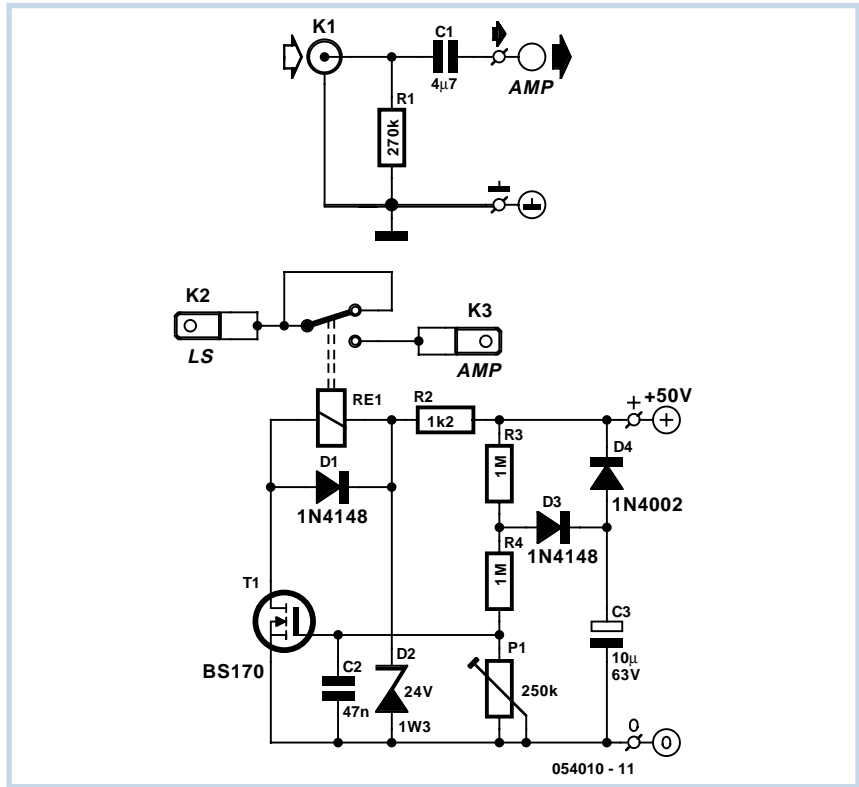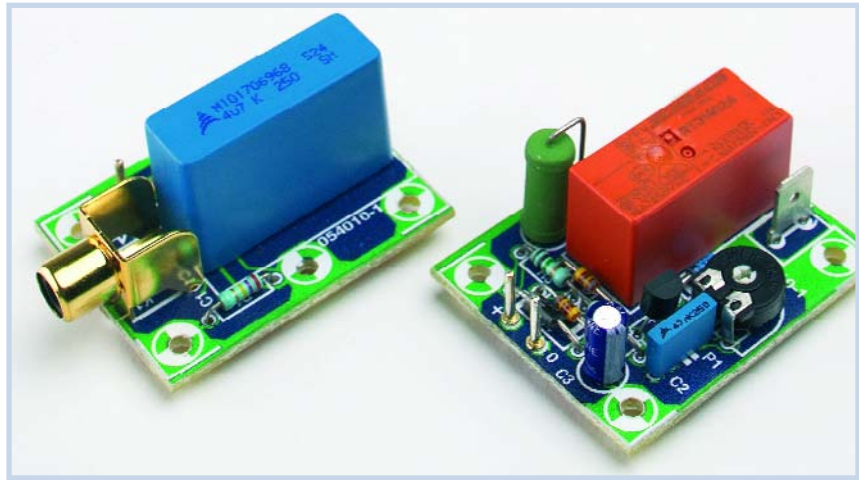
This is also used to compensate for the tolerance in the MOSFET threshold voltage. The relay operating voltage is limited to about 24 V by resistor R2. D2 restricts the voltage across T1 from rising above 24 V, stopping this voltage from rising too much when the relay is not actuated It also keeps the voltage at 24 V when a relay with a higher coil resistance is used (see parts list). When a relay with a lower coil resistance is used, the value of R2 needs to be adjusted accordingly. To calculate the value for R2 you should take the minimum acceptable supply voltage, subtract 24 V and divide the result by the current through the relay. This value should then be rounded to a value in the E12 series. There is room on the PCB for a vertically mounted 5W resistor for R2, so it's even possible to use a 12 V relay (D2 should then be changed to a 12 V type as well). D1 protects T1 from induced voltages when the relay is turned off. The voltage at the gate only reaches its end value slowly

due to the addition of D3 and C3. D3 prevents C3 from keeping the MOSFET conducting when the voltage drops. When the voltage has fallen below half the normal supply voltage, C3 starts to discharge via D4. In this way the switch-on delay is at a maximum even when the

power is turned off and on repeatedly. It should be clear that this circuit can only be used with amplifiers that are stable until the threshold voltage is reached and hence do not create an offset at the output before the relay turns off.

(054010-1)

COMPONENTS LIST

Resistors:
R1 = 270kΩ
R2 = 1kΩ2
R3,R4 = 1MΩ
P1 = 250kΩ preset

Capacitors:
C1 = 4µF7 MKT or MKP (see text)
C2 = 47nF
C3 = 10µF 63V radial

Semiconductors:
D1,D3 = 1N4148

D2 = zener diode 24V 1.3W
D4 = 1N4002
T1 = BS170

Miscellaneous:
K1 = cinch socket, PCB mount, e.g.
  Monacor / Monarch T-709G
K2, K3 = spade terminal, PCB mount,
  vertical, 2 pins
RE1 = PCB relay 24 V/16 A (e.g.,
  Omron G2R-1-24, 1100 Ω, or Schrack
  RT314024, 1440 Ω)
PCB, ref. 054010-1 from The PCBShop

Modifying Stripboard for SO Packages

075

Dirk Gehrke

This technique for modifying standard predrilled prototyping stripboard ('perfboard' or veroboard') to accept SO IC packages is intended to be used for inexpensive breadboard constructions. It provides an economical alternative to using special circuit boards that accept SO packages and increase the lead spacing from 1.27 mm to the 2.54 mm grid spacing. The standard dimensions of SO and plastic DIP packages are shown for comparison in **Figure 1** (with metric dimensions in parentheses).

The grid spacing of predrilled stripboard is 2.54 mm. Predrilled stripboard is available in various sizes with glass–epoxy or paper–phenolic substrate material. It is commonly sold in Eurocard format with dimensions of 100 × 160 mm To allow an IC in a SO package to be soldered to the predrilled stripboard, a utility knife is used to separate a section of a strip down the middle through the holes, thus reducing the grid spacing from 2.54 mm to 1.27 mm. After being prepared in this manner, the board can accept SO packages. **Figure 2** shows a diagram of simple example application using a TL5001 in a SO
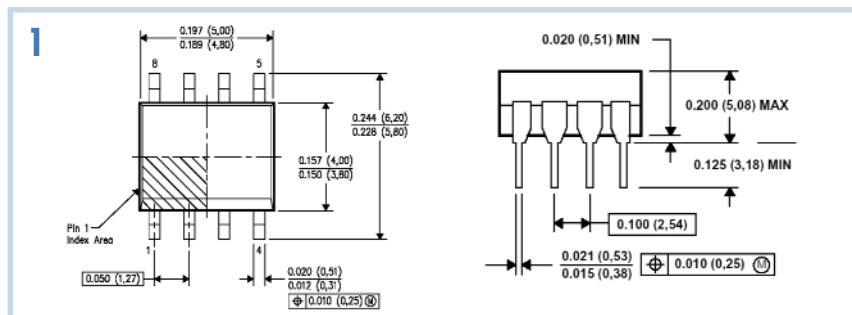
package. Here the green points and lines represent cuts that must be made

using a strip cutter and/or a utility knife.

(050119-1)

Remote Control Extension using RF
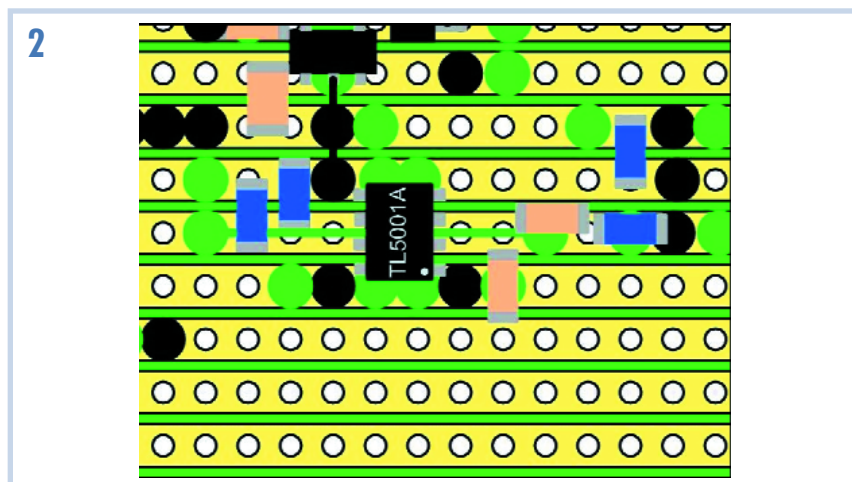
Transmitter

Ton Giesberts

We have, over the years, published numerous variations of remote control extenders in *Elektor Electronics*, but not yet one using RF.

These days, transmit- and receive modules that operate on the well-known 433-MHz licence-free frequency are reasonably cheap and freely available at electronics stores. The circuit described here makes use of the transmitter/receiver combination available from Conrad Electronics, which stands out because of its low price. A disadvantage with this setup is the available bandwidth. At 2 kHz this is quite limited, but still sufficient for our purpose.

We assume that the RC5 remote control system from Philips is being used. It is now a little dated but still has many applications, particularly for your own designs. The minimum pulse width of RC5 amounts to 0.89 ms. The maximum frequency is therefore 562 Hz [$1/(2 \cdot 0.89 \cdot 10^{-3})$]. This still passes reasonably well through the RF link. However, at the receiver some pulse stretching is required.

The transmitter is simplicity itself. IC1 is an IR receiver for remote control systems. The output signal is active low. The pulses at the output, with RC5, have a minimum length of 0.89 ms. The transmitter is activated with an active high signal that is supplied by T1. When IC1 receives a pulse, T1 will leave conduction and the transmitter is turned on via R2.

The little transmitter module has 4 connections: ground, power (3 to 12 V), data input and antenna output. The transmitter module is mounted on our PCB and connected with four pieces of wire. The overlay makes incorrect assembly just about impossible. You can use a piece of wire of about 15.5 cm long (1/4 λ) as the antenna.

Current consumption in the idle state is about 4 mA and about 5.3 mA while transmitting. For the protection of IC1, a 5.1 V zener diode is connected in parallel with its power supply connections. An excessive power supply voltage is then turned into heat via decoupling resistor R1. That means that a power supply voltage of up to 10 V can be connected to the circuit without any problems (with a

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054013-1
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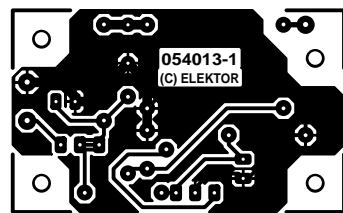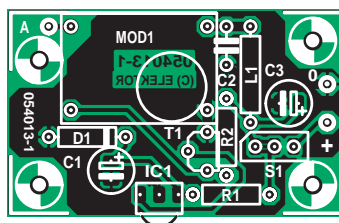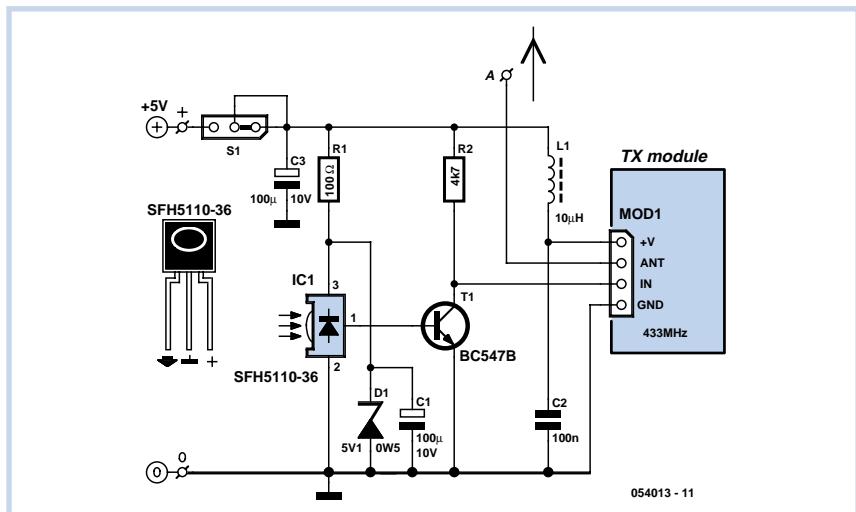
COMPONENTS LIST

Resistors:
R1 = 100Ω
R2 = 4kΩ7

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

Inductors:
L1 = 10µH

Semiconductors:
D1 = zener diode 5V1 0.5W
T1 = BC547B
IC1 = SFH5110-36

Miscellaneous:
S1 = miniature slide switch SX254 (Hartmann) (Conrad Electronics # 708062) or 3-way pinheader with jumper
MOD1 = 433.92 MHz AM transmitter module from Conrad Electronics set, # 130428
PCB, ref. 054013-1 from The PCBShop

power rating of at least 0.25 W for R4). A disadvantage is that the circuit draws a little less than 50 mA additional current. You can increase the value of R1, of course, when the power supply voltage is always at the high end of the range. The transmitter module can deal with 3 to 12 V and that limits the maximum supply voltage to 12 V.

According to the datasheet, the current consumption of IC1 is 5 mA. In our prototypes the current consumption was actually lower, less than 3 mA. R1 is then roughly $(U–5.1)/3.5 \cdot 10^{-3}$. However, just to be sure, measure the voltage across the IR receiver and check that it is correct.

You can use other devices for IC1, but keep in mind the current consumption and the pinout of the terminals. Another requirement is that the alternative IR-receiver has an active low output and an internal pull-up resistor. C1, L1 and C2 provide additional decoupling and C3 decouples the common power supply.

In place of S1 you could just fit a wire link or a 3-way pin header with a jumper. The switch is really only useful when the circuit is powered from batteries.

It is likely that the circuit will be placed in a fixed location and a regulated mains adapter as a power supply is more appropriate. On the PCB there is enough space so that IC1 can be fitted horizontally. The electrolytic capacitors can also be placed horizontally, so that the entire assembly can be quite thin, so that it can easily be mounted between, behind or in something.

(054013-1)

Cheap Dot-mode Bargraph Display

Rev. Thomas Scarborough

The five-stage linear dot-mode bargraph display shown in here has a number of distinct advantages, which may be summarized as:

● the resistor chain is fully customizable;
● IC1's high input impedance results in minimal loading on circuits;
● IC1 and IC2 have a wide supply voltage range, between 3V and 15V
● If a higher supply voltage is used, all colour LEDs may be employed with a single ballast resistor R3.

Four op-amp comparators are used to provide a five-stage output, as follows: as the voltage at the signal input rises, so the outputs of comparators IC1.A to IC1.D go High in succession. This creates the sequence at IC2's binary channel select and output channels shown in the **Table**. The last binary number in this sequence is created as IC1.D goes High, thus pulling IC2 binary input 1 Low through T1. In this way, five of the (IC2) 8-to-1 analogue multiplexer/demultiplexer output channels are utilised to produce a five-stage linear dot-mode bargraph display. The signal input voltage required to switch any one of IC1's four outputs may be calculated by dividing the supply voltage by the values in the resistor chain. For example, if the supply voltage is 12 V, and all of the resistors in the chain are 10 kΩ, then IC1.C's output pin 8 (and IC2's output channel 6) will swing High as the voltage of the signal input exceeds

$$12 \text{ V} \times [(R3+R4+R5) \div (R1+R2+R3+R4+R5)] = 7.2 \text{ V}$$

The only aspect of the circuit which might require special clarification is T1. T1 pulls IC2's binary channel select input 1 Low by

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shorting it to 0 V, thus overriding IC1.B's output pin 7. This creates one additional binary input number (binary 101) for IC2, and adds a fifth stage to the bargraph. A 'logic' MOSFET such as a BUZ11 or IRF510 would also work in this position, and in this case R1 may be omitted.

The LMC6484IN opamp indicated in the circuit diagram is a rail-to-rail type which may be difficult to source. If you use an 'old fashioned' opamp like the LM324, do remember that the input voltage may not exceed the supply voltage minus about 1.5 volts. In the case of the TL074 (TL084), the reverse applies: the input voltage must be comprised between 1.5 volts and the supply rail level. This is called the *common-mode range* of the opamp — check the datasheets!

Resistor R3 determines the LED current and may need to be adapted to match

IC2 Channel Select	IC2 Output Channel
2 1 0	
0 0 0	0
1 0 0	4
1 1 0	6
1 1 1	7
1 0 1	5

whatever LEDs you have available for the readout. Since the output current of 4000 series CMOS ICs needs to be observed, it is a good idea to use high-efficiency LEDs of the 2-mA class. The value of R3 is calculated from

$$R3 = (V_b – 2) \text{ volts} / 3$$

where the result is in kilo-ohms.

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RF Remote Control Extender: Receiver

Ton Giesberts

This circuit works together with a transmitter described elsewhere in this issue to form a remote-control extender. Due to its limited bandwidth, the output of the RF receiver module does not exactly reproduce the original pulses from the IR receiver. That problem is remedied here by the circuit around T1. The modulator circuit for the data received from this stage is active low, so the primary function of T1 is to invert the received signal. However, the stage built around T1 also acts as a pulse stretcher in order to restore the original pulse length. Capacitor C2, which is connected in parallel with P1, charges quickly. The maximum current is limited by R3 to protect T1. The discharge time is determined by P1 and C2, and P1 can be adjusted to compensate for various deviations and tolerance errors. The timing should be matched to the RC5 code with P1 set to approximately its midrange position. In practice, the pulse length also proved to be slightly dependent on the signal strength.

T1 provides the reset signal for a 74HC4060 IC (14-stage binary ripple counter with built-in oscillator). This counter restores the original modulation with a frequency of 36 kHz. Each received pulse starts the oscillator, and a frequency of exactly 36 kHz is present on pin 13 (division factor 2^9) if the crystal frequency is 18.432 MHz. Other oscillator frequencies can also be selected using J1, and various combinations are possible using other division factors (for 36 kHz, connect a jumper between pins 11 and 12 of J1). At frequencies below 12 MHz, C5 must be replaced by a resistor with a value of 1–2.2 kΩ (fitted vertically). The main reason for including J1 is to allow the remote control extender to be used with other modulation frequencies. The counter output drives a transistor stage (T2) with two IR diodes (type LD271, but other types can also be used). The current through LEDs D1 and D2 is limited to approximately 90 mA by R18. R6 and R7 are connected in parallel with D1 and D2, respectively, to reduce the turn-off time. A normal LED (D3) is connected in parallel with the IR LEDs to provide a supplementary visible indication of a transmitted signal (IR or RF). The circuit needs nice stiff 5-V supply,
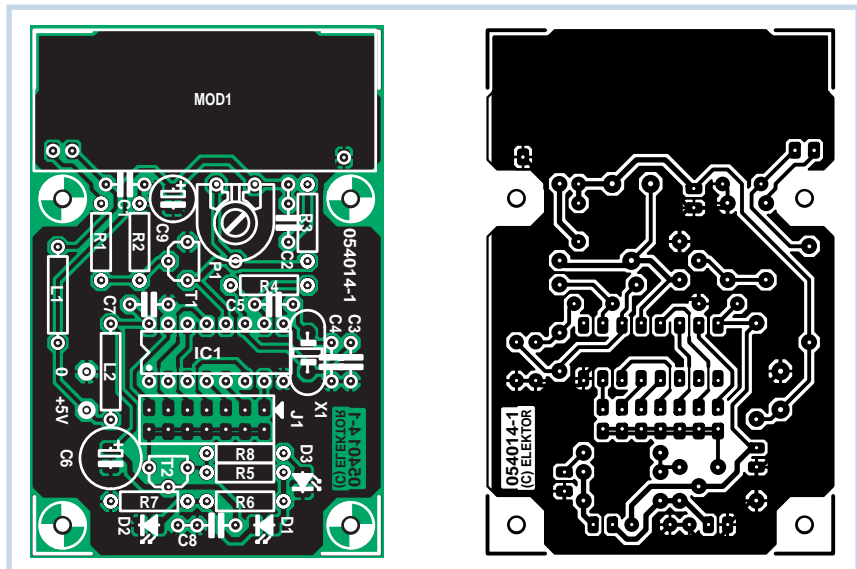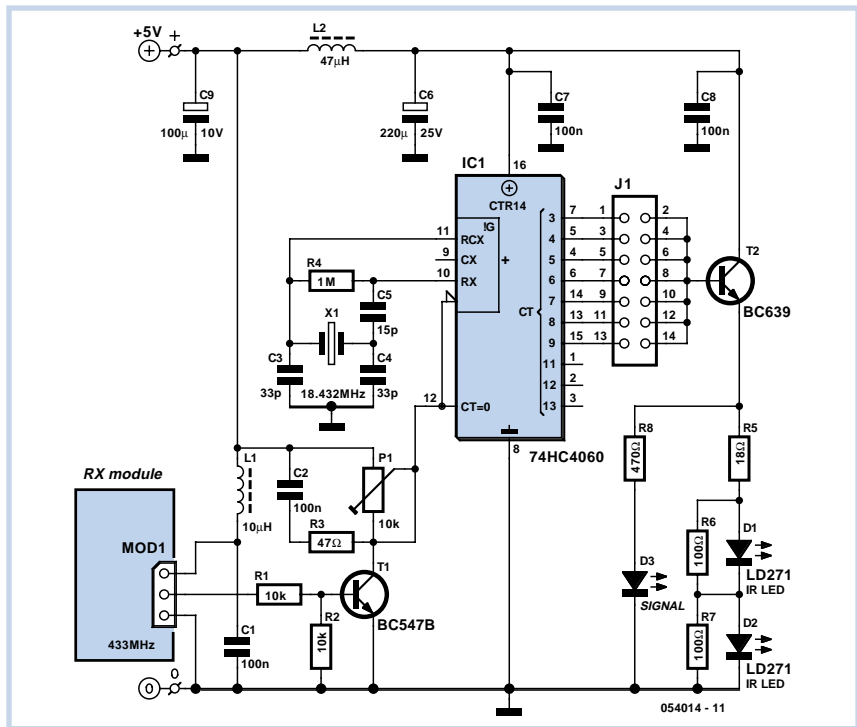
which means that battery operation is not suitable (unless a hefty electrolytic capacitor is connected across the supply terminals). L1 and L2 ensure that the supply voltage for the receiver module is as clean as possible. The quiescent current consumption is approximately 1.3 mA, and it increases to around 8 mA on average with a good received signal level.

Assembling the circuit board (see **Figure 2**) is straightforward. Naturally, a wire bridge can be used in place of J1 if you only want to use a single IR code. The receiver module is supplied with quite long connection leads and a pre-fitted antenna. It's a good idea to shorten the antenna slightly. With our modules, the length was nearly 18 cm. In practice, a length of 15.5 cm is more suitable at a frequency of 433.92 MHz.

The circuit board is designed to allow the receiver module to be fitted to the board, but we chose to fit it next to the board (along its long axis). That puts the receiver a bit further away from the noise generated by the IR LEDs and the counter, which reduces the interference to signal reception. The module leads are long enough for this. You will also have to experiment with the orientation of the module and the antenna, since the arrangement proved to be critical in practice (the RF aspects, that is).

(054014-1)

Simple Cable Tester 079

Bert Vink

This cable tester allows you to quickly check audio cables for broken wires. Because of the low power supply voltage, batteries can be used which makes the circuit portable, and therefore can be used on location. The design is very simple and well organised: using the rotary switch, you select which conductor in the cable to test. The corresponding LED will light up as indication of the selected conductor. This is also an indication that the power supply voltage is present. If there is a break in the cable, or a loose connection, a second LED will light up, corresponding to the selected conductor. You can also see immediately if there is an internal short circuit when other than the corresponding LEDs light up as well.

You can also test adapter and splitter cables because of the presence of the different connectors. Two standard AA- or AAA- batteries are sufficient for the power supply. It is recommended to use good, low-current type LEDs. It is also a good idea not to use the cheapest brand of connectors, otherwise there can be doubt as to the location of the fault. Is it the cable or the connector?

(040250-1)

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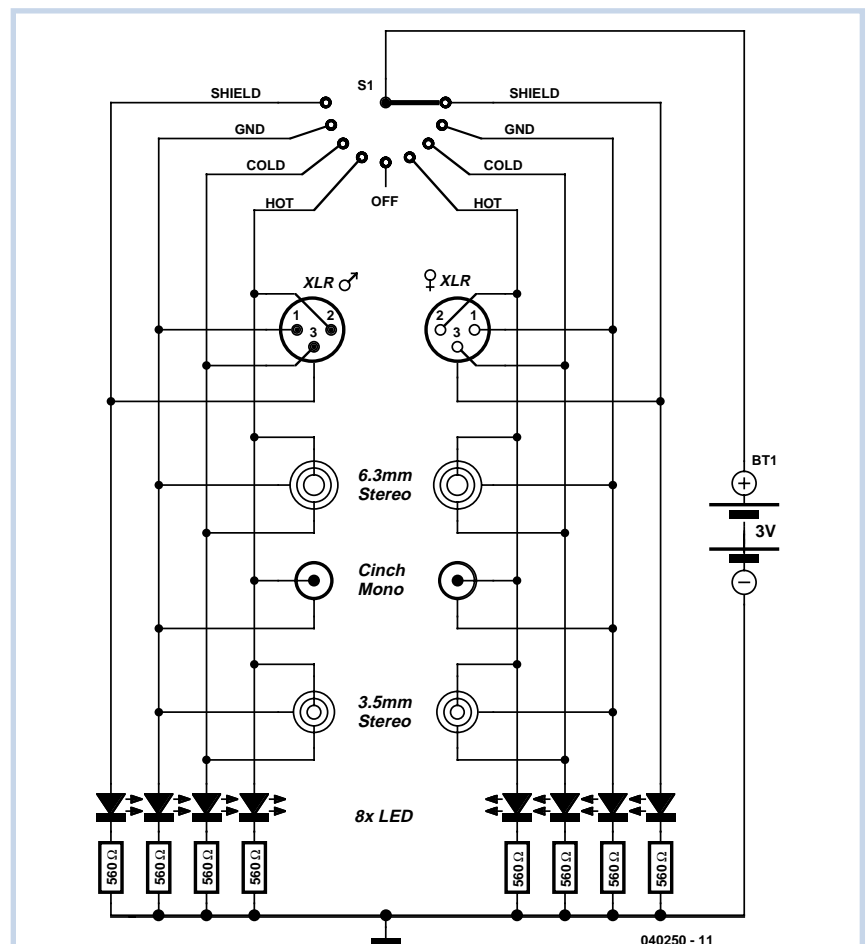
1 MHz Frequency Counter

H. Breitzke

The XR 2206 function generator chip is a very popular device and forms the basis of many analogue function generator designs. A disadvantage of this chip is that in its most basic configuration the output frequency is adjusted manually by rotating an output frequency control knob and lining it up on a printed scale. Without a frequency counter its difficult to tell the value of the output frequency, especially at the high end of the scale. The frequency counter design presented here offers a low cost solution to this problem and achieves good accuracy. Power for the circuit is derived from the dc power supply of the existing function generator. The input signal to the counter is taken in parallel from the TTL output of the XR2206. The frequency counter circuit contains an Atmel AT90S2313 microcontroller together with an LCD display. The frequency counter program is written in Basic.

The fundamental components needed to build a frequency counter are a timer, which is used to time an accurate measurement window and a counter to count the number of transitions that the input signal makes during the measurement window period. The microcontroller contains two internal hardware counters of 8 and 16 bit length and these can be configured as either a timer or counter. Operating with a crystal frequency of 8.388608 MHz the counter achieves an accuracy of 1 Hz at 1 MHz or with a more readily available 4.194304 MHz crystal the accuracy will be 1 Hz with a 500 kHz input signal.
The 16-bit counter is configured as the frequency counter and the input signal is connected to pin 9 at TTL logic levels. A 16-bit counter can only count to a maximum value of 65536 so to extend its range the software keeps note of the number of counter timer overflow interrupts that occur during the measurement window. At the end of the measurement window it multiplies this value by 65536 and adds it to the current value of the counter:

$$F = \text{interrupts} \times 65536 + \text{Timer1}$$

The time base is generated by the 8-bit timer which together with a prescaler counts to 1024. Using the crystal fre-

quency from above the timer 0 overflow occurs at a frequency of 32 Hz. The measurement timing window is closed when 32 interrupts have been counted and the frequency of the input signal is calculated and displayed.
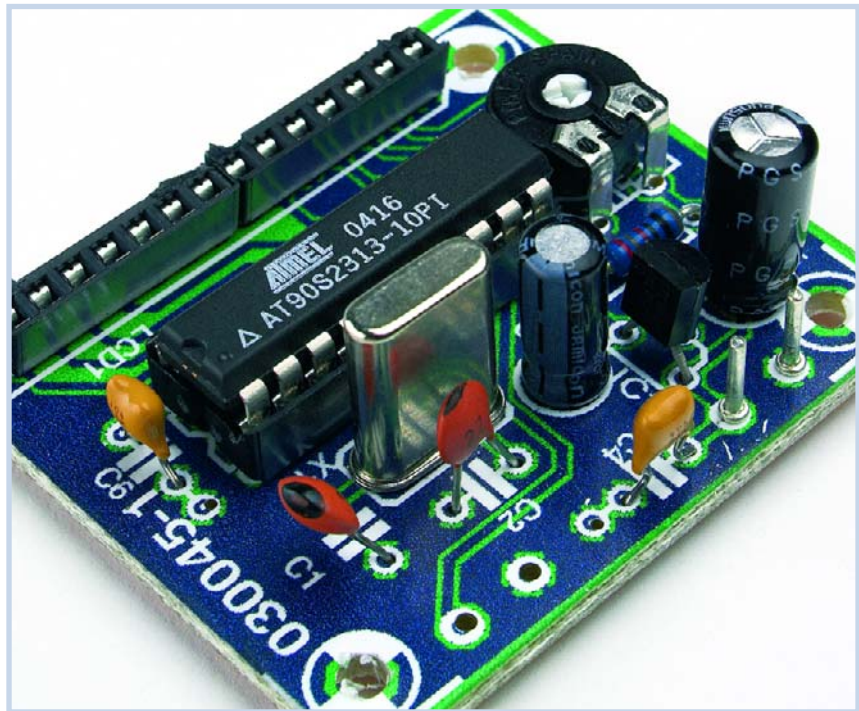
The interrupt rate restricts the maximum input to 1.5 MHz and at this frequency the display will exhibit a jitter of 4 Hz i.e. the displayed frequency will 'wander' by 4 Hz. All input frequencies below 200 kHz should not display any jitter.

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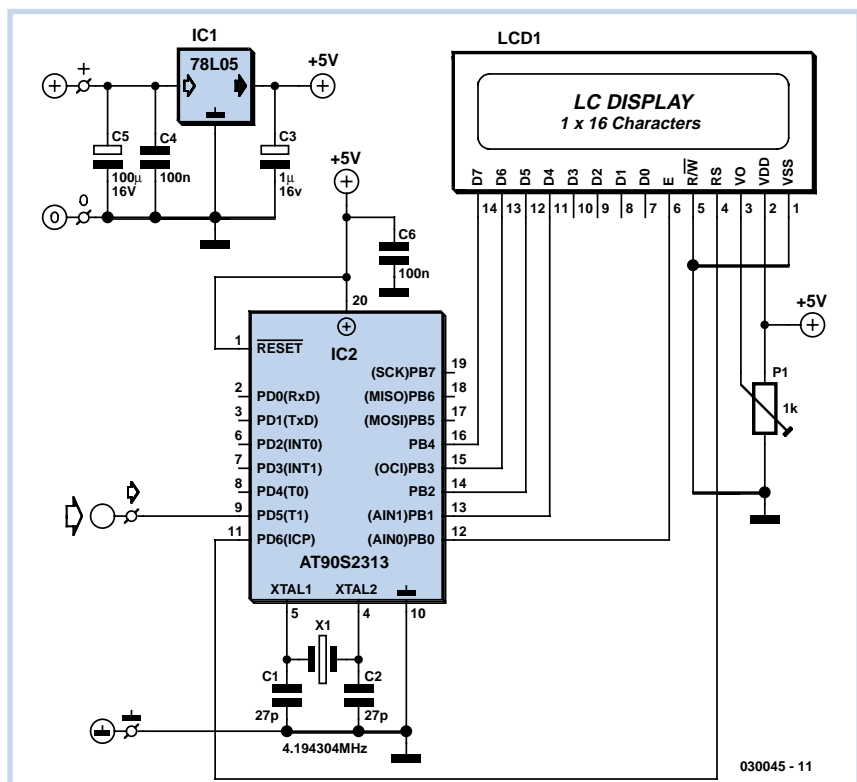
The program is written in AVR Basic and is small enough to be compiled and downloaded to the microcontroller by the free demo version of the BASCOM AVR compiler (Download from: www.mcselec.com). The single line LCD display interface is designed for a Hitachi 16x1 or compatible display. Preset R1 allows adjustment of the display contrast. IC1 provides a regulated 5 V for the microcontroller and display.

The frequency counter accuracy depends on the precision of the crystal and its frequency stability together with capacitors C1 and C2. PAL crystals generally are produced to close tolerances and exhibit low drift. During testing the crystal showed an offset of 60 ppm, which would produce a display error of 60 Hz on a 1 MHz signal. Adjustment of the capacitive loading (C1 and C2) on the crystal was able to 'pull' the crystal frequency and reduce the error to zero. At audio frequencies the counter measures to an accuracy of 1 Hz across the entire audio spectrum without any need for circuit alignment.

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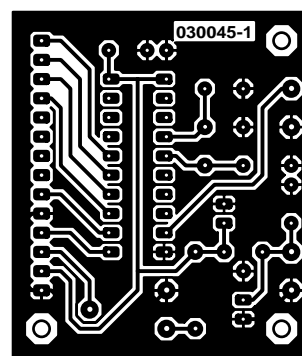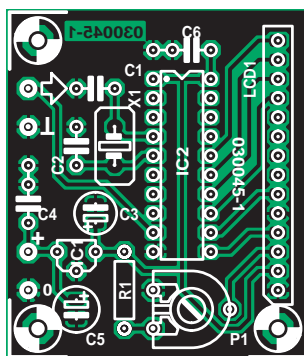
COMPONENTS LIST

Resistors:
R1 = 10kΩ
P1 = 1kΩ preset

Capacitors:
C1, C2 = 27pF
C3 = 1µF / 16V radial
C4, C6 = 100nF

Semiconductors:
IC1 = 78L05

IC2 = AT90S2313-10PI, programmed, order code **030045-41** *

Miscellaneous:
X1 = 4.194304MHz or 8.388608MHz quartz crystal (see text)
LCD1 = LCD Module, 1 line, 16 characters
PCB, ref. 030045-1 from The PCBShop Disk, project software, order code **030045-11** * or Free Download

* see Elektor SHOP pages or www.elektor-electronics.co.uk

High Voltage Regulator

Ton Giesberts

The LR12 made by Supertex Inc. is a good choice for applications where a supply voltage of more than 35 to 40 V needs to be stabilised. This small regulator can cope with input voltages of up to 100 V, when the output voltage can be adjusted between 1.2 and 88 V. A small disadvantage is that the input voltage needs to be at least 12 V more than the output voltage.

The regulator keeps the voltage between the output and adjust pin constant at 1.2 V. With a potential divider the output voltage can be set using the following equation:

$$V_{out} = 1.2 \times (R2 / R1 + 1) + I_{adj} \times R2.$$

The circuit shows a standard application where the LR12 is used as a 5 V regulator. C1 decouples the input voltage. Its value and working voltage depend on the input voltage and the current consumption. The bypass capacitor (C2) is required to
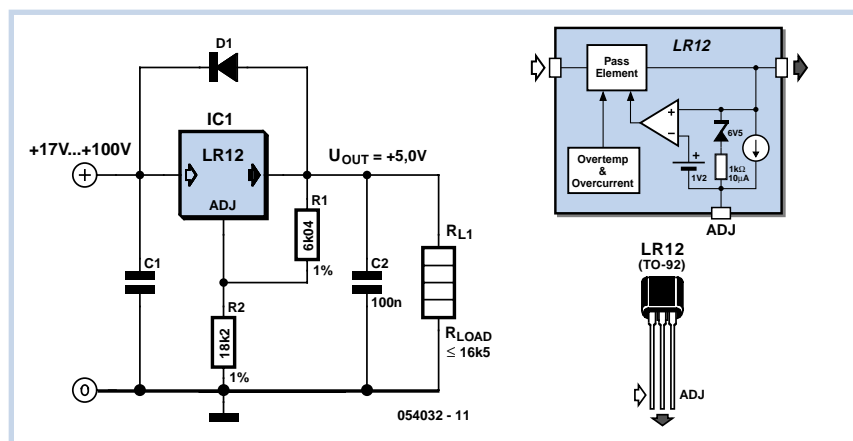
keep the LR12 stable. In cases where the voltage at the input may be smaller than at the output an extra protection diode is required, for example a 1N4004.

The output current of the IC needs to be at least 0.5 mA. In the circuit shown here the potential divider made by R1/R2 already draws 0.2 mA. This means that with a 5 V output the load resistor needs to be less than 16k5. If the resistance is

higher, the total output current drops below the required value of 0.5 mA.

The output current of the LR12, with a 12 V difference between input and output, is limited to 100 mA (max. dissipation of a TO92 package: 0.6 W at 25 °C). The ripple suppression is at least 50 dB. The current consumption of the IC itself is very low at only 5 to 15 µA.

(054032-1)

Klaus-Juergen Thiesler

PDM Pulse Generator

082

This pulse generator, which offers a mark-space ratio that is adjustable in exponentially increasing steps, is a novel use for a familiar IC. It can come in handy in a range of situations: for example, when testing the dynamic regulation characteristics of a power supply. In this test a load is applied to a power supply that draws a square-wave, rather than constant, current. An oscilloscope can then be used to check how quickly the regulator in the power supply responds and to observe any undesirable artefacts in the output such as overshoots or oscillation. A disadvantage of such an arrangement is that the dynamic characteristics of the power supply are only measured at one average current, determined by the mark-space ratio of the current and by its maximum value. Modern computers, for example, draw varying amounts of current depending on what they are doing, and the current can vary over very short timescales. A modern PC power supply must therefore deliver accurate and stable voltages not only under high and intermediate load, but also at low load (in stand-by mode).

The PDM pulse generator is ideal for this situation. As can be seen from the table, S1 allows the mark-space ratio to be adjusted from 1:17 to 1:2. The frequency varies from 566 Hz to 302 Hz, making it suitable for testing PC power supplies. The variation in frequency with mark-space ratio is a consequence of how the circuit works.

At the heart of the circuit is our old friend the CMOS 4060. This includes an RC oscillator circuit and a 14 bit binary counter. The basic clock frequency, which can be calculated using the formula shown, is around 77 kHz for the given values of R1 and C1. The space time is constant at around 1660 µs. When the IC is reset, all outputs are initially low. Consider now the voltage at the gate of T1. If it were not for D1, when Q7 goes high after the 128th clock pulse (the divide-by-2^8 output spends 128 clock periods low and then 128 periods high) IC1 would be reset immediately via R3. T1, and therefore the load, would thus receive extremely short pulses with long pauses between. Because of the switching speed of the IC, the width of the pulses would only be of the order of the
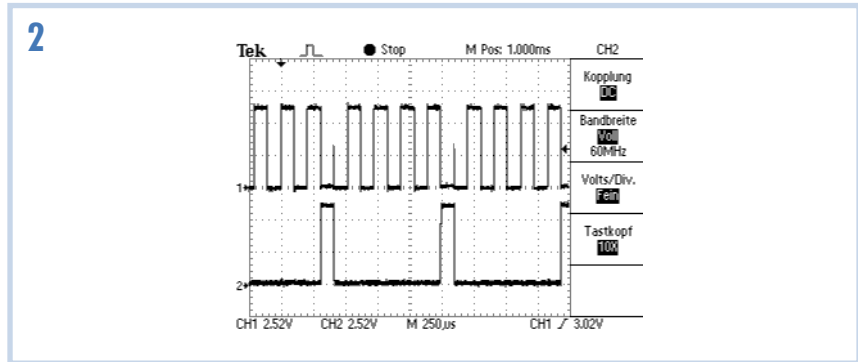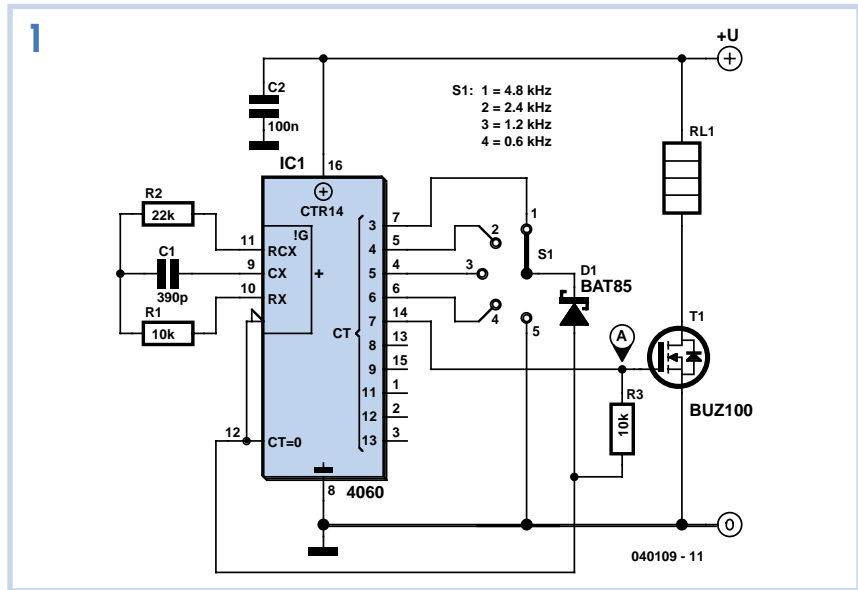
ten nanoseconds. A low level via D1 and S1, however, delays the resetting of the IC for exactly as many clock periods as it takes for the output selected by S1 to go high. For example, if Q3 is selected, this happens after a further eight periods. The

cycle time is then 128+8 clock periods, of which 128 clock periods are space and just eight are mark. This gives a duty cycle, as shown in the table, of 8/136 or 1/17. If Q6 were used the pulse would be $0.5 \times 2^7 = 64$ clock periods wide with

1

S1: 1 = 4.8 kHz
2 = 2.4 kHz
3 = 1.2 kHz
4 = 0.6 kHz

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Table 1. Pulse width in exponentially increasing steps

Reset pulse		Q 7 (junction A)				
Switch position	CLR pin connected to	Duty cycle		Frequency *	Period *	Pulse width *
		as percentage	as a fraction **	Hz	µs	µs
1	Q 3	5.9 % approx.	1/17	566	1765	103
2	Q 4	11 1/9 %	1/9	535	1868	207
3	Q 5	20.0 %	1/5	480	2082	415
4	Q 6	33 1/3 %	1/3	401	2495	830
5	GND	50.0 %	1/2	302	3320	1660

* = measured to ±1 in last digit
** = see text (duty cycle is mark time as a proportion of period, a dimensionless quantity)

the same space period of 128 clocks. The duty cycle in this case is 1/3. If the cathode of D1 is tied to ground, the IC does not receive a reset signal and so a symmetrical square wave with a 128-clock mark and 128-clock space is produced. T1 functions as a power switch. Load R4 is chosen so that the maximum rated current of the power supply flows when T1 conducts. The average load on the power supply can be calculated using the duty cycle values given in the table. It should go without saying that the current drawn must be within the specification of the power supply, and that R4 must be capable of the necessary power dissipation. At higher currents a heatsink is recommended for T1. It can pass a maximum of 60 A and although it has a very low resistance in the conducting state (just 18 mΩ) it is no superconductor! At currents above about 10 A it starts to get warm.

The oscilloscope traces show the circuit operating at one of the possible mark-space ratios. The upper trace is the basic clock on pin 11 of IC1, and the lower trace shows the signal at test point A, which has a duty cycle of 1/5.

Low-cost Step-down Converter 083

with Wide Input Voltage Range

Dirk Gehrke

The circuit described here is mostly aimed at development engineers who are looking for an economical step-down converter which offers a wide input voltage range. As a rule this type of circuit employs a step-down converter with integrated switching element. However, by using a more discrete solution it is possible to reduce the total cost of the step-down converter, especially when manufacturing in quantity. The TL5001A is a low-cost PWM controller which is ideal for this project.

The input voltage range for the step-down converter described here is from 8 V to 30 V, with an output voltage of 5 V and a maximum output current of 1.5 A.

When the input voltage is applied the PWM output of IC1 is enabled, taking one end of the voltage divider formed by R1 and R2 to ground potential. The current through the voltage divider will then be at most 25 mA: this value is obtained by dividing the maximum input voltage (30 V) minus the saturation voltage of the output driver (2 V) by the total resistance of the voltage divider (1.1 kΩ). T1 and T3 together form an NPN/PNP driver stage to charge the gate capacitance of P-channel MOSFET T2 as quickly as possible, and then, at the turn-off point, discharge it again.

The base-emitter junction of T3 goes into a conducting state when the PWM output is active and a voltage is dropped across R2. T3 will then also conduct from collector to emitter and the gate capacitance of T2 will be discharged down to about 800 mV. The P-channel MOSFET will then conduct from drain to source. If the open-collector output of the controller is deactivated, a negligibly small current flows through resistor R2 and the base of T1 will be raised to the input voltage level. The base-emitter junction of T1 will then conduct and the gate capacitance of T2 will be charged up to the input voltage level through the collector and emitter of T1. The P-channel MOSFET will then no longer conduct from drain to source. This driver circuit constructed from discrete components is very fast, giving very quick switch-over times.

Diodes D2 and D3 provide voltage limiting for the P-channel MOSFET, whose maximum gate-source voltage is 20 V. If the Zener voltage of diode D2 is exceeded it starts to conduct; when the forward voltage of diode D3 is also exceeded, the two diodes together clamp the gate-source voltage to approximately 19 V.

The switching frequency is set at approximately 100 kHz, which gives a good compromise between efficiency and component size. Finally, a few notes on component selection. All resistors are 1/16 W, 1 %. Apart from electrolytic C1 all the capacitors are ceramic types. For the two larger values (C2 and C5) the following are used:

C2 is a Murata type GRM21BR71C105KA01 ceramic capacitor, 1 µF, 16 V, X7R, 10 %;
**C5** is a Murata type GRM32ER60J476ME20 ceramic capacitor, 47 µF, 6.3 V, X5R, 10 %.
D1 (Fairchild type MBRS340T3) is a 40 V/3 A Schottky diode. Coil L1 is a Würth WE-PD power choke type 744771147, 47 µH, 2.21 A, 75 mΩ.
T1 (BC846) and T3 (BC856) are 60 V, 200 mA, 310 mW complementary bipolar transistors from Vishay.
The TL5001AID (IC1) is a low-cost PWM controller with an open-collector output from Texas Instruments.
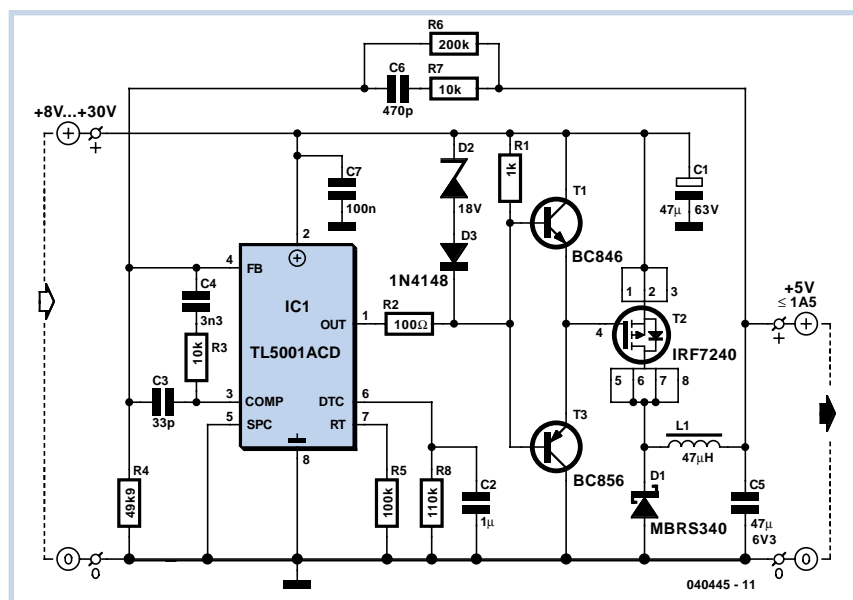
Noise Suppression for R/C Receivers

0841

Paul Goossens

Receiver interference is hardly an unknown problem among model builders. Preventive measures in the form of ferrite beads fitted to servo cables are often seen in relatively large models and/or electrically driven models, to prevent the cables from acting as antennas and radiating interference to the receiver.

If miniature ferrite beads are used for this purpose, the connector must be first be taken apart, after which the lead must be threaded through the bead (perhaps making several turns around the core) and then soldered back onto the connector. An interference source can also cause problems in the receiver via the power supply connection. The battery is normally connected directly to the receiver, with the servos in turn being powered from the receiver. The servos can draw high currents when they operate, which means they can create a lot of noise on the supply line. This sort of interference can be kept under control by isolating the supply voltage for the receiver from the supply voltage for the servos.

All of these measures can easily be implemented 'loose' in the model, but it's a lot nicer to fit everything onto a single small circuit board. That makes everything look a lot tidier, and it takes up less space. The schematic diagram is shown in **Figure 1**. Connectors K1–K8 are located at the left. They are the inputs for the servo signals, which are connected to the receiver by the servo leads. The outputs (K9–K16) are located on the right. That is where the servos are connected. Finally, the battery is connected to K17.

Interference on the supply voltage line due to the motors and servos is suppressed by a filter formed by L10, R1, C1 and C2. L10 is a ferrite-core coil with an impedance of 2000 ohms at 30 MHz. In combination with C1 and C2, it forms a substantial barrier to interference in the 35-MHz R/C band. Signals with frequencies close to the 10.4-MHz intermediate frequency (which is used in many receivers) are also effectively blocked by this filter.

L9 filters out common-mode noise on the supply line for the servos, which effec-

tively means that it prevents the supply lines to the servos from acting as antennas.
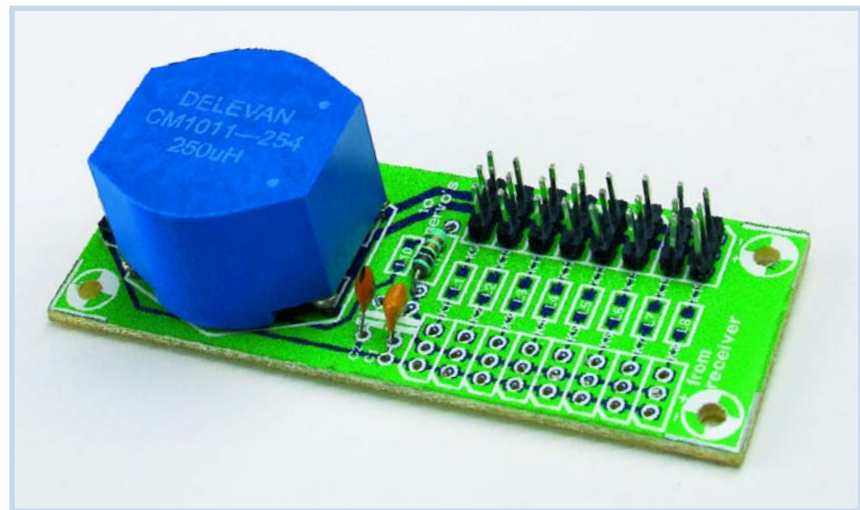
Finally, high-frequency currents on the

servo signals are filtered out by ferrite beads in order to limit the antenna effects of these connection lines.

(054018-1)

054018 - 11
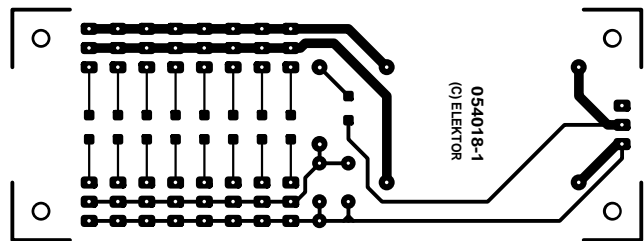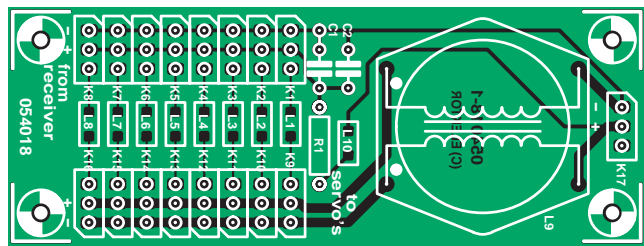
EE-ternal Blinker

085

Burkhard Kainka

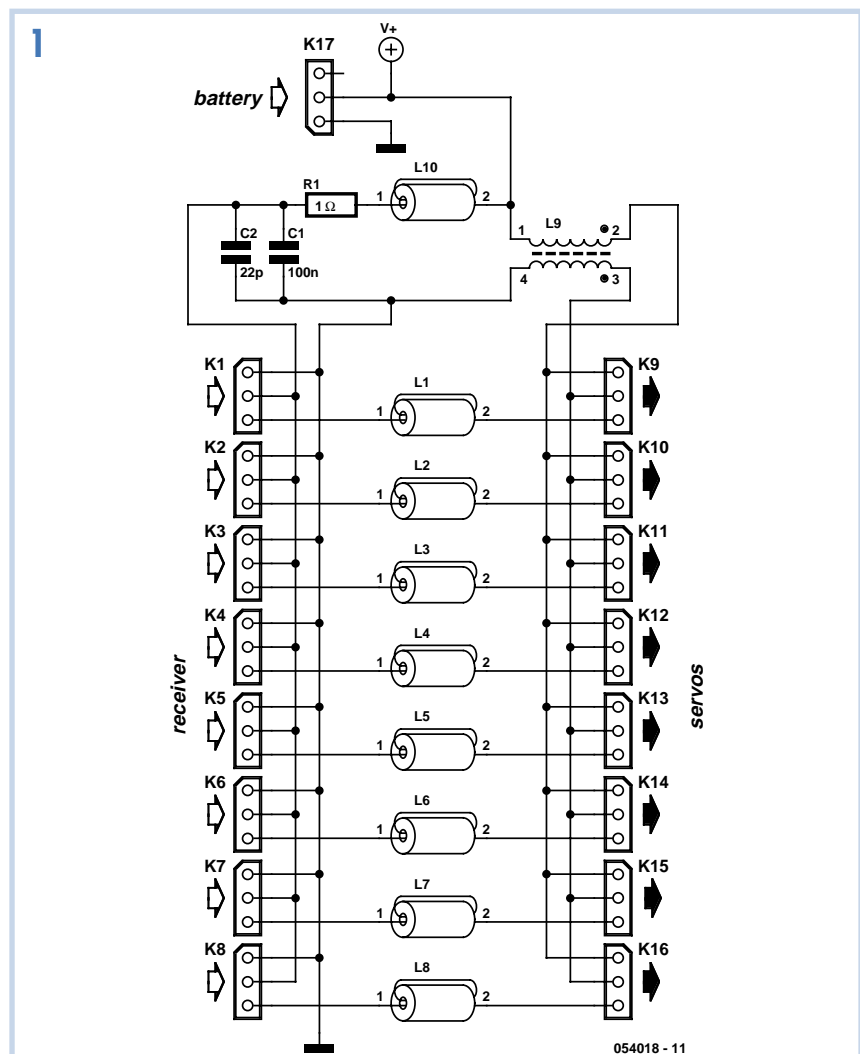You occasionally see advertising signs in shops with a blinking LED that seems to blink forever while operating from a single battery cell. That's naturally an irresistible challenge for a true electronics hobbyist…

And here's the circuit. It consists of an astable multivibrator with special properties. A 100-µF electrolytic capacitor is charged relatively slowly at a low current and then discharged via the LED with a short pulse. The circuit also provides the necessary voltage boosting, since 1.5 V is certainly too low for an LED.

The two oscillograms demonstrate how the circuit works. The voltage on the collector of the PNP transistor jumps to approximately 1.5 V after the electrolytic capacitor has been discharged to close to 0.3V at this point via a 10-kΩ resistor. It is charged to approximately 1.2 V on the other side. The difference voltage across the electrolytic capacitor is thus 0.9 V when the blink pulse appears. This voltage adds to the battery voltage of 1.5 V to enable the amplitude of the pulse on the LED to be as high as 2.4 V. However, the voltage is actually limited to approximately 1.8 V by the LED, as shown by the second oscillogram. The voltage across the LED automatically matches the voltage of the LED that is used. It can theoretically be as high as 3 V.

The circuit has been optimised for low-power operation. That is why the actual flip-flop is built using an NPN transistor
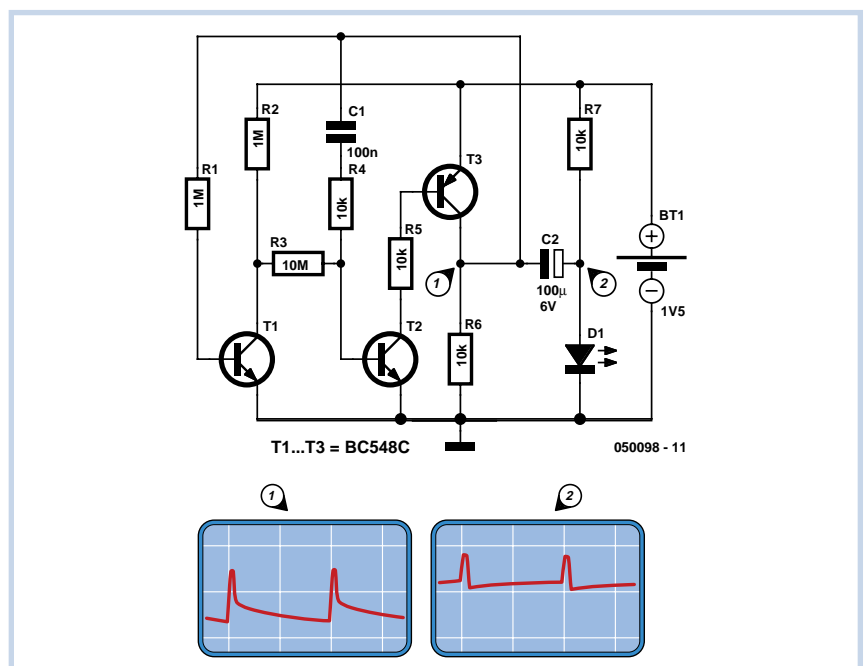
and a PNP transistor, which avoids wasting control current. The two transistors only conduct during the brief interval when the LED blinks. To ensure stable operating conditions and reliable oscillation, an additional stage with negative DC feedback is included. Here again, especially high resistance values are used to minimise current consumption.

The current consumption can be estimated based on the charging current of the electrolytic capacitor. The average voltage across the two 10-kΩ charging resistors is 1 V in total. That means that the aver-

age charging current is 50 µA. Exactly the same amount of charge is also drawn from the battery during the LED pulse. The average current is thus around 100 µA. If we assume a battery capacity of 2500 mAh, the battery should last for around 25,000 hours. That is more than two years, which is nearly an eternity. As the current decreases slightly as the battery voltage drops, causing the LED to blink less brightly, the actual useful life could be even longer. That makes it more than (almost) eternal.

(050098-1)

086

Slave Flash with Red-Eye Delay

Paul Goossens

Digital cameras are becoming more and more affordable. At the economy end of the market cameras are usually equipped with a small built-in flash unit that is ideal for close-ups and simple portraiture. The power rating of the built-in flash unit is quite low so that any subject further away than about 2 to 3 metres (maybe 4 m if you are lucky) tends to disappear into the gloom. You soon become aware of the limitations if you need to photograph a larger group of people say at a function under artificial light in a large hall or outdoors. The majority of these cameras are not fitted with an accessory socket so it is not possible to simply connect a second flash unit to increase the amount of light. Single lens reflex cameras also need additional lighting (e.g. fill-in flash) to reduce the harsh contrast produced by a single light source. For all these cases an additional slave flashgun is a useful addition to the equipment bag. Rather than shelling out lots of cash on a professional slave flashgun, the circuit here converts any add-on flashgun into a slave flash unit triggered by light from the camera flash. Simple slave flash circuits can have problems because most modern cameras use a red eye reduction pre-flash sequence. This pre-flash is useful for portraiture. It is designed to allow time for the subjects pupils to contract so that the red inner sur-

face of the eye is not visible when the picture is taken. Some cameras use information gathered at this pre-flash time to estimate the light power required for the main flash period and some use this time to fine-tune the autofocus. A simple slave flash circuit will be triggered by the pre-flash sequence and will therefore not provide any additional lighting when the main flash occurs and the picture is actually taken. The circuit shown here is quite simple but neatly solves the pre-flash problem.

With switch S1 set to 'Normal', the pulse produced by D1 when it detects the cam-
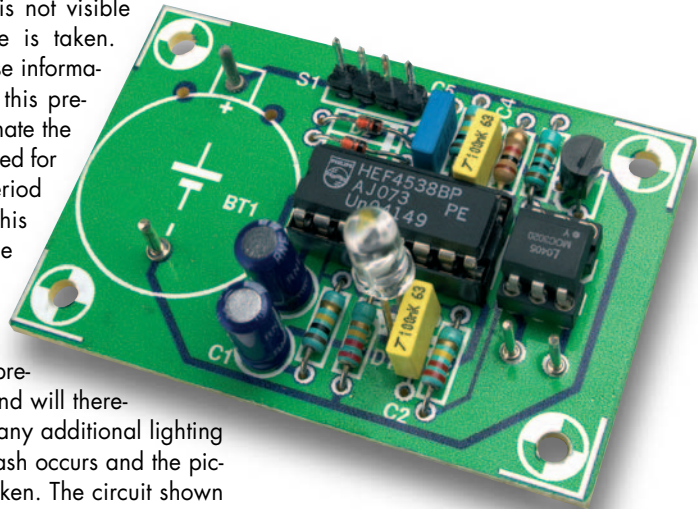
COMPONENTS LIST

Resistors:
R1, R3 = 100kΩ
R2 = 100ø
R4, R5 = 220kΩ
R6 = 1kΩ

Capacitors:
C1, C3 = 10µF 16 V radial
C2, C4 = 100nF
C5 = 47nF

Semiconductors:
D1 = TLRH180P (Farnell # 352-5451)
D2, D3 = BAT85
IC1 = 4538P
IC2 = MOC3020
T1 = BC547B

Miscellaneous:
Bt1 = two 1.5V batteries (LR44) with PCB mount holder
S1 = 3-position slide switch
PCB, ref. 040070-1 from The PCBShop
Cable or adaptor for external flasher

040070 - 11

era flash will trigger both monoflops IC1a and IC1b. The output of IC1.A does not perform any useful action in this mode because the logic le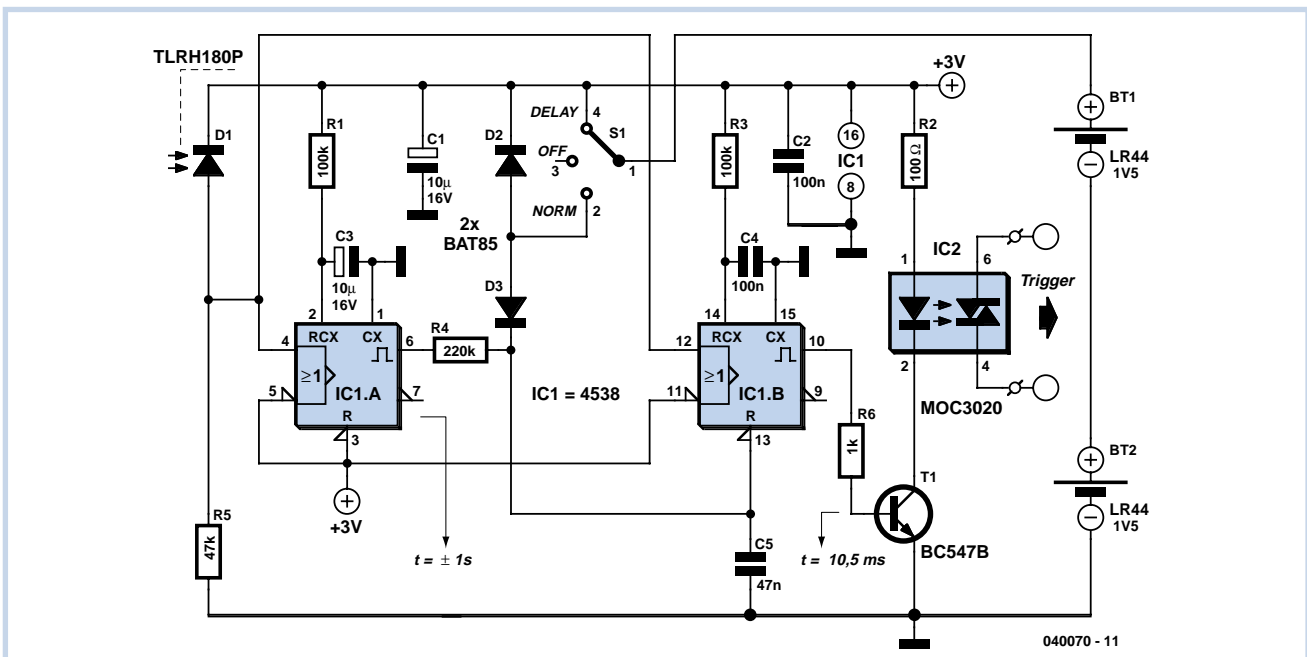vel on the other side of resistor R4 is pulled high by D3. The output of IC1.B will go high for approximately 10 ms switching T1 on and causing the triac to conduct and trigger the slave flash. The use of a triac optocoupler here has the advantage that the circuit can be used on older types of flashgun triggered by switching a voltage of around 100 V as well as newer types that require only a few volts to be switched.

With switch S1 in the delay position the first flash will trigger IC1.A and its output will enable IC1.B but the low pass characteristics of the filter formed by R4 and C5 slow the rising edge of this waveform so that IC1.B will only be enabled 10 ms after the first flash is detected. IC1.B is now enabled for a period of about 1 s (governed by R1 and C3). When the main flash occurs in this time window it will immediately trigger IC1.B and the
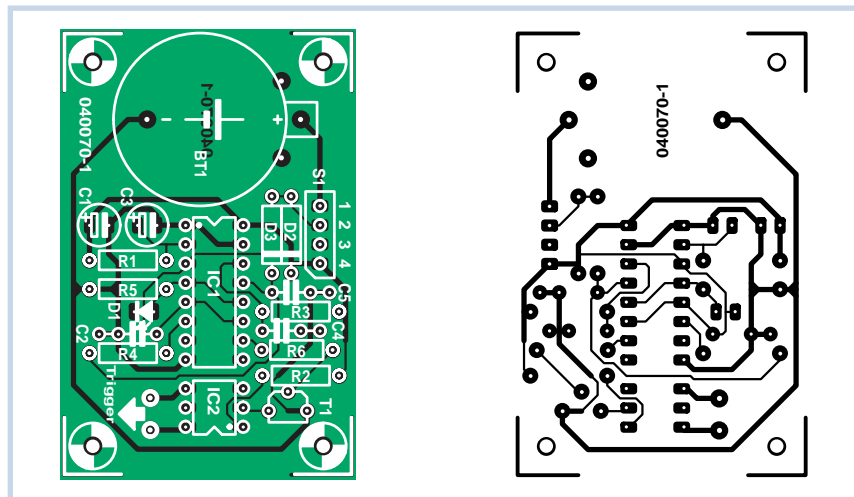
triac will be switched as described above. The circuit requires a supply of 3 V and draws very little current from the two 1.5 V button cells. It will run continuously for quite a few days, should it be accidentally left on. Switch S1 can be either a three-position toggle or slider type.

Circuit construction is greatly simplified and the finished unit looks much neater if it is built on the available PCB. Space is also provided to fit the PCB mounted battery holders. A suitable flash extension cable or adapter can be found in most photo shops.

(040109-1)

Short-Wave Converter

Burkhard Kainka

This short-wave converter, which doesn't have a single coil requiring alignment, is intended to enable simple medium-wave receivers to be used to listen to short-wave signals. The converter transforms the 49-m short-wave band to the medium-wave frequency of 1.6 MHz. At the upper end of the medium-wave band, select an unoccupied frequency that you want to use for listening to the converted short-wave signals. Good reception performance can be obtained using a wire antenna with a length of one to two metres.

The converter contains a free-running oscillator with a frequency of around 4.4 MHz, which is tuned using two LEDs (which act as variable-capacitance diodes!) and a normal potentiometer. The frequency range is set by adjusting the emitter current using a 1-kΩ trimpot. The oscillator frequency depends strongly on the operating point. This is due to the combination of using an audio transistor and the extremely low supply voltage. Under these conditions, the transistor capacitances are relatively large and strongly dependent on the operating point.
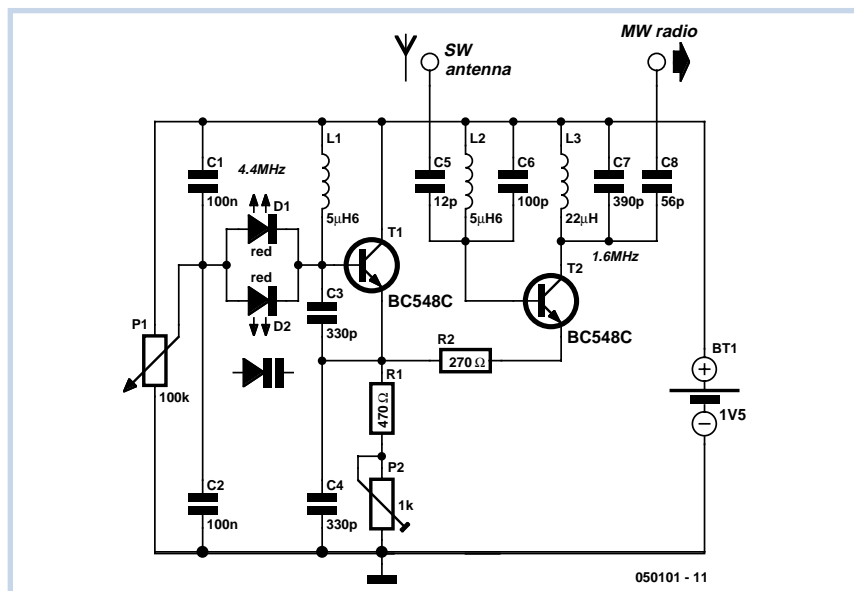
The second transistor forms the mixer stage. If you calculate the resonant frequencies of the tuned circuits, you will obtain 6.7 MHz for the antenna circuit and 1.7 MHz for the output circuit. Additional transistor capacitances and the effects of the coupling capacitors shift each of the resonant frequencies downward. The tuned circuits are relatively heavily damped to obtain bandwidths that are large enough to allow the circuit to be used without any specific alignment. The results are good despite the low collector–emitter voltage of around only 0.6 V, due to the fact that only a modest amount of mixer gain is necessary. The entire circuit also draws less than 1 mA.

(050101-1)

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PIC PWM Controller

Jean-Marc Bühler

An efficient and economical method to control the power into a load (for example the speed of a motor or the temperature of a heating element) is to use PWM (Pulse Width Modulation). But things are a little bit more involved of we want an accurate adjustment from 0 to 100 % and an indication of the power.

A little 8-pin microcontroller can do these tasks easily: generating a PWM signal and indicating the power via a 4017 (see schematic).

This configuration of the microcontroller does not require an external reset circuit (so that there is a spare pin), because we use the automatic internal one. A quartz crystal is not required either, since we're using the integrated 4-MHz oscillator, which despite being based on an RC network, is accurate to 1 % thanks to the calibration carried out at the factory.

Once the microcontroller has been provided with a suitable program, it can carry out the instructions from the user by
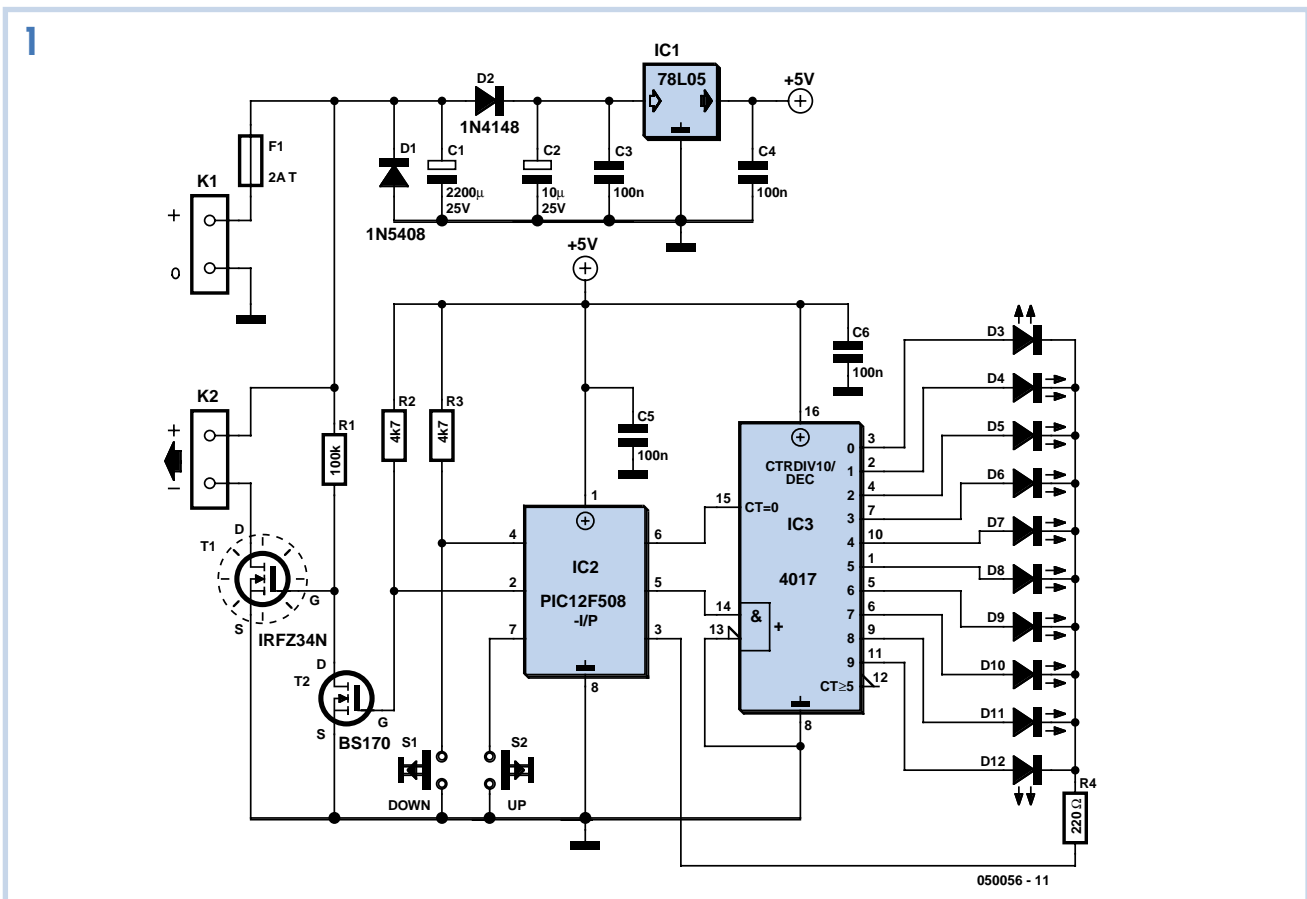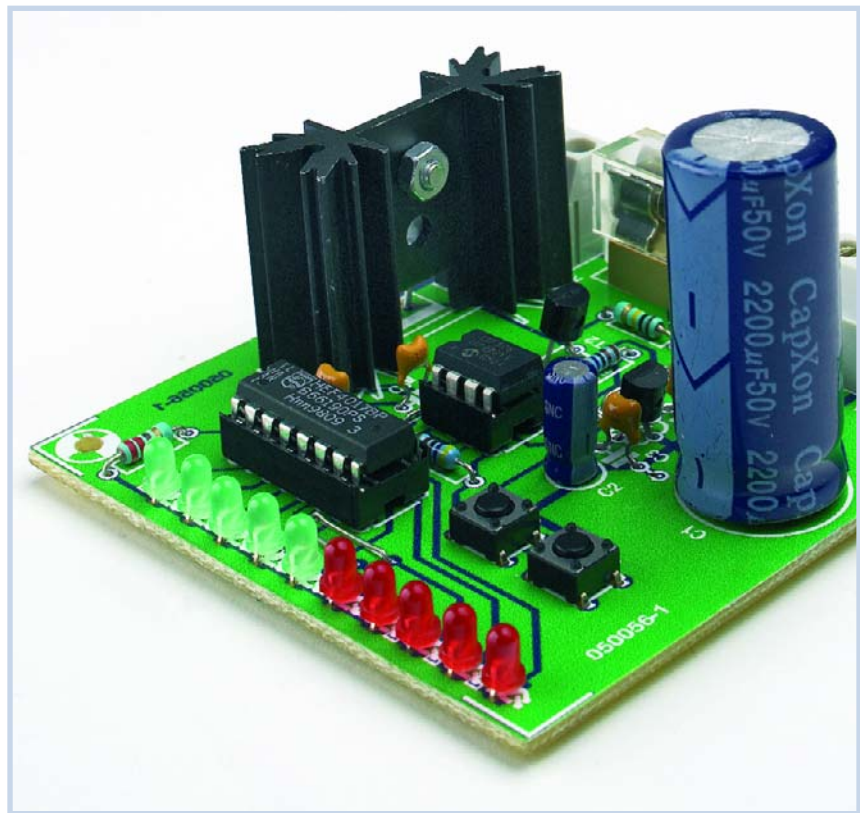
means of two pushbuttons. A PWM signal with a frequency of 100 Hz is generated, while the power is indicated with a classical 4017.

The circuit can be kept very simple because the microcontroller carries out all the complicated tasks. A 78L05 provides the power supply, a 4017 for the indicator and a pair of MOSFETs for the power stage.

Connector K1 receives the input power supply voltage (9 to 12 V at 1 to 5 A). The load to be controlled is connected to K2.

With 2 pushbuttons we can control the power in steps of 10 %. To stop immediately, both need to be pressed at the same time. That concludes the user manual!

A special feature of the circuit is the power indication with the 4017 and 10 LEDs. When first powered up, a back-and-forth running light indicates that the circuit is powered but the output is not active. As soon as the load is switched on with pushbutton S1, the first LED (10%) will light up. The correct operation of the circuit is indicated in an eye-catching manner by flashing the LED that indicates the power, using pin 3 of the controller.

The program is of a very simple design and the source code together with the hex file are available from the *Elektor Electronics* website or on a floppy disk (order code **050056-11**). You are free to add improvements, because there is plenty of space left in the program memory of the controller.

To compile the code (written in C) you can use the evaluation version of the CC5X-compiler (limited to 1024 words, which in our case is more than enough). This is available from the website www.bknd.com/cc5x (choose the Free Edition). Another handy piece of freeware is the ConText editor. It can be found at www.context.cx.

If you would like to experiment with the circuit, it is recommended to use the reprogrammable 12F629. In this case R3 is required. It is not necessary when a 12x508 is used.

When programming, don't forget to check that all the fuses are configured correctly:

Oscillator: Internal_RC
WatchDog_Timer: ON
Master_Clear_Enable: Internal
Code_Protect: OFF

This is particularly important when using the 12C508, because this is an OTP-type (can be programmed only once).

Figure 2 shows the printed circuit board, which, because of the 4 wire links has remained single-sided and provides enough space for all the parts.

T1 only requires a heatsink of you intend to regulate currents greater than 2 A over extended periods of time.

The choice of fuse depends on the current requirements of the load that is connected. T1 and the PCB traces can easily handle 5 A.

As soon as the power supply is applied to the circuit, fitted with a programmed PIC, the LEDs should light up as a running light. Every button press of S2 increases the on/off ratio with 10 % to a maximum of 100 %.

Thanks to the accurate oscillator in the 12C506, each step of 10 % corresponds to 1 ms and the entire cycle is repeated at a rate of 10 ms, which corresponds to a frequency of 100 Hz. Ideal for small motors.

A final note is that the program uses the watchdog functionality of the 12C508. This generates an automatic reset within 20 ms if the program crashes for some reason (for example large voltage surges). So there is nothing left to be desired regarding the reliability of the circuit…

(050056-1)
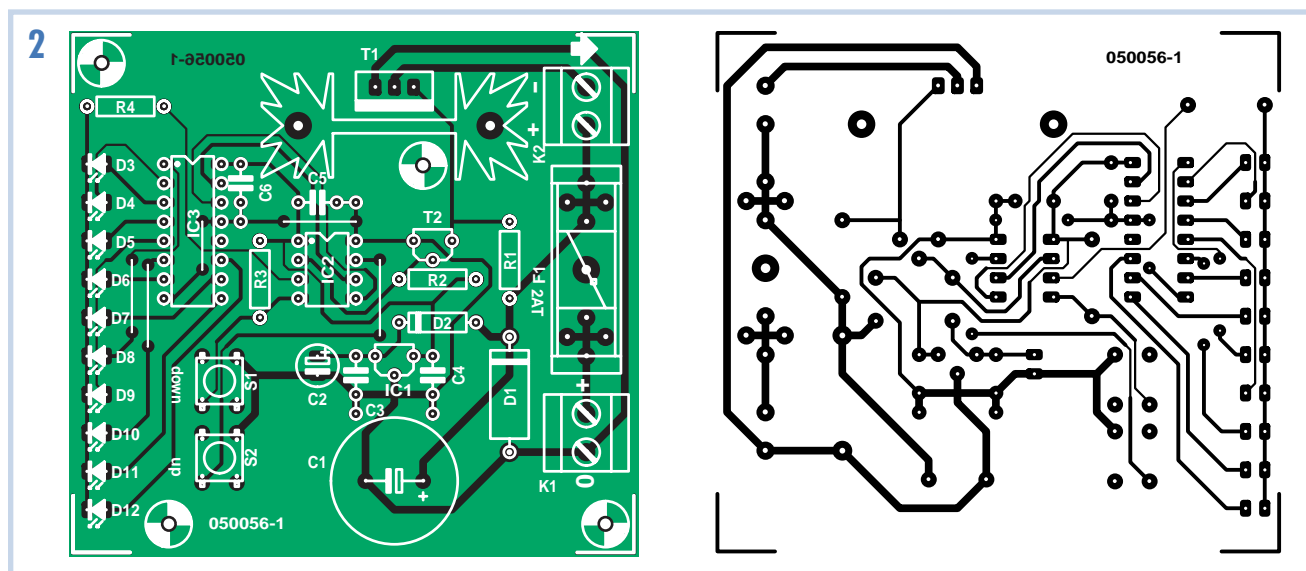
COMPONENTS LIST

Resistors:
R1 = 100kΩ
R2,R3 = 4kΩ7
R4 = 220Ω

Capacitors:
C1 = 2200µF 25V
C2 = 10µF 25V
C3-C6 = 100nF

Semiconductors:
D1 = 1N5408
D2 = 1N4148
D3-D7 = LED, 3mm, green
D8-D12 = LED, 3mm, red
T1 = IRFZ34N
T2 = BS170
IC1 = 78L05
IC2 = PIC 12C508-I/P
IC3 = CD 4017

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead pitch 5mm
S1,S2 = pushbutton, 1 make contact, DTS6
F1 = 2 AT (time lag) fuse with PCB mount holder
Heatsink type SK104 (Fischer)
PCB, ref. 050056-1 from The PCBShop
Disk, PIC source and hex code: order code **050056-11** or Free Download

089 DVI Interface

Paul Goossens

The PAL, NTSC and SECAM television standards are all several decades old. Even in this digital era, most people still have television sets that use complex analogue signals complying with these standards.

Nevertheless, the end is nigh for these standards. The DVI standard is on its way to becoming the new standard for transmitting video information. The most important property of this interface is that the information is transferred in digital form (24-bit words) instead of in the form of analogue signals.

Figure 1 shows how the required signals are divided into three data streams in a single-link interface, along with a clock signal. In DVI terminology, the clock signal is called 'Channel C'. A double-link interface with three additional information channels has also been specified to double the bandwidth. Whether these three additional channels are actually used depends on the selected resolution and repetition rate. Each channel consists of a differential signal pair. That makes this interface significantly less sensitive to interference. The technology behind these differential signal pairs is called 'transition-minimized differential signalling', or TMDS for short. **Figure 2** shows how the signals are generated in electronic terms. The connector and associated signal names are shown in **Figure 3** and **Table 1**. Besides the six TMDS signal pairs and clock signal (seven pairs in total), there are several other signals on the connector. DDC Clock and DDC Data allow a connection to be established in accordance with the DDC protocol. That protocol allows a connected device to determine which resolutions and frequencies the monitor can handle. The Hot Plug Detect signal makes it easy to recognise whether a monitor is connected. The +5-V line naturally does not need much explanation. Besides all these digital signals, the (old-fashioned) analogue RGB signals and associated sync signals are still present. Unfortunately, the illustrated connector is not the only type that is available. The illustrated connector is a DVI-I connector. It can transport both analogue and digital signals. There is also a DVI-D (digital only) and DVI-A (analogue only) connector. With the digital version, when you

1

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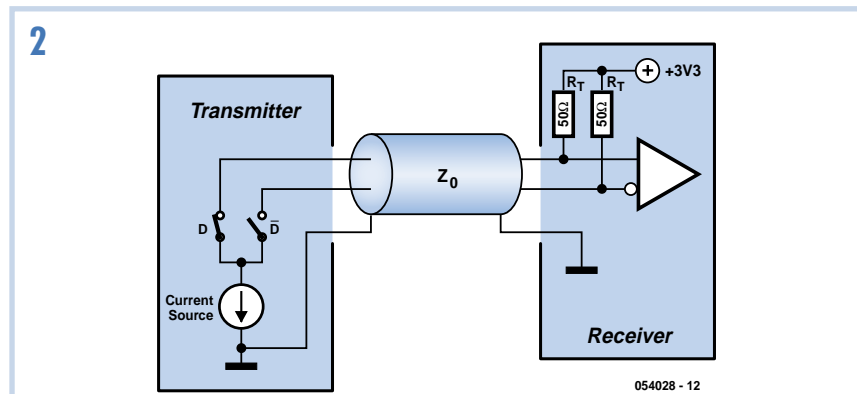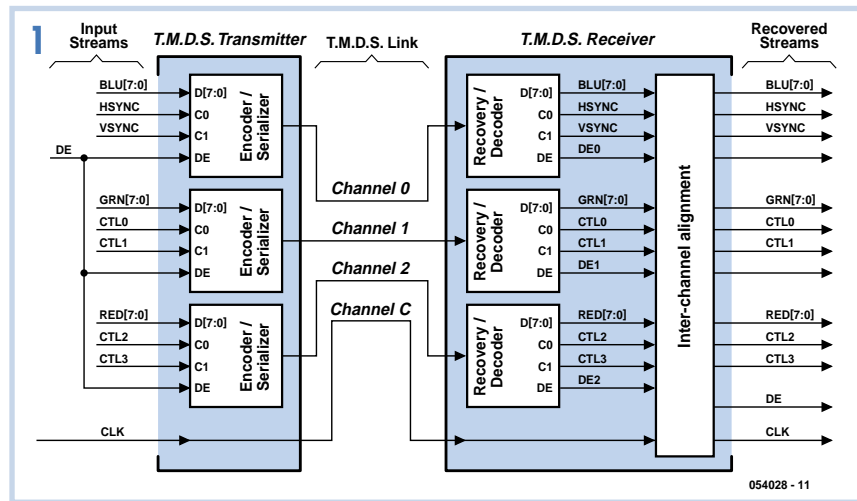
acquire a monitor or playback equipment you have to check both types of equipment to see whether they use a double-link interface (six data channels) or a single-link interface (three data channels). The DVI 1.0 standard supports several different resolutions. They are listed in **Table 2**. Each resolution can also be

Pin	Signal	Pin	Signal	Pin	Signal
	Table 1. DVI interface connector pin assignments				
1	TMDS Data2 –	9	TMDS Data 1 –	17	TMDS Data 0 –
2	TMDS Data2 +	10	TMDS Data 1 +	18	TMDS Data 0 +
3	TMDS Data2/4 shield	11	TMDS Data 1/3 shield	19	TMDS Data 0/5 shield
4	TMDS Data 4 –	12	TMDS Data 3 –	20	TMDS Data 5 –
5	TMDS Data 4 +	13	TMDS Data 3 +	21	TMDS Data 5 +
6	DDC clock	14	+5 V supply	22	TMDS clock shield
7	DDC data	15	Ground	23	TMDS clock +
8	Analog Vertical Sync	16	Hot Plug Detect	24	TMDS clock –
C1	Analog Red	C2	Analog Green	C3	Analog Blue
C4	Analog Horizontal Sync	C5	Analog ground		

3 *Combined Analog and Digital Receptacle Connector* ♀

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Table 2. Resolutions supported by DVI-1.0

VGA	640x400
SVGA	800x600
XGA	1024x768
SXGA	1280x1024
UXGA	1600x1200
HDTV	1920x1080
QXGA	2048x1536
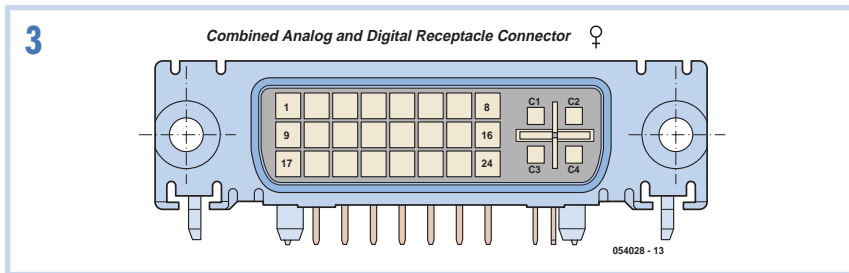
used with a variety of repetition rates, which are 60 Hz, 75 Hz and 85 Hz. That's a good selection of options, which (unfortunately) also makes for a good chance of confusion among consumers.
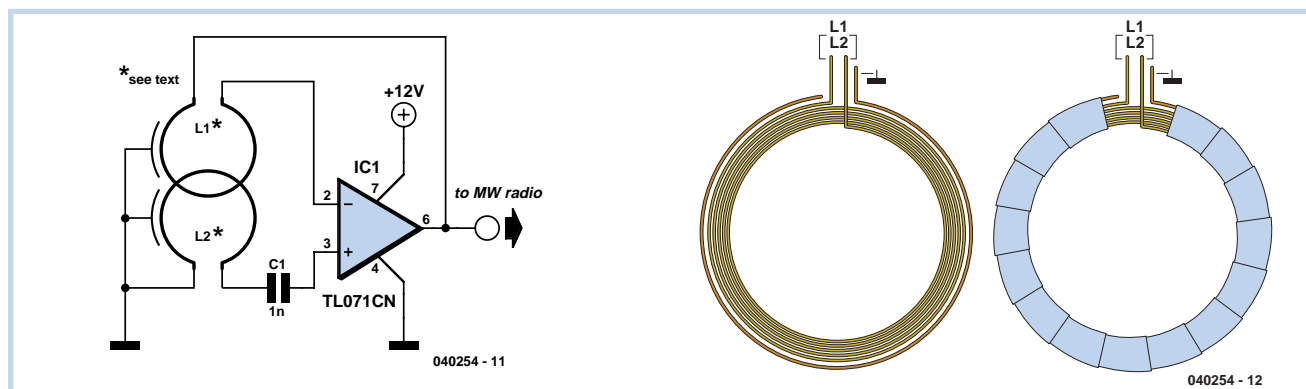
(054028-1)

CCO Metal Detector

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040254 - 12

Rev. Thomas Scarborough

To the best of the author's knowledge, the metal detector shown here represents another new genre. It is presented here merely as an experimental idea, and operates in conjunction with a Medium Wave radio.

If a suitable heterodyne is tuned in on the medium waves, its performance is excellent. An old Victorian penny, at 180 mm, should induce a shift in frequency of one tone through the radio speaker. This suggests that the concept will match the performance of induction balance (IB) detector types, while employing a fraction of the components.

In principle, the circuit is loosely based on a transformer coupled oscillator (TCO), a well known oscillator type. This essentially consists of an amplifier which, by means of a transformer, feeds the output back to the input, thus sustaining oscillation. On this basis, the author has named the detector a Coil Coupled Operation (CCO) Metal Detector.

In fact the circuit would oscillate even without L2 and C1. However, in this case one would have nothing more than a beat frequency operation (BFO) detector. Coil L2 is added to bring the induction balance principle into operation, thus modifying the signal which is returned to the output, and greatly boosting performance.

This does not mean, however, that we are dealing strictly with an IB detector type, since the design requires a beat frequency oscillator for detection. Also, unlike IB, its Rx section (L2) is active rather than passive, being an integral part of a TCO. Nor is this strictly a BFO type, since its performance far outstrips that of BFO, and of course it uses two coils.

Search oscillator IC1 oscillates at around 480 kHz, depending on the positioning of the coils on the search head. The presence of metal induces changes both in the inductance and coupling of the two coils, thereby inducing a shift in oscillator IC1's frequency.

The output (pin 6) is taken via a screened cable to a Medium Wave radio aerial. A crocodile clip termination would make a convenient connection.

The two coils are each made of 50 turns 30swg (0.315mm) enamelled copper wire, wound on a 120mm diameter former. Each has a Faraday shield, which is connected to 0V as shown. A sketch of the coil is shown in the separate drawing. The coils are positioned on the search head to partly overlap one another, in such a way as to find a low tone on the best heterodyne, which should match the performance mentioned above.

Oscillator IC1 will sustain oscillation no matter which way the coils are orientated — however, orientation significantly affects performance. The correct orientation may be determined experimentally by flipping one of the coils on the search head. Ideally, the coils will finally be potted in polyester resin.

The CCO Metal Detector's search head offers a wide area of sensitivity, so that it is better suited to sweeping an area than pinpointing a find. As with both BFO and IB, it offers discrimination between ferrous and non-ferrous metals, making it well suited to 'treasure hunting'. And if you get fed up with searching, there's always the radio to listen to.

(0x0000-1)

Balancing LiPo Cells

Paul Goossens

Things change fast in the electronics world, and that's also true for recharge-able batteries. The rate of development of new types of rechargeable batteries has been accelerated by the steadily increasing miniaturisation of electronic equipment.

LiPo cells have conquered the market in a relatively short time. Their price and availability have now reached a level that makes them attractive for use in DIY circuits.

Unlike its competitors *Elektor Electronics* has already published several articles about the advantages and disadvantages of LiPo batteries. One of the somewhat less well-known properties of this type of rechargeable battery is that the cells must be regularly 'balanced' if they are connected in series. This is because no two cells are exactly the same, and they may not all have the same temperature. For instance, consider a battery consisting of a block of three cells. In this case the outer cells will cool faster than the cell in the middle. Over the long term, the net result is that the cells will have different charge states. It is thus certainly possible for an individual cell to be excessively discharged even when the total voltage gives the impression that the battery is not fully discharged. That requires action – if only to prolong the useful life of the battery, since LiPo batteries are still not all that inexpensive.

One way to ensure that all of the cells have approximately the same charge state is limit the voltage of each cell to 4.1 V during charging. Most chargers switch over to a constant voltage when the voltage across the batter terminals is 4.2 V per cell. If we instead ensure that the maximum voltage of each cell is 4.1 V, the charger can always operate in constant-current mode.

When the voltage of a particular cell reaches 4.1 V, that cell can be discharged until its voltage is a bit less than 4.1 V. After a short while, all of the cells will have a voltage of 4.1 V, with each cell thus having approximately the same amount of charge. That means that the battery pack has been rebalanced.

The circuit (**Figure 1**) uses an IC that is actually designed for monitoring the supply voltage of a microcontroller circuit.
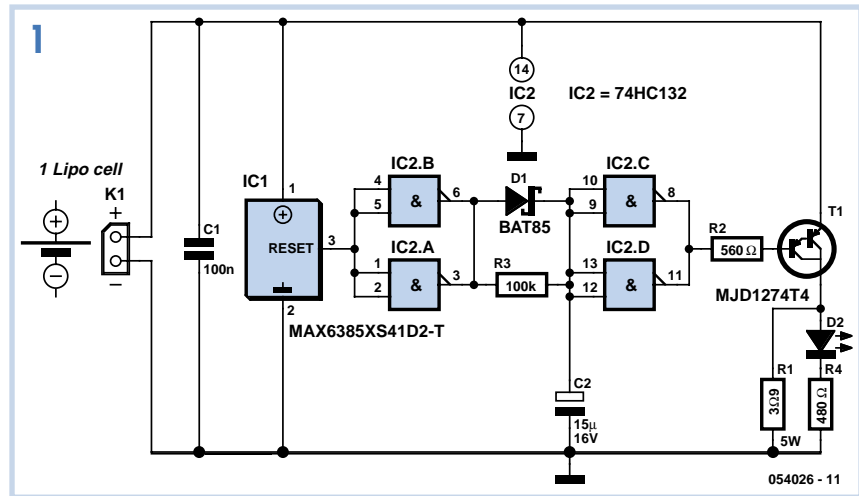
The IC (IC1) normally ensures that the microcontroller receives an active-high reset signal whenever the supply voltage drops below 4.1 V. By contrast, the output goes low when the voltage is 4.1 V or higher.

In this circuit the output is used to discharge a LiPo cell as soon as the voltage rises above 4.1 V. When that happens, the push-pull output of IC1 goes low, which in turn causes transistor T1 to conduct. A current of approximately 1 A then flows via resistor R1. LED D2 will also shine as a sign that the cell has reached a voltage of 4.1 V.

The function of IC2 requires a bit of explanation. The circuit built around the four NAND gates extends the 'low' interval of the signal generated by IC1. That

acts as a sort of hysteresis, in order to prevent IC1 from immediately switching off again when the voltage drops due the internal resistance of the cell and the resistance of the wiring between the cell and the circuit. The circuitry around IC2 extends the duration of the discharge pulse to at least 1 s.

Figure 2 shows how several circuits of this type can be connected to a LiPo battery. Such batteries usually have a connector for a balancing device. If a suitable connector is not available, you will have to open the battery pack and make your own connections for it. The figure also clearly shows that a separate circuit is necessary for each cell.
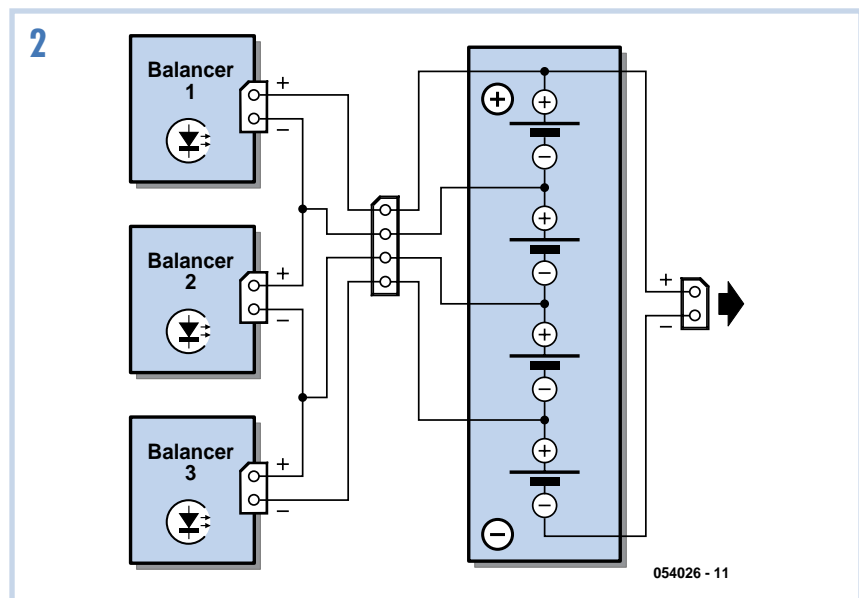
(054026-1)

Plant Growth Corrector

Paul Goossens

House plants can make things more pleasant and cheerful. However, they have the drawback that they require a fair amount of care, since otherwise their life expectancy is usually quite short. This care is not limited to watering them and occasionally adding a bit of fertilizer to the soil. The problem is that sun-loving plants always try to grow toward the source of sunlight. Regular rotation of these plants can prevent them from growing crooked.

That's not especially difficult with small plants, but it can be a highly unpleasant (and difficult) task with large types, which often have large pots as well.

It's even worse if the plants are located in the garden. These plants always try to grow toward the south (or for readers located south of the equator, toward the north; readers located close to the equator don't have to worry about this!).

One solution is to place a light source on the side of the plant that receives the least amount of sunlight. As the selected light source must be energy-efficient, a standard grow lamp is out of the question. LEDs, by contrast, are a very good choice for this application. Plants contain three different substances that can extract energy from incident light. From **Figure 1**, it can be seen that blue light can be used as a source of energy by all three substances. Red light can only be used by chlorophyll a and chlorophyll b. From this, it can be deduced that blue light is the most suitable source of light for plants, but red light is also quite usable. That's quite fortunate, because red LEDs are a lot cheaper than blue LEDs.

The circuit shown in **Figure 2** can be used as a guide for building your own plant lamp. The AC voltage at the transformer output is converted into a DC voltage by bridge rectifier B1. C1 smoothes this voltage to produce a more constant voltage across the resistor and LEDs. R1 ensures that the proper current flows through the LEDs. These LEDs emit energy in the form of red light. No component values are given here, since suitable values must be selected according to your particular wishes.

The first thing you need to know is the nominal current rating of the LEDs and the

054033 - 11

054033 - 12
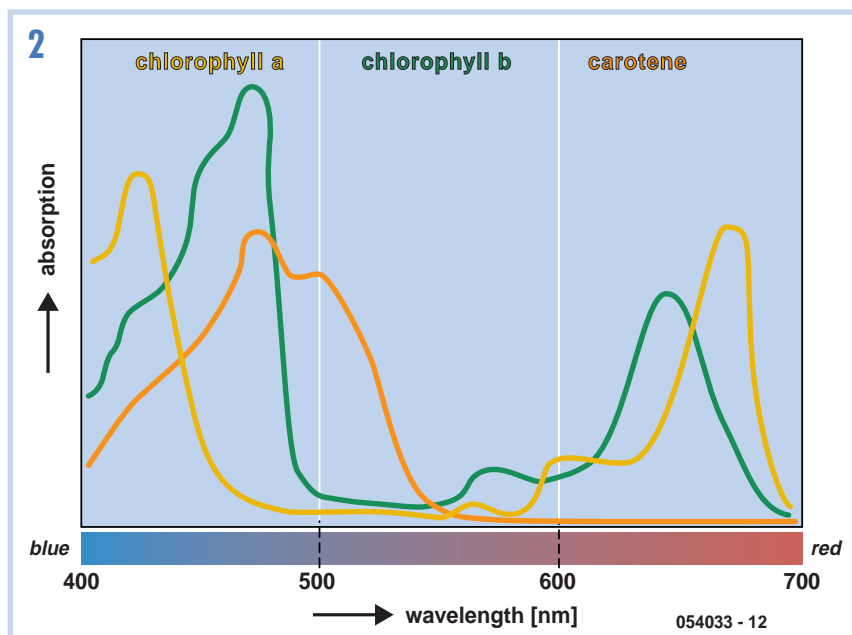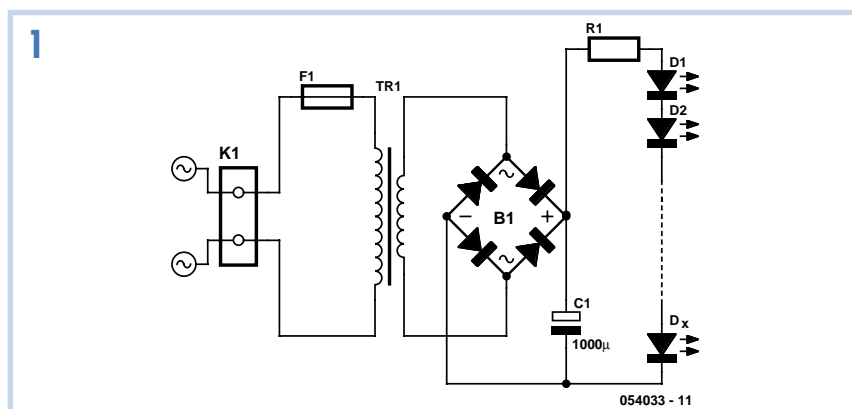
voltage across each LED at the nominal current. The total voltage across the LEDs is then:

$$V_{LEDtotal} = V_{LED} \times \text{(number of LEDs)}$$

You should ensure that at least 5% of this voltage appears across R1, which means that:

$$V_{R1min} = 0.05 \times V_{LEDtotal}$$

The voltage across C1 is approximately 1.4 times the output voltage of the transformer, so the secondary voltage of the transformer must be

$$V_{xfmr} = (V_{R1min} + V_{LEDtotal}) \div 1.4$$

Select a transformer that can provide at least this voltage at the desired nominal current.

Now you can calculate the actual voltage across R1:

$$V_{R1} = (1.4 \times V_{xfmr}) - V_{LEDtotal}$$

Finally, calculate the value of R1:

$$R1 = V_{R1} \div I_{nominal}$$

R1 also has to dissipate a certain amount of power, so you have to first calculate this in order to determine what type of resistor to use for R1:

$$P_{R1} = V_{R1} \times I_{nominal}$$

The value if C1 is not especially critical. Something between 100 µF and 1000 µF is a good guideline value. Ensure that the capacitor is suitable for use with the selected supply voltage.

(054033-1)

093 Valve Sound Converter

Stefan Dellemann

'Valve sound' is not just an anachronism: there are those who remain ardent lovers of the quality of sound produced by a valve amplifier. However, not everyone is inclined to splash out on an expensive valve output stage or complete amplifier with a comparatively low power output. Also, for all their aesthetic qualities, modern valve amplifiers burn up (in the full sense of the word!) quite a few watts even at normal listening volume, and so are not exactly environmentally harmless.

This valve sound converter offers a cunning way out of this dilemma. It is a low-cost unit that can be easily slipped into the audio chain at a suitable point and it only consumes a modest amount of energy. A valve sound converter can be constructed using a common-or-garden small-signal amplifier using a readily-available triode. Compared to using a pentode, this simplifies the circuit and, thanks to its less linear characteristic, offers even more valve sound. For stereo use a double triode is ideal. Because only a low gain is required, a type ECC82 (12AU7) is a better choice than alternatives such as the ECC81 (12AT7) or ECC83 (12AX7). This also makes things easier for homebrewers only used to working with semiconductors, since we can avoid any difficulties with high voltages, obscure transformers and the like: the amplifier stage uses an anode voltage of only 60 V, which is generated using a small 24 V transformer and a voltage doubler (D3, D4, C4 and C5). Since the double triode only draws about 2 mA at this voltage, a 1 VA or 2 VA transformer will do

the job. To avoid ripple on the power supply and hence the generation of hum in the converter, the anode voltage is regulated using Zener diodes D1 and D2, and T1. The same goes for the heater supply: rather than using AC, here we use a DC supply, regulated by IC1. The 9 V transformer needs to be rated at at least 3 VA. As you will see, the actual amplifier circuit is shown only once. Components C1 to C3, R1 to R4, and P1 need to be duplicated for the second channel. The inset valve symbol in the circuit diagram and the base pinout diagram show how the anode, cathode and grid of the other half of the double triode (V1.B) are connected. Construction should not present any great difficulties. Pay particular attention to screening and cable routing, and to the placing of the transformers to minimise the hum induced by their magnetic fields.

Adjust P1 to set the overall gain to 1 (0 dB). The output impedance of 47 kΩ is relatively high, but should be compatible with the inputs of most power amplifiers and preamplifiers.

For a good valve sound, the operating point of the circuit should be set so that the audio output voltage is in the region of a few hundred millivolts up to around 1.5 V. If the valve sound converter is inserted between a preamplifier and the power amplifier, it should be **before** the volume control potentiometer as otherwise the sound will change significantly depending on the volume. As an example, no modifications are needed to an existing power amplifier if the converter is inserted between the output of a CD player and the input to the amplifier.

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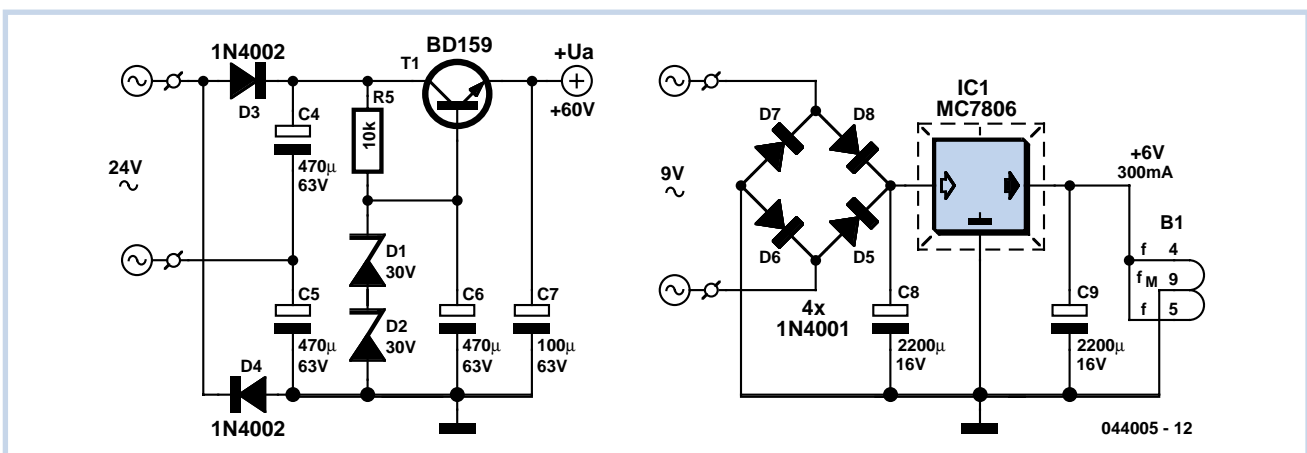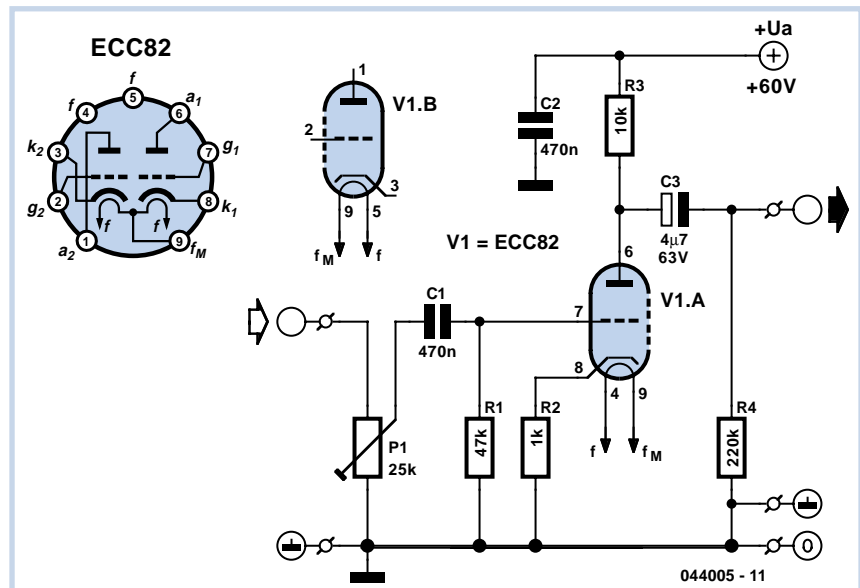
THD: Sallen–Key versus MFB

1 Sallen-Key
054034 - 11

2 Multiple-Feedback
054034 - 12
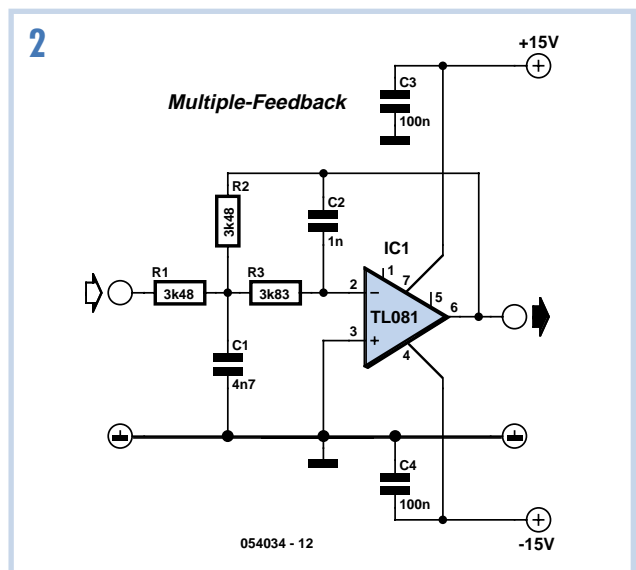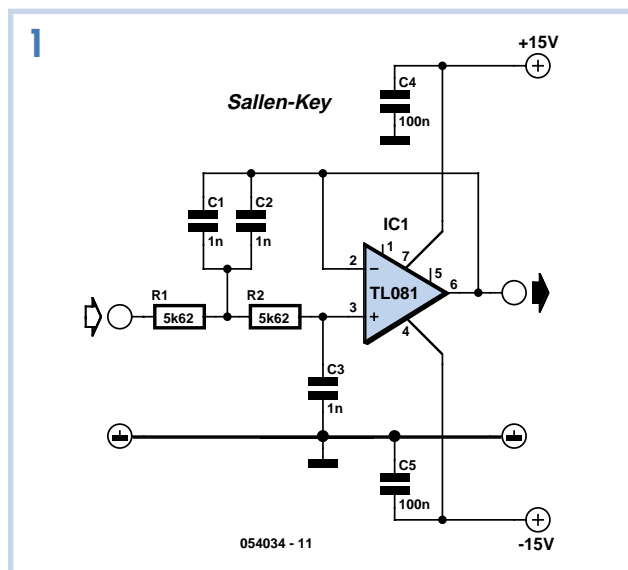
Ton Giesberts

There are various types of active filters, and the Sallen–Key version is probably the most commonly used type. A voltage follower is usually used for such filters, although gain can also be realised using two additional resistors. A disadvantage of this type of filter is its relatively high sensitivity to component tolerances. Measurements made on such filters have shown that component variations affect not only the filter characteristic but also the amount of distortion. However, an advantage is that filters more complex than third-order types can also be realised using a single amplifier stage, although severe requirements are placed on the component values in such cases.

One of the alternatives to the Sallen–Key filter is the 'multiple feedback' (MFB) filter. It owes its name to the fact that the feedback occurs via two paths. The inverting architecture can perhaps be regarded as a slight disadvantage, but that is offset by the fact that non-unity gain can be obtained without using extra components. In addition, the filter is less sensitive to component tolerances. Another drawback

3
054034 - 13

is that the implementation is restricted to third-order filters, so additional stages (and thus opamps) are necessary for higher-order filters.

That's all very nice, you might think, but how can multiple-feedback filters be calculated? That's practically impossible to do by hand. Fortunately, various software programs have been developed to do this for you, such as the quite usable FilterPro program from Texas Instruments, which can even calculate component values that exactly match the various E series.
For both types of filter, we designed a 20-kHz low-pass Butterworth bandpass filter using a standard TL081 IC (**Figures 1 and 2**) and then measured the distortion

in the output signal for an input signal of 5 V$_{rms}$. Standard polyester (MKT) capacitors were used in the circuits. To make the ultimate result more distinct, we intentionally used a simple opamp (TL081) and avoided using expensive polypropylene, polystyrene or silver-mica capacitors.

The results of the measurements can be characterised as astonishing. The multiple-feedback filter proved to generate considerably less distortion than the Sallen–Key architecture. **Figure 3** shows the measurements for the two filters, which speak for themselves. The amplitude curves were the same within a few tenths of a dB. The Sallen–Key filter clearly generates up to more than ten times as much distortion at certain frequencies. With the Sallen–Key architecture, better results can be obtained by using better capacitors and opamps (such as an OPA627). From the results, it is clear the multiple-feedback architecture is less sensitive to the components used in the filter.

(054034-1)

FilterPro:
http://focus.ti.com/docs/toolsw/folders/print/filterpro.html

An Electronic Watering Can

095
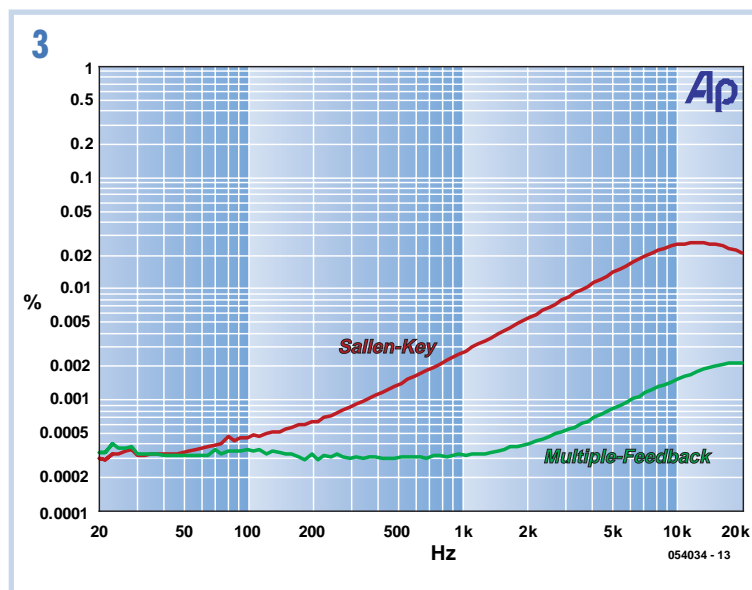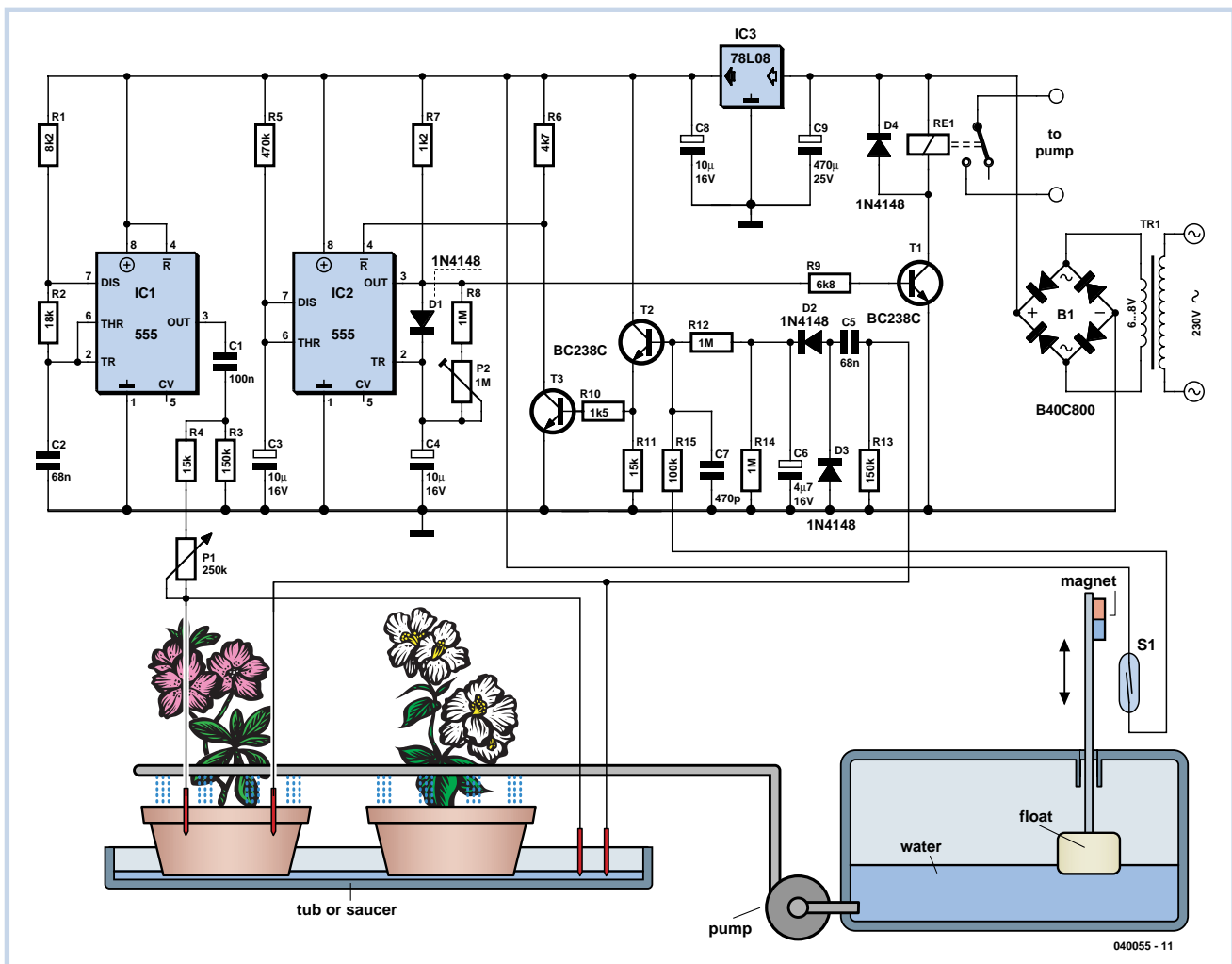
Robert Edlinger

Summertime is holiday time but who will be looking after your delicate houseplants while you are away? Caring for plants is very often a hit or miss affair, sometimes you under-water and other times you over-water. This design seeks to remove the doubt from plant care and keep them optimally watered.

The principle of the circuit is simple: first the soil dampness is measured by passing a signal through two electrodes placed in the soil. The moisture content is inversely proportional to the measured resistance. When this measurement indicates it is too dry, the plants are given a predefined dose of water. This last part is important for the correct function of the automatic watering can because it takes a little while for the soil to absorb the water dose and for its resistance to fall. If the water were allowed to flow until the soil

resistance drops then the plant would soon be flooded.

The circuit shows two 555 timer chips IC1 and IC2. IC1 is an astable multivibrator producing an ac coupled square wave at around 500 Hz for the measurement electrodes F and F1. An ac signal reduces electrode corrosion and also has less reaction with the growth-promoting chemistry of the plant. Current flowing between the electrodes produces a signal on resistor R13. The signal level is boosted and rectified by the voltage doubler produced by D2 and D3. When the voltage level on R13 is greater than round 1.5 V to 2.0 V transistor T2 will conduct and switch T3. Current flow through the soil is in the order of 10 µA.
T2 and T3 remain conducting providing the soil is moist enough. The voltage level on pin 4 of IC2 will be zero and IC2 will be disabled. As the soil dries out the signal across R13 gets smaller until eventually T2 stops conducting and T3 is

switched off. The voltage on pin 4 of IC2 rises to a '1' and the chip is enabled. IC2 oscillates with an 'on' time of around 5 s and an 'off' time (adjustable via P2) of 10 to 20 s. This signal switches the water pump via T1. P1 allows adjustment of the minimum soil moisture content necessary before watering is triggered.

The electrodes can be made from lengths of 1.5 mm^2 solid copper wire with the insulation stripped off the last 1 cm. The electrodes should be pushed into the earth so that the tips are at roughly the same depth as the plant root ball. The distant between the electrodes is not critical; a few centimetres should be sufficient. The electrode tips can be tinned with solder to reduce any biological reaction with the copper surface. Stainless steel wire is a better alternative to copper, heat shrink sleeving can used to insulate the wire with the last 1 cm of the electrode left bare. Two additional electrodes (F1) are con-

nected in parallel to the soil probe electrodes (F). The F1 electrodes are for safety to ensure that the pump is turned off if for some reason water collects in the plant pot saucer. A second safety measure is a float switch fitted to the water reservoir tank. When the water level falls too low a floating magnet activates a reed switch and turns off the pump so that it is not damaged by running with a dry tank.

Water to the plants can be routed through closed end plastic tubing (with an internal diameter of around 4 to 5 mm) to the plant pots. The number of 1 mm to 1.5 mm outlet holes in the pipe will control the dose of water supplied to each plant. The soil probes can only be inserted into one flowerpot so choose a plant with around average water consumption amongst your collection. Increasing or decreasing the number of holes in the water supply pipe will adjust water supply to the other plants depending on their needs. A 12 V water pump is a good choice for this application but if you use a mains driven pump it is essential to observe all the necessary safety precautions.

Last but not least the electronic watering can is too good to be used just for holiday periods, it will ensure that your plants never suffer from the blight of over or under-watering again; provided of course you remember to keep the water reservoir topped up…

(044055-1)

Precision Headphone Amplifier

Hergen Breitzke

Designs for good-quality headphone amplifiers abound, but this one has a few special features that make it stand out from the crowd.

We start with a reasonably conventional input stage in the form of a differential amplifier constructed from dual FET T2/T3. A particular point here is that in the drain of T3, where the amplified signal appears, we do not have a conventional current source or a simple resistor. T1 does indeed form a current source, but the signal is coupled out to the base of T5 not from the drain of T3 but from the source of T1. Notwithstanding the action of the current source this is a low impedance point for AC signals in the differential amplifier. Measurements show that this trick by itself results in a reduction in harmonic distortion to considerably less than –80 dB (much less than 0.01 %) at 1 kHz.

T5 is connected as an emitter follower and provides a low impedance drive to the gate of T6: the gate capacitance of HEXFETs is far from negligible. IC1, a voltage regulator configured as a current sink, is in the load of T6. The quiescent current of 62 mA (determined by R11) is suitable for an output power of 60 mW$_{eff}$ into an impedance of 32 Ω, a value typical of high-quality headphones, which provides plenty of volume. Using higher-impedance headphones, say of 300 Ω, considerably more than 100 mW can be achieved.

The gain is set to a useful 21 dB (a factor of 11) by the negative feedback circuit involving R10 and R8. It is not straightforward to change the gain because of the single-sided supply: this voltage divider also affects the operating point of the amplifier. The advantage is that excellent audio quality can be achieved even using a simple unregulated mains supply. Given the relatively low power output the power supply is considerably overspecified. Noise and hum thus remain more than 90 dB below the signal (less than 0.003 %), and the supply can also power two amplifiers for stereo operation.

The bandwidth achievable with this design is from 5 Hz to 300 kHz into 300 Ω, with an output voltage of 10 V$_{pp}$. The damping factor is greater than 800 between 100 Hz and 10 kHz.

A couple of further things to note: somewhat better DC stability can be achieved by replacing D1 and D2 by low-current red LEDs (connected with the right polarity!). R12 prevents a click from the discharge of C6 when headphones are plugged in after power is applied. T6 and IC1 dissipate about 1.2 W of power each as heat, and so cooling is needed. For low impedance headphones the current through IC1 should be increased. To deliver 100 mW
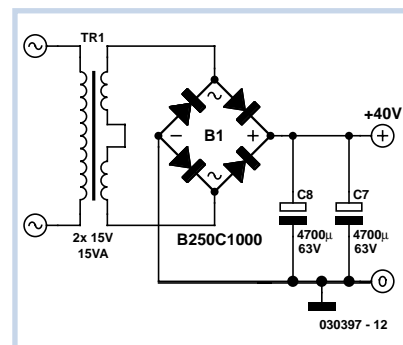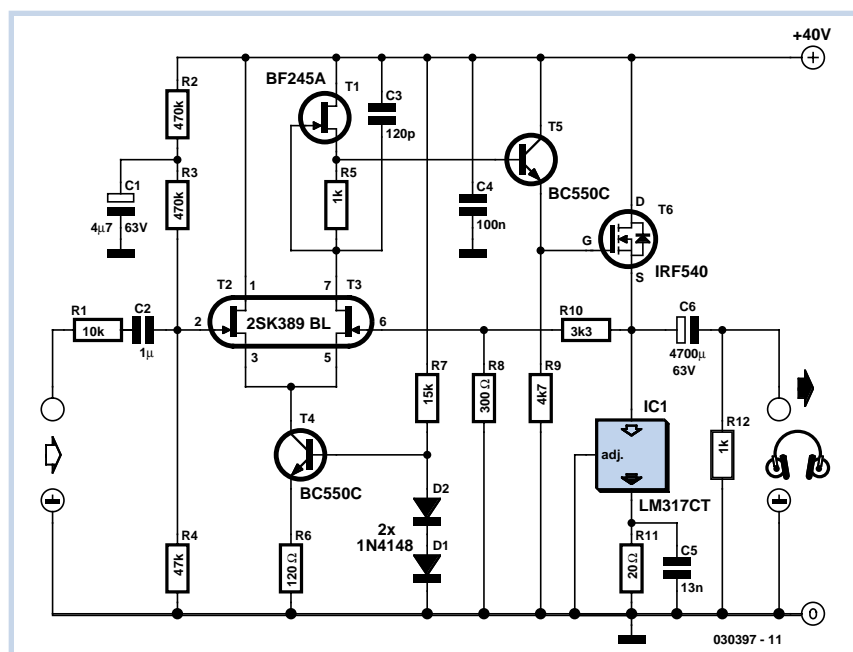
into 8 Ω, around 160 mA is required, and R11 will need to be 7.8 Ω (use two 15 Ω resistors in parallel). To keep heat dissipation to a reasonable level, it is recommended to reduce the power supply voltage to around 18 V (using a transformer with two 6 V secondaries). This also means an adjustment to the operating point of the amplifier: we will need about 9 V between the positive end of C6 and ground. R4 should be changed to 100 Ω, and R8 to 680 Ω. The gain will now be approximately 6 (15 dB). The final dot on the 'i' is to increase C7 by connecting another 4700 µF electrolytic in parallel with it, since an 8 Ω load will draw higher currents.

(030397-1)

097

USB Power Booster

Myo Min

Power shortage problems arise when too many USB devices connected to PC are working simultaneously. All USB devices, such as scanners, modems, thermal printers, mice, USB hubs, external storage devices and other digital devices obtain their power from PC. Since a PC can only supply limited power to USB devices, external power may have to be added to keep all these power hungry devices happy.

This circuit is designed to add more power to a USB cable line. A sealed 12-V 750 mA unregulated wall cube is cheap and safe. To convert 12 V to 5 V, two types of regulators, switching and linear are available with their own advantages and drawbacks. The switching regulator is more suitable to this circuit because of high efficiency and compactness and now most digital circuits are immune to voltage ripple developed during switching. The simple switcher type LM2575-5 is chosen to provide a stable 5 V output voltage. This switcher is so simple it just needs three components: an inductor, a capacitor and a high-speed or

040453 - 11
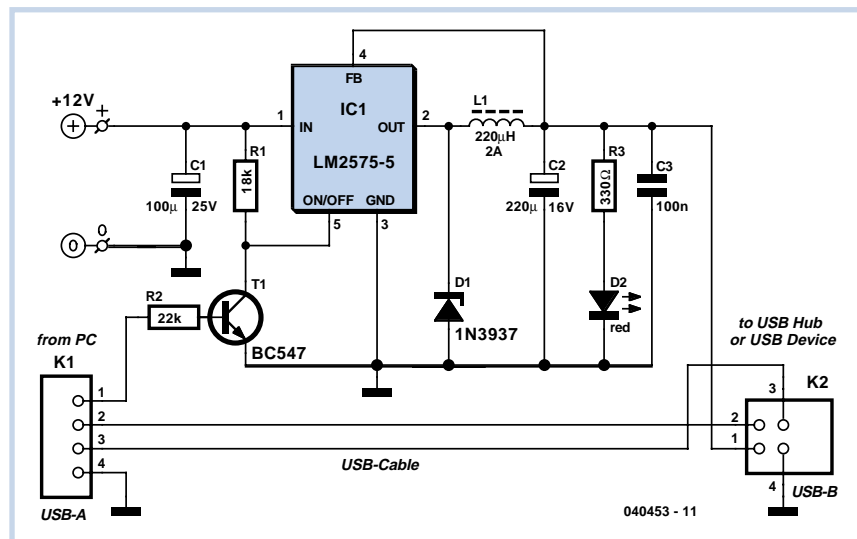
fast-recovery diode. Its principle is that internal power transistor switch on and off according to a feedback signal. This chopped or switched voltage is converted to DC with a small amount of ripple by D1, L1 and C2.

The LM2575 has an ON/OFF pin that is switched on by pulling it to ground. T1, R2, and R1 (pull-up resistor) pull the ON/OFF pin to ground when power signal from PC or +5 V is received. D2, a red LED with current resistor R3, serves to indicate 'good' power condition or stable 5 V. C3 is a high-frequency decoupling capacitor. The author managed to cut a USB cable in half without actually cutting data wires. It is advisable to look at the USB cable pin assignment for safety.

(040453-1)

098

Dual Oscillator for µCs

Ton Giesberts

The MAX7378 contains two oscillators and a power-on reset circuit for microprocessors. The Speed input selects either 32.768 kHz (LF) or a higher frequency, which is pre-programmed. The type number corresponds to the standard pre-programmed value and the value of the reset threshold. There is a choice of two threshold values: 2.56 V and 4.29 V. Both thresholds are available with all standard frequencies, which are 1 MHz, 1.8432 MHz, 3.39545 MHz, 3.6864 MHz, 4 MHz, 4.1943 MHz, and 8 MHz. However, any frequency between 600 kHz and 10 MHz is also possible. An internal synchronisation circuit ensures that no glitches occur when switching between the two oscillators. The Reset output of the MAX7378 is available in three different options. Two of the options are push-pull types, either active low or active high. The third option is open drain, which thus requires an external pull-up resistor. That is the only standard option (which is why a resistor in dashed outline

is shown connected to the Reset output). The Reset signal remains active for 100 μs after the supply voltage rises above the threshold voltage. The Reset signal becomes active immediately if the voltage drops below the threshold.

The IC is powered via two separate pins. The V_L pin powers the reset and oscillator circuitry, while the V_{CC} pin powers the remainder of the chip. The two pins must always have the same potential. Good decoupling in the form of two 100-nF ceramic capacitors (SMD types) is also necessary.

The IC is housed in the tiny 8-pin μMAX package and has dimensions of only 3.05×5.03 mm including pins, with a pin pitch of only 0.65 mm.

Unfortunately, the accuracy of the oscillators is not especially good. The HF oscillator has an error of ±2% at 25 °C with a 5-V supply voltage and a maximum temperature coefficient of +325 ppm, which doesn't exactly correspond to crystal accuracy, but it is certainly usable for most non-time-critical applications. The error over the full supply voltage range (2.7–5.5 V) is twice as large. The 32.768-kHz oscilla-

tor is more accurate, with an error of only 1% at 5 V and 25 °C, although this is still a bit too much for time measurements. The error can be as much as ±3% over the
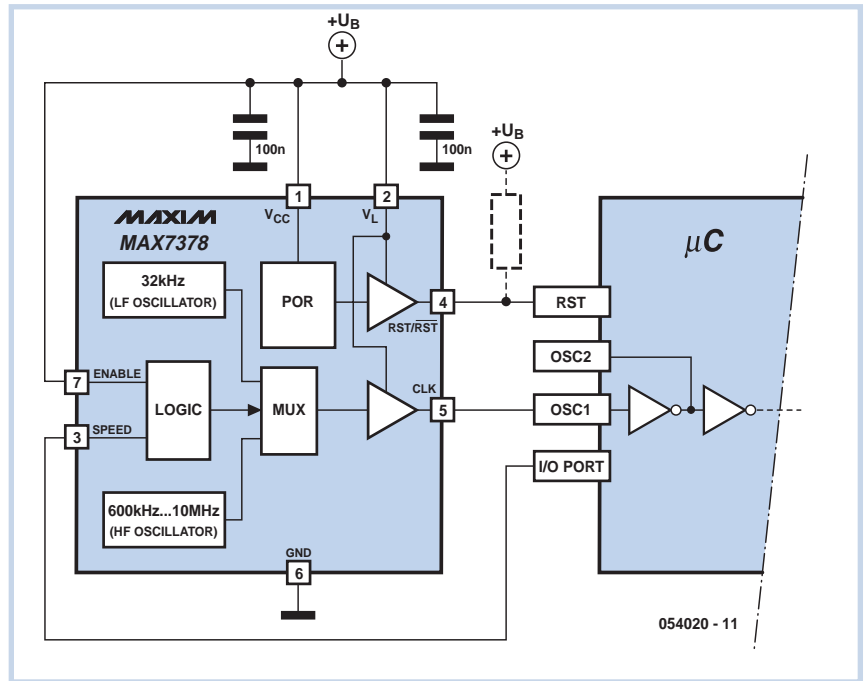
entire supply voltage range. The maximum current consumption is 5.5 mA, which is relatively low.

(054020-1)

Step-up Converter for 20 LEDs

099

Dirk Gehrke

The circuit described here is a step-up converter to drive 20 LEDs, designed to be used as a home-made ceiling night light for a child's bedroom. This kind of night light generally consists of a chain of Christmas tree lights with 20 bulbs each consuming 1 W, for a total power of 20 W. Here, in the interests of saving power and extending operating life, we update the idea with this simple circuit using LEDs.

Power can be obtained from an unregulated 12 V mains adaptor, as long as it can deliver at least about 330 mA. The circuit uses a low-cost current-mode controller type UCC3800N, reconfigured into voltage mode to create a step-up converter with simple compensation. By changing the external components the circuit can easily be modified for other applications. To use a current-mode controller as a voltage-mode controller it is necessary to couple a sawtooth ramp (rising from 0 V to 0.9 V) to the CS (current sense) pin, since this pin is also an input to the internal PWM comparator. The required ramp is
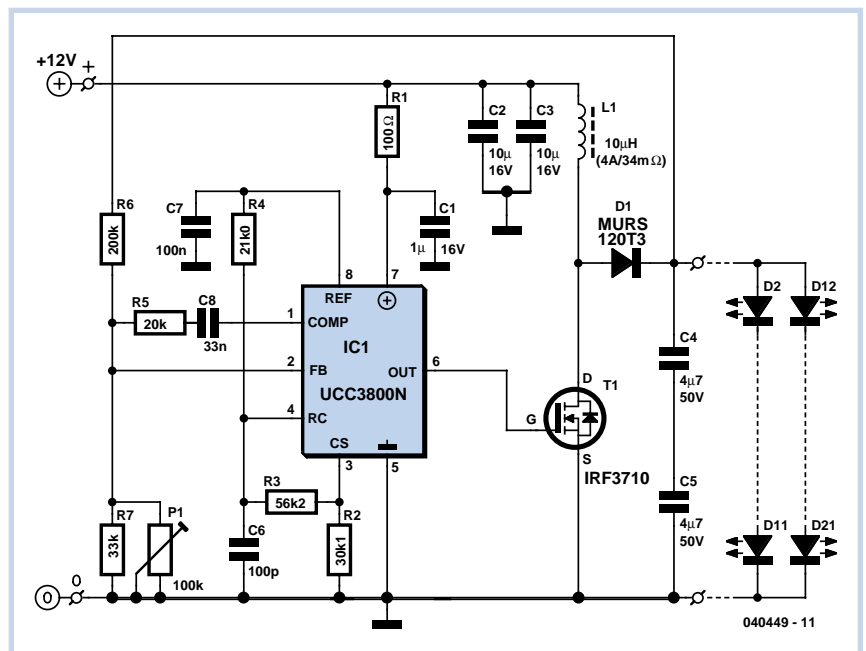
present on the RC pin of the IC and is reduced to the correct voltage range by the voltage divider formed by R3 and R2. The RC network formed by R4 and C6 is

dimensioned to set the switching frequency at approximately 525 kHz.

The comparator compares the ramp with the divided-down version of the output

voltage produced by the potential divider formed by R6 and R7. Trimmer P1 allows the output voltage to be adjusted. This enables the current through the LEDs to be set to a suitable value for the devices used.

The UCC3800N starts up with an input voltage of 7.2 V and switches off again if the input voltage falls below 6.9 V. The circuit is designed so that output voltages of between 20 V and 60 V can be set using P1. This should be adequate for most cases, since the minimum and maximum specified forward voltages for white LEDs are generally between 3 V and 4.5 V. For the two parallel chains of ten LEDs in series shown here a voltage of between 30 V and 45 V will be required. The power components D1, T1 and L1 are considerably overspecified here, since the circuit was originally designed for a different application that required higher power.

To adjust the circuit, the potentiometer should first be set to maximum resistance and a multimeter set to a 200 mA DC current range should be inserted in series with the output to the LEDs. Power can now be applied and P1 gradually turned until a constant current of 40 mA flows. The step-up converter is now adjusted correctly and ready for use.

(040449-1)

Resistor-Programmable Temperature Switch

T in °C	R_{SET}	T in °C	R_{SET}
−40	150 kΩ	35	62 kΩ
−30	136 kΩ	40	57.6 kΩ
−20	122 kΩ	45	53.3 kΩ
−10	108 kΩ	50	49.2 kΩ
−5	102 kΩ	60	41.3 kΩ
0	96.5 kΩ	70	33.9 kΩ
5	92 kΩ	80	27 kΩ
10	86.2 kΩ	90	20.4 kΩ
15	81 kΩ	100	14.1 kΩ
20	76 kΩ	110	8.2 kΩ
25	71 kΩ	120	2.6 kΩ
30	66.5 kΩ	125	0

040431 - 11

Gregor Kleine

The switching threshold of the MAX6509 temperature switch from Maxim (www.maxim-ic.com) can be programmed over a range of −40 °C to +125 °C using an external resistor. The IC needs only two external components (see **Figure 1**). A hysteresis value of 2 °C (typical) or 10 °C (typical) can be selected by connecting the HYST pin to ground or Vcc, respectively.

The standard version of the IC is the MAX6509C, which pulls its open-drain output to ground when the temperature is below the threshold value set using the resistor. As shown in **Figure 2**, this version of the IC can be used to control a fan via an external MOSFET. The MAX6509H version has an inverted output, which means it is switched to ground when the temperature is above the threshold. A possible application for this version is switching on a heater in an oven when the temperature drops below the set point. The IC is housed in a SOT232 SMD package (**Figure 3**). The MAX6509 operates over a supply voltage range of +2.7–5.5 V with a supply current of only approximately 40 µA. The resulting self-heating is thus small enough to avoid corrupted temperature measurements (as long as the output transistor is not required to switch high currents to ground). The table lists suitable values of resistor R_{SET} for various threshold temperatures.

The companion MAX6510 has an output stage that can be configured via a separate pin. The options are active high, active low, and open drain with an internal pull-up resistor. Like the MAX6510, MAX6510 is available in a -C version (open drain when the threshold temperature is exceeded) and an -H version (output pulled to ground when the threshold temperature is exceeded).

(040431-1)

040431 - 12

040431 - 13

PCI Express

PCI-Express 1x

054036 - 11
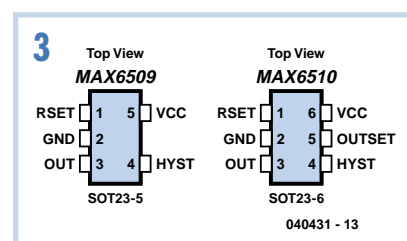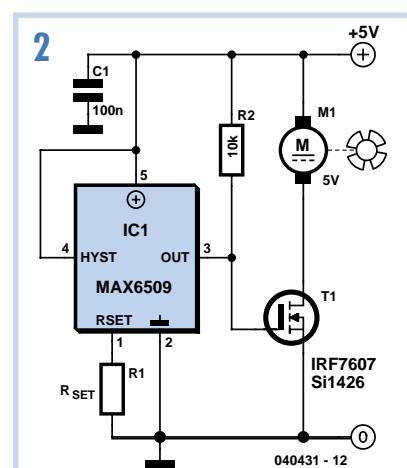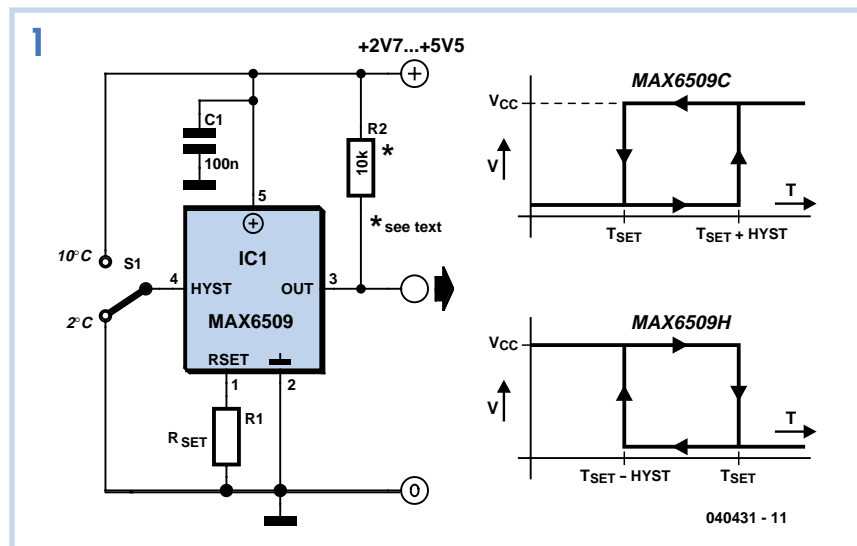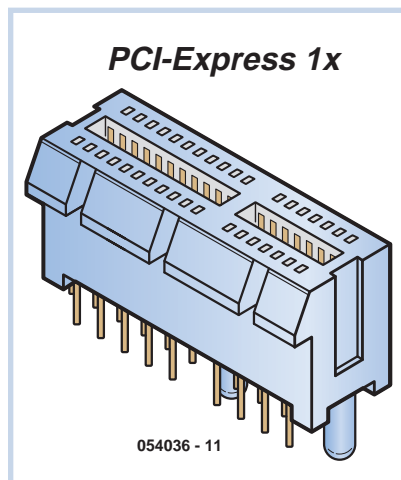
Paul Goossens

Many new PCs now come equipped with one or more PCI Express slots on the motherboard. Eventually, PCI Express will make the old PCI standard obsolete, but for now most expansion cards still use the (old) PCI standard.

The old standard (PCI 1.0) had a maximum bandwidth of 133 MB per second. In the meantime there have been many developments in the computer industry. We can now watch videos over the Internet, as well as listen to the radio. MP3s (also unheard of then) are decoded in real-time, while we might also watch a DVD in another window.

All these applications place a big demand on the PC hardware. To process these data streams efficiently, contemporary PCs have a separate memory bus, another bus for the graphics card (AGP) and yet another bus (PCI) that lets the processor communicate with expansion cards.

There have been several enhancements to the PCI bus (e.g. the 66 MHz PCI bus, 64 bit versions, etc.), but the time has come for a complete overhaul. The result is PCI Express. The x1 version has a bandwidth of 250 MB/s, but other versions are waiting in the wings (including a x16 version) to provide even greater bandwidths.

One way in which the data rate can be increased is to increase the number of bits that are moved at the same time. This technique has already been used in processors to increase their speed. For PCI Express however, a serial transport mechanism was chosen (as with SATA, USB, firewire, etc.).

The slowest version of PCI Express uses a connector with only 26 connections. The connection details for the PCI Express connector are shown in **Table 1**.

There are only four signals on this connector that take care of the actual data transmission via the PCI Express protocol. These are the signal pairs PETn0/PETp0 and PERn0/PERp0. Signal pair PETx0 (PCI Express Transmit 0) moves data from the host (PC) to the slave (slot), while PERx0 (PCI Express Receive 0) moves the data in the opposite direction. The small letter p or n denotes the polarity (positive or negative).

The data has to be in step with a clock signal, provided by the signal pair CLK+ and CLK-.

The rest of the connections are for the supply, plus a few more signals for housekeeping tasks. It is noteworthy that the connector also has a USB port and an SMBus (a type of I_C bus). This bus is used in PCs for power management and system monitoring. PCI Express cards could, for example, return measurements of the supply voltage and temperature. The PC could also put the expansion card into standby mode while it wasn't needed.

Faster versions of PCI Express make use of multiple transmit and receive channels, (hence the '0' in, for example, PERn0). In this way a form of parallelism is still used to provide a speed increase.

(054036-1)

Table 1				
Pin	**Name**	**From**	**To**	**Description**
1	GND	N/A		Ground
2	USBD–	bidirectional		USB signals
3	USBD+			
4	CPUSB	slave	host	Detection of USB device
5	reserved			
6	reserved			
7	SMBCLK	bidirectional		SMBus clock
8	SMBDATA			SMBus data
9	+1.5V	N/A		+1.5V supply voltage
10	+1.5V			
11	WAKE	slave	host	Wake-up signal for host
12	+3.3V	N/A		+3.3V supply voltage
13	PERST	host	slave	Reset signal
14	+3.3V	N/A		+3.3V supply voltage
15	+3.3V			
16	CLKREQ	slave	host	Clock request
17	CPPE	slave	host	PCI Express detection
18	REFCLK–	host	slave	Differential clock signal pair synchronous with data
19	REFCLK+	host	slave	
20	GND	N/A		Ground
21	PERn0	slave	host	Differential data signal pair from slave to host
22	PERp0	slave	host	
23	GND	N/A		Ground
24	PETn0	host	slave	Differential data signal pair from host to slave
25	PETp0	host	slave	
26	GND	N/A		Ground

Passive 9th-order Elliptical Filter
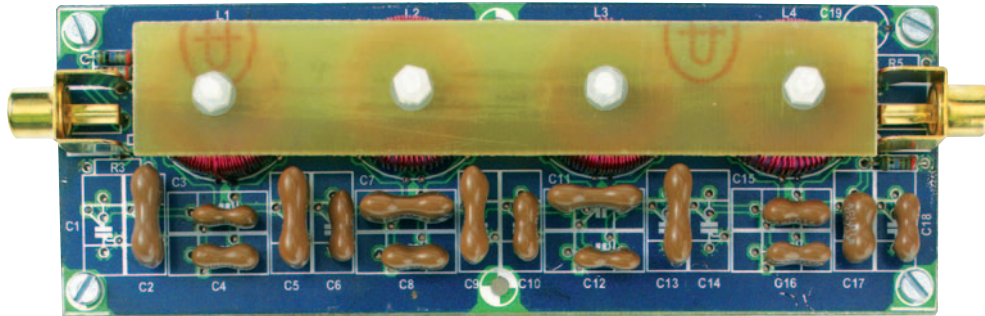
Ton Giesberts

Steep filters can be realised in many different ways, for example by connecting active 2nd to 5th-order sections in series and calculating the component values for the higher order. They can also be made passive, but in practice this has a few difficulties associated with it. You cannot avoid the need for inductors with values that deviate from the standard series. You will have to wind them yourself on a specially selected core. The filter presented here was originally designed to enable measurements to be made on the Class-T Amplifier (yes indeed, the one in *Elektor Electronics,* June 2004).

When designing and testing audio equipment, we use a System Two Cascade Plus Analyzer made by Audio Precision. The accuracy of the measurements with this instrument is reduced if frequency components above 200 kHz are present at significant levels. This is the case with our amplifier, particularly at low signal levels. We immediately went for large artillery, namely a 9th-order elliptical filter. During the design of the filter we made use of normalised tables. In the end it became a filter with identical termination impedances, which unfortunately means an attenuation of two times within the pass band. When converting to realistic values we selected

pure E12-series values for C1(+C2). All capacitors are arranged as two in parallel in order to closely approximate the calculated value. This applies to the resistors as well. With the inductors there is no way to avoid 'funny' values and series or parallel connections don't make much sense because to achieve a certain quality, standard coils are not appropriate. So we had to think of a solution ourselves. The input and output impedance are theoretically 1.060 kΩ and are approximated quite well with components in parallel (1.05996 kΩ). By making use of a voltage divider it becomes possible for R3 to handle a higher voltage (otherwise note the dissipation of R1!). Any voltage divider needs to have an output impedance of 1.06 kΩ (R1//R2//R3). In the last section, the parasitic capacitance of the connecting cable and input impedance of the analyser has been taken into account. Trimmer C19 can be used to compensate the attached capacitance and R5 can be omitted if the input impedance is about 100 kΩ. A deviation of about 50 pF makes little difference to the amplitude characteristic in the pass-band.

The advantage of an elliptical filter compared to, for example a Chebyshev filter, is to trade off a limited attenuation in the stop- band to a much steeper transition from pass- to stop-band. It suffices to men-

tion that the curve from 180 kHz to 200 kHz falls by more than 60 dB, quite steep and certainly not bad for a passive filter! In practice the attenuation in the stop-band at –63 dB was a little lower than the theoretical value of 60.2 dB, which was the design value.

Frequency characteristic A shows mainly the stop-band and the characteristic behaviour of an elliptical filter can be clearly seen. Frequency characteristic B shows an enlarged version of the ripple in the pass-band, which also shows the phase behaviour of the filter (scale on the right). At 20 kHz the attenuation is only 0.1 dB and the phase shift only -30°. The first dip of only -0.263 dB occurs at about 46 kHz and the attenuation at 100 kHz is only 0.276 dB. Above that, the non-ideal behaviour of the components becomes noticeable and the curve starts to drop a little too soon, but the characteristic elliptical behaviour is still clearly visible at 180 kHz.

The filter proved to be quite useful in filtering the PWM signal and analyse the LF- amplitude. The only disadvantage is the increasing distortion at 20 kHz (from 0.5 V input signal) so that good THD+N measurements can only be done at 1 kHz. This can be seen clearly in Graph C. With 1 W into 8 Ω (2.828 V) the distortion at 1 kHz is less than 0.001%, but at 20 kHz the distortion is

044042 - 11
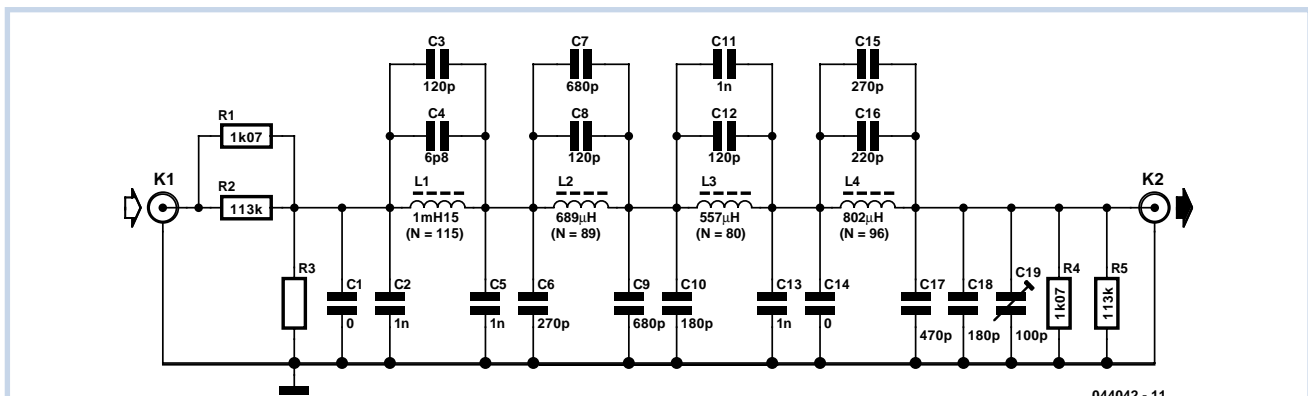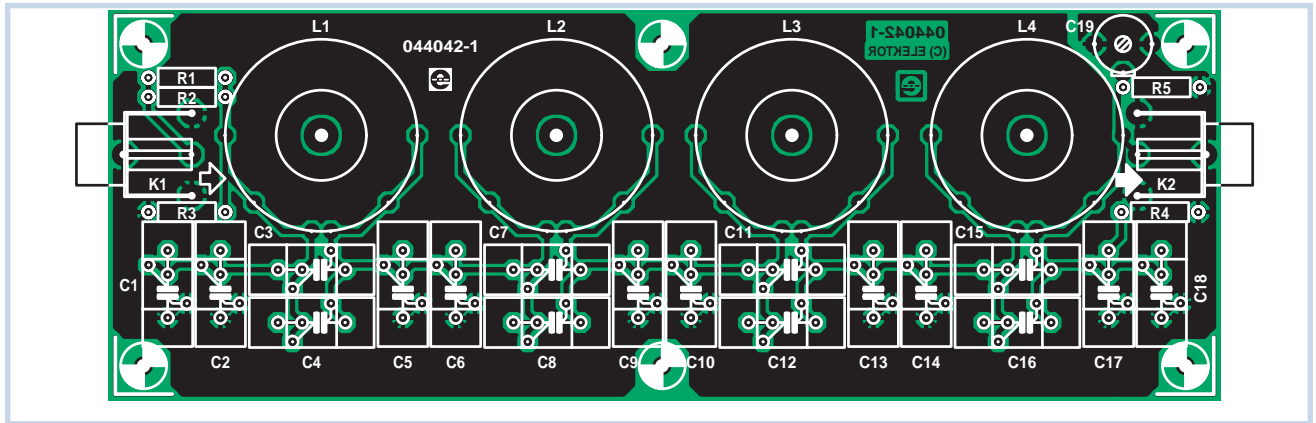
COMPONENTS LIST

Resistors:
R1,R4 = 1kΩ07
R2,R5 = 113kΩ
R3 = not fitted *

Capacitors:
C1,C14 = not fitted *
C2,C5,C11,C13 = 1nF 500V 1%
  silvered mica (Farnell 868-012)
C3,C8,C12 = 120pF 500V 1% silvered
  mica (Farnell 867-901)

C4 = 6pF8 500V 1% silvered mica
  (Farnell 867-779)
C6,C15 = 270pF 500V 1% silvered mica
  (Farnell 867-949)
C7,C9 = 680pF 500V 1% silvered mica
  (Farnell 867-998)
C10,C18 = 180pF 500V 1% silvered
  mica (Farnell 867-925)
C16 = 220pF 500V 1% silvered mica
  (Farnell 867-937)
C17 = 470pF 500V 1% silvered mica
  (Farnell 867-974)
C19 = 100pF trimmer

Inductors:
L1 = 1mH15, 115 turns of 0.5mm dia.
  ECW on core TN23/14/7-4C65 from

BCcomponents (Farnell # 180-009)
L2 = 689µH, 89 turns of 0.5mm dia.
  ECW on core TN23/14/7-4C65 from
  BCcomponents (Farnell # 180-009)
L3 = 557µH, 80 turns of 0.5mm dia.
  ECW on core TN23/14/7-4C65 from
  BCcomponents (Farnell 1# 80-009)
L4 = 802µH, 96 turns of 0.5mm dia.
  ECW on core TN23/14/7-4C65 from
  BCcomponents (Farnell # 180-009)

Miscellaneous:
K1,K2 = cinch socket, PCB mount, e.g., T-709G (Monacor/Monarch)
PCB, available from The PCBShop

* see text
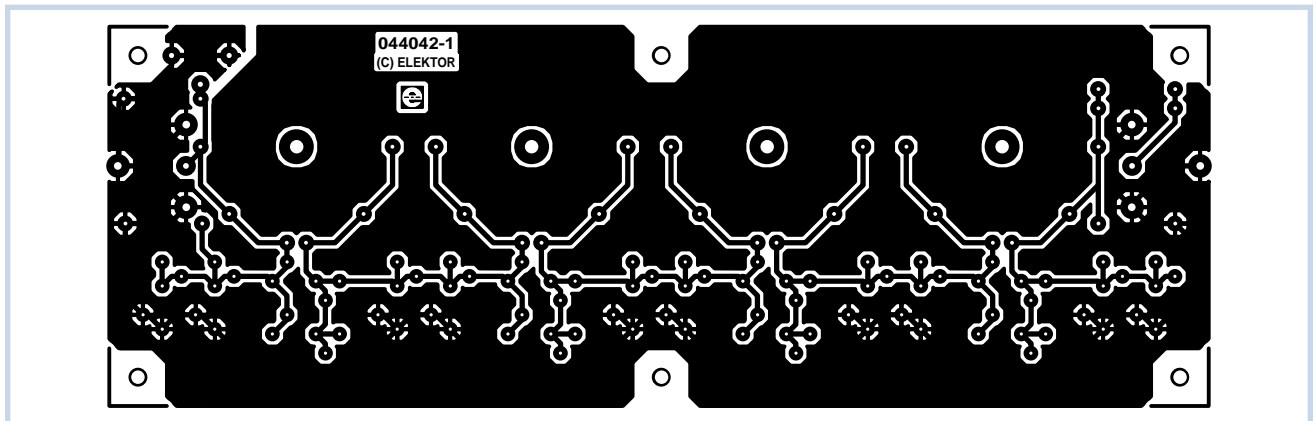
20 times larger. In this measurement the maximum input signal was 13.33 V (maximum from the analyser).

For those who love to experiment and wind inductors, we have also designed a PCB. A low permeability core material (TN23/14/7-4C65) was selected for the inductors, so that saturation and material properties are less of a problem. Unfortunately this results in a higher number of turns, but also means that the inductor value can be made more accurate. A larger core may have resulted in a lower distortion, but it would have been harder to obtain an accurate value. Toroids were selected to minimise mutual coupling — that this was successful is shown in Graph A. It is easiest when winding the cores to calculate the amount of wire required beforehand and

then add 10 or more centimetres. You have to wind tightly and put the turns close together to prevent the second layer dropping in between the first layer. This applies to the inside of the ring core. When using 0.5 mm enamelled wire the second layer turns easily fit between the first layer turns. The PCB has been designed such that connections can be made in several places (3 inside a quarter circle). The capacitors are 1% silvered mica types with an operating voltage of 500 V. That way even extreme voltage peaks will not cause any harm. There is also room for 1% tolerance 'Styroflex' (polystyrene) capacitors from Siemens (that are not made any more), which we have used in the past. Other manufacturers also use this shape.

(044042-1)

Theoretical component values

R1//R2 = 1.060 kΩ
R4//R5 = 1.060 kΩ
C1+C2 = 1.000 nF
C3+C4 = 128.0 pF
C5+C6 = 1.277 nF
C7+C8 = 809.0 nF
C9+C10 = 860.4 nF
C11+C12 = 1.125 nF
C13+C14 = 996.8 pF
C15+C16 = 492.7 nF
C17+C18+C19 = 742.4 pF
L1 = 1.148 mH
L2 = 693.3 µH
L3 = 556.4 µH
L4 = 809.6 µH

Adjustable Duty Cycle
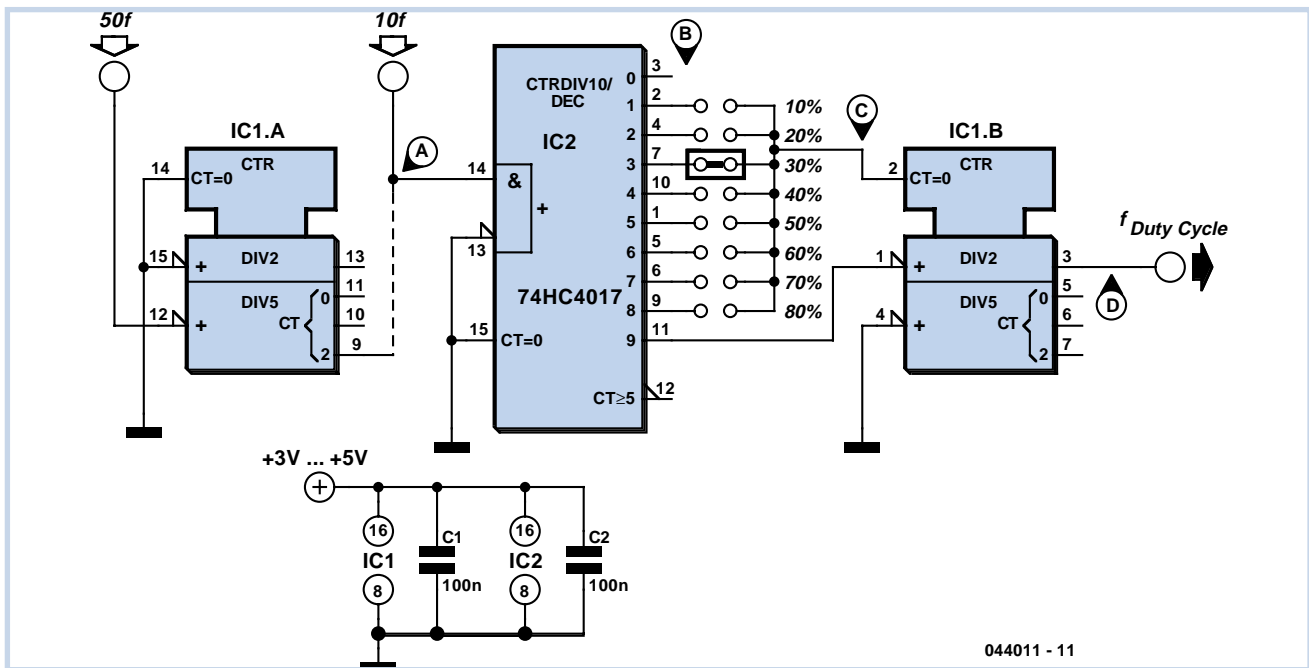
044011 - 11

Gregor Kleine

The circuit shown here can be used to convert a digital input signal having any desired duty cycle into a output signal having a duty cycle that can be adjusted between 10% and 80% in steps of 10%. The circuit is built around a 74HC4017 decade Johnson counter IC. Individual pulses appear on the ten outputs (Q0–Q9) of this IC at well-defined times, depending on the number of input pulses (see the timing diagram).

This characteristic is utilised in the circuit. The selected output is connected via a jumper to the Reset input (MR, pin 2) of a 74HC390 counter. A High level resets the output signals of the 74HC390 counter. Q9 of the 74HC4017 is permanently connected to the CP0 input of the counter to set the Q0 output of the 74HC390 (pin 3) High on its negative edge. As can be seen from the timing diagram, which shows the signals for a duty cycle of 30% as an example, this produces a signal with exactly the desired duty cycle.

The circuit cannot be used to produce a duty cycle of 10% (which would be equivalent to taking the signal directly from the Q0 output of the 74HC4017) or 90%. In both cases, the edges of the pulses used for the count input (CP0) and the asynchronous reset input (MR) of the

74HC390 would coincide, with the result that the output state of the 74HC390 would not be unambiguously defined.

The input frequency must be ten times the desired output frequency. If the second half of the 74HC390 is wired as a prescaler, a prescaling factor of 2, 5 or 10 can be achieved, thus allowing the

ratio of the of input frequency to the output frequency to be 20, 50 or 100.

If the circuit is built using components from the 74HC family, it can be operated with supply voltages in the range of 3–5 V.

(044011-1)

≙ D = 30%
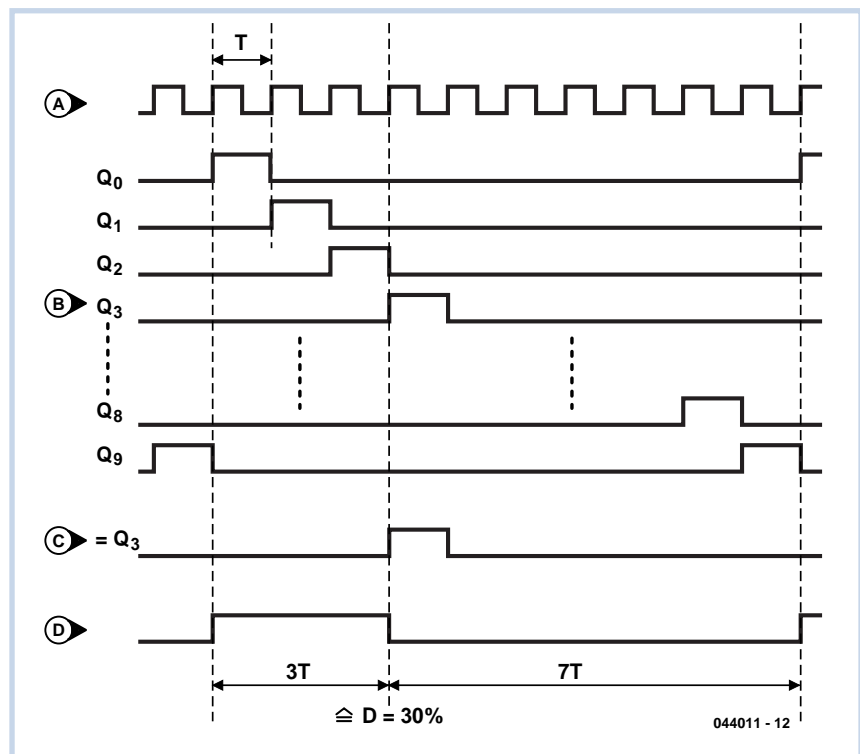
044011 - 12

Bridge-Rectifier LED Indicator

Karel Walraven

Using a few diodes and a LED, you can make a nice indicator as shown in associated schematic diagram that can be used for a lot of applications (with a bit of luck). It's quite suitable for use in series with a doorbell or thermostat (but don't try to use it with an electronically controlled central-heating boiler!). This approach allows you to make an attractive indicator for just a few pennies.

The AC or DC current through the circuit causes a voltage drop across the diodes that is just enough to light the LED. As the voltage is a bit on the low side, old-fashioned red LEDs are the most suitable for this purpose. Yellow and green LEDs require a somewhat higher forward voltage, so you'll have to first check whether it works with them. Blue and white LEDs are not suitable. You also don't have to use modern high-efficiency types (sometimes called '2-mA LEDs' or '3-mA LEDs'). If a DC current flows through the circuit and the LED doesn't light up, reverse the plus and minus leads.

When building the circuit, you'll notice that despite its simplicity it involves fitting quite a few components to a small printed circuit board or a bit of prototyping board. That's why we'd like to give you the tip of using a bridge rectifier, since that allows everything to be made much more compact, smaller and more tidy, and it eliminates the need for a circuit board to hold the components. Besides that, you can surprise friend and foe alike, because even an old hand in the

trade won't understand the trick at first glance and will likely mumble something like "Huh? That's impossible."

A bridge rectifier contains four diodes, which is exactly what you need. If you short the + and – terminals of the bridge, you create a circuit with two pairs of diodes connected in parallel with opposite polarity.
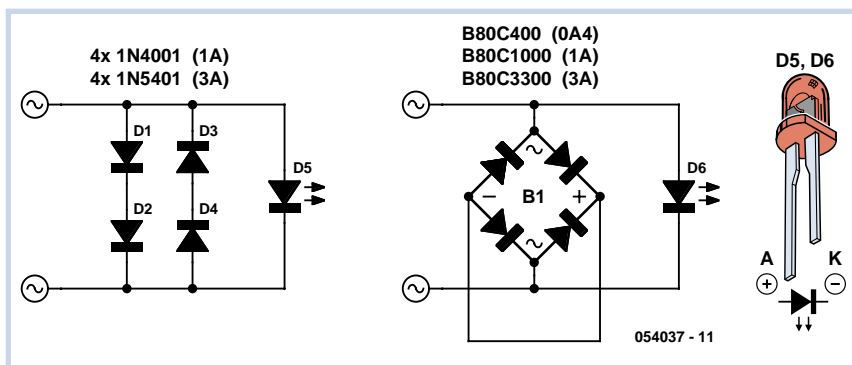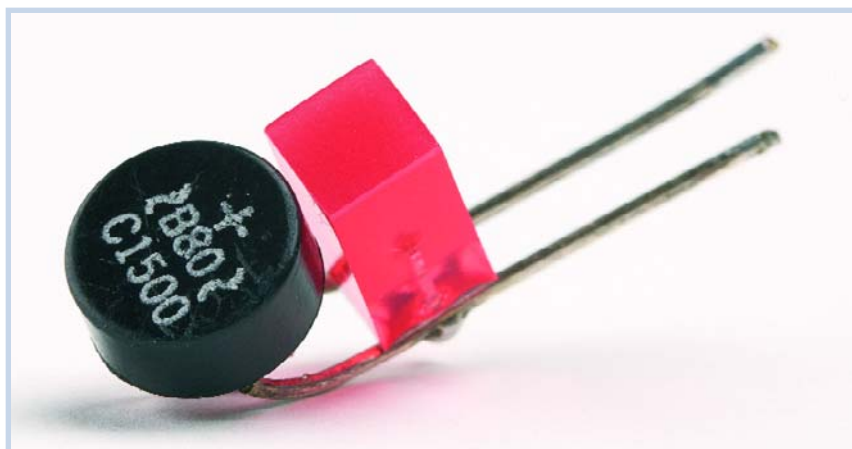
Select a bridge rectifier that can handle the current that will flow through it. In the case of a doorbell, for example, that can easily be 1 A. Select a voltage of 40 or 80 V.

Never use this circuit in combination with mains voltage, due to the risk of contact with a live lead.

(054037-1)

Stable USB Power Supply

A common problem when an AC mains adapter is used to power a USB device is that the voltage does not match the nominal 5 V specified by the USB standard. The circuit shown here accepts an input voltage in the range of 4–9 V and converts it into a 6-V output voltage, which is then stabilised to a clean 5-V level by a series regulator. The combined boost/buck converter used here operates on the SEPIC

principle. That principle is quite similar to the operating principle of the Cuk converter (see the January 2005 issue of *Elektor Electronics*), but without the disadvantage of a negative output voltage.

The circuit is built around a MAX668, which is intended to be used as a controller for boost converters. The difference between a SEPIC converter and a standard boost (step-up) converter is that the

former type has an additional capacitor (in this case C2) and a second inductor (in this case, the secondary winding of transformer L1). If C2 is replaced by a wire bridge and the secondary winding of L1 is left open, the result is a normal boost converter. In that case, a current can always flow from the input to the output via L1 and D1, even when the FET is not driven by IC1. Under these condi-

tions, the output voltage can never be less than the input voltage less the voltage drop across the diode.

The operation of a SEPIC converter can be explained in simple terms by saying that C2 prevents any DC voltage on the input from appearing at the output, so the output voltage can easily be made lower than the input voltage. The second coil causes a defined voltage to be present at the anode of D1. It is also possible to replace the transformer by two separate coils that are not magnetically coupled. However, the efficiency of the circuit is somewhat higher if coupled coils are used as shown here.

The value of resistor R4 is chosen to limit the maximum current to 500 mA, which is also the maximum current that a USB bus can provide according to the specifications. Resistors R1 and R2 cause the voltage across C3 and C7 to be regulated at a value of around 6 V. A low-drop regulator (LM2940) is used to generate a sta-
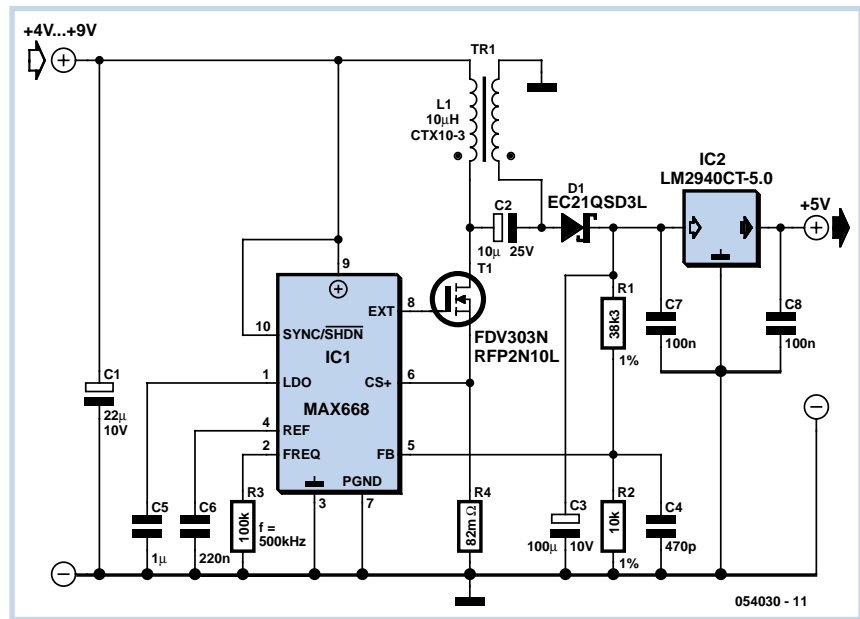
054030 - 11

bilised 5 V from the 6-V output (with ripple voltage). The efficiency should be somewhere between 60 % and 80 %.

(054030-1)

106

Efficient Current Source for High-power LEDs

Juergen Heidbreder

To get the maximum brightness and working life out of a high-power LED, it needs to be driven at the optimum specified current. Allowing the current to exceed the permitted value is to be avoided at all costs, since it will severely affect the life of the device. A power supply or a battery with a small current-limiting resistor is not really an ideal solution, since not only is energy wasted in heating the resistor, but, if a small value is chosen to minimise this wastage, small changes in the applied voltage will lead to large changes in the current that flows. It is well known that LEDs have a small dynamic resistance in the neighbourhood of their optimal operating point. We will therefore need more in the way of electronics than a simple series resistor to meet our requirements.

The most direct way to provide a highly constant current in the face of relatively small changes in supply voltage is to use a conventional regulated current source. Unfortunately this type of circuit unnecessarily wastes energy in its series transistor, which rather detracts from the charm

040160 - 11
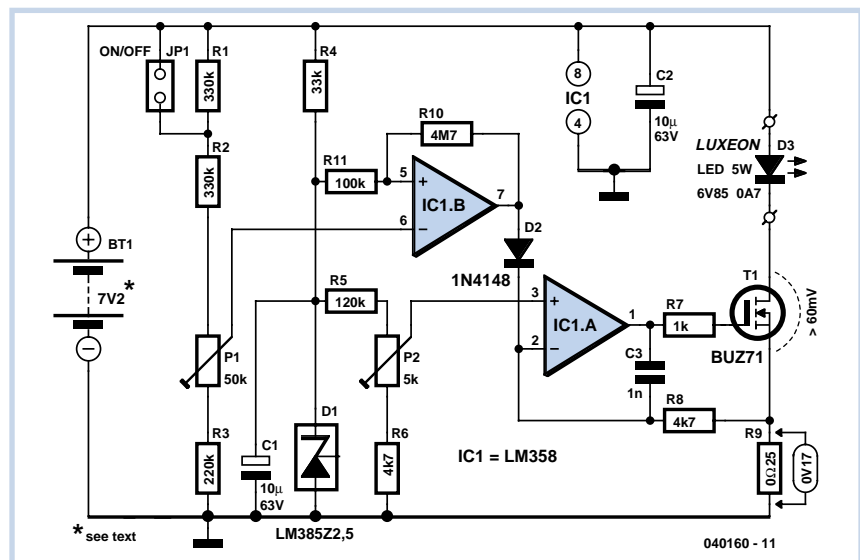
of using a semiconductor-based circuit. The inefficiency can be mitigated by using a modern device such as a power MOS-FET as the series component. Power loss is then limited to that in any current sense resistor that might be used and the dissipation in the relatively small 'on' resistance of the switching transistor.

The circuit suggested here drives a commercially-available Luxeon LED using a BUZ71. The 5 W version of this LED draws 0.7 A. This means that 0.175 V is dropped across R9, making for a power dissipation of 122 mW. T1 has a typical resistance in the 'on' state of 85 mΩ. In the ideal scenario this means that about 60 mV is dropped across it, for a dissipation of at least 42 mW. The supply voltage therefore needs to be about 230 mV higher than the nominal voltage

of the LED (6.85 V). To have something in reserve, 7.2 V, allowing 0.35 V for T1 and R9, is a good compromise. Serendipitously, a series of six NiCd or NiMH cells will give almost exactly this value under load!

A further happy coincidence is that an unregulated mains power supply with a 6 V transformer with bridge rectifier and smoothing capacitor will also give us almost exactly our target voltage when loaded. A 7.5 VA transformer is suitable, along with a 2200 µF/16 V electrolytic smoothing capacitor.

Now to how it works. D1 acts as a reference, with a voltage of 2.5 V being dropped across it. IC1b, together with T1, form a current source, whose current can be set between 360 mA and 750 mA using P2. The otherwise unused opamp IC1a is connected to form an under-voltage cutout switch which prevents a connected battery from being discharged too deeply. The threshold point is set using P1. IC1a is configured as a comparator with a small hysteresis. If its output is high, IC1b is fooled into thinking that the current through R9 is too high, whereupon it

switches off the LED. The same happens if R1 is not shorted by a switch. For the purposes of this circuit only opamps with input stages constructed using PNP transistors should be used.

One last look at the energy budget: if six cells are used, the average voltage during discharge will be around 7.4 V. Subtract the nominal voltage of the LED and 0.55 V is left to be converted into heat. About 0.4 W will be dissipated by T1, which therefore will not require cooling. Efficiency is very good, at over 90 %.

(040160-1)

Simple Overcurrent Indicator

107

Myo Min

This circuit eventually surfaced while pondering over the design of a current indicator for a small power supply. Fortunately, it proved possible to employ the supply voltage as a reference by dividing it down with the aid of R1 and R2. C1 is an essential capacitor to suppress noise and surges. The half supply voltage level is applied to the non-inverting pin of opamp IC1. The value of the R3 determines the trip level of the indicator, according to

$$R3 = 0.4 \times \text{(desired voltage drop)} / I_{trip}$$

Actually this is *high side sensing* but the method can be used as low side sensing, too! The desired voltage or sense voltage can be any value between 0.35 V and 0.47 V. If currents greater than about 1 A are envisaged, you should not forget to calculate R3's dissipation on penalty of smoke & smells.

040284 - 1
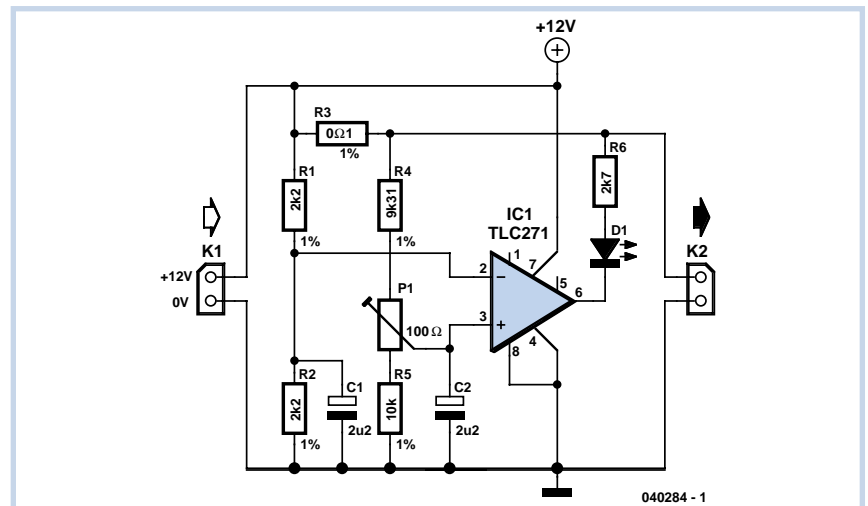
Another voltage divider network, R4, R5 and P1 divide the voltage between supply voltage and desired voltage. This divided voltage, filtered by C2, is fed to the inverting input of IC1 to compare levels. The result causes D1 to light or remain off. Turn P1 to the end of R4 to hold off

D1. Then connect a load causing over current and adjust P1 towards the end of R5 until D1 lights. The accuracy of the circuit depends entirely on the tolerances of the resistors used — high stability types are recommended.

(040284-1)

Low-drop Regulator with Indicator

108

Karel Walraven

Even today much logic is still powered from 5 volts and it then seems obvious to power the circuit using a standard regulator from a rectangular 9-V battery. A disadvantage of this approach is that the capacity of a 9-V battery is rather low and the price is rather high. Even the NiMH revolution, which has resulted in

considerably higher capacities of (penlight) batteries, seems to have escaped the 9-V battery generation.

It would be cheaper if 5 volts could be

derived from 6 volts, for example. That would be 4 'normal' cells or 5 NiMH-cells. Also the 'old fashioned' sealed lead-acid battery would be appropriate, or two lithium cells.

Using an LP2951, such a power supply is easily realised. The LP2951 is an evergreen from National Semiconductor, which you will have encountered in numerous *Elektor Electronics* designs already. This IC can deliver a maximum current of 100 mA at an input voltage of greater than 5.4 V. In addition to this particular version, there are also versions available for 3.3 and 3 V output, as well as an adjustable version.

In this design we have added a battery indicator, which also protects the battery from too deep a discharge. As soon as the IC has a problem with too low an input voltage, the ERROR output will go low and the regulator is turned off via IC2d, until a manual restart is provided with the RESET-pushbutton.

The battery voltage is divided with a few resistors and compared with the reference voltage (1.23 V) of the regulator IC. To adapt the indicator for different voltages you only need to change the 100-k resistor. The comparator is an LP339. This is an energy-friendly version of the LM339. The LP339 consumes only 60 µA and can sink 30 mA at its output. You can also use the LM339, if you happen to have one
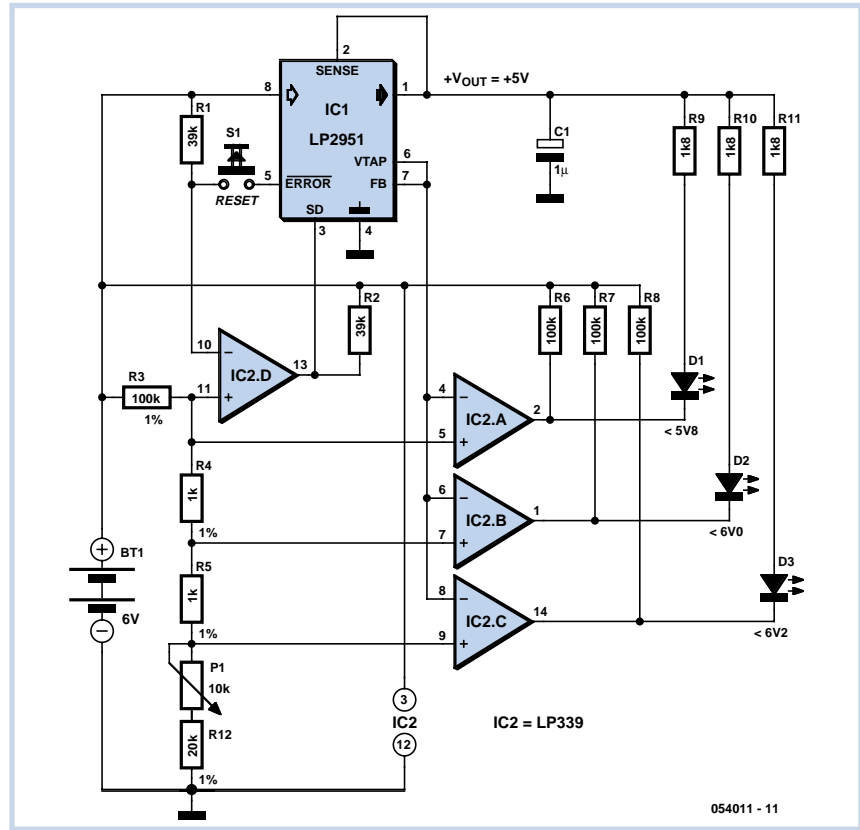
around, but the current consumption in that case is 14 times higher (which, for that matter, is still less than 1 mA).

Finally, the LP2951 in the idle state, consumes about 100 µA and depend-

ing on the output current to be delivered, a little more.

(054011-1)

(National Semiconductor application note)

Navigator Assistant
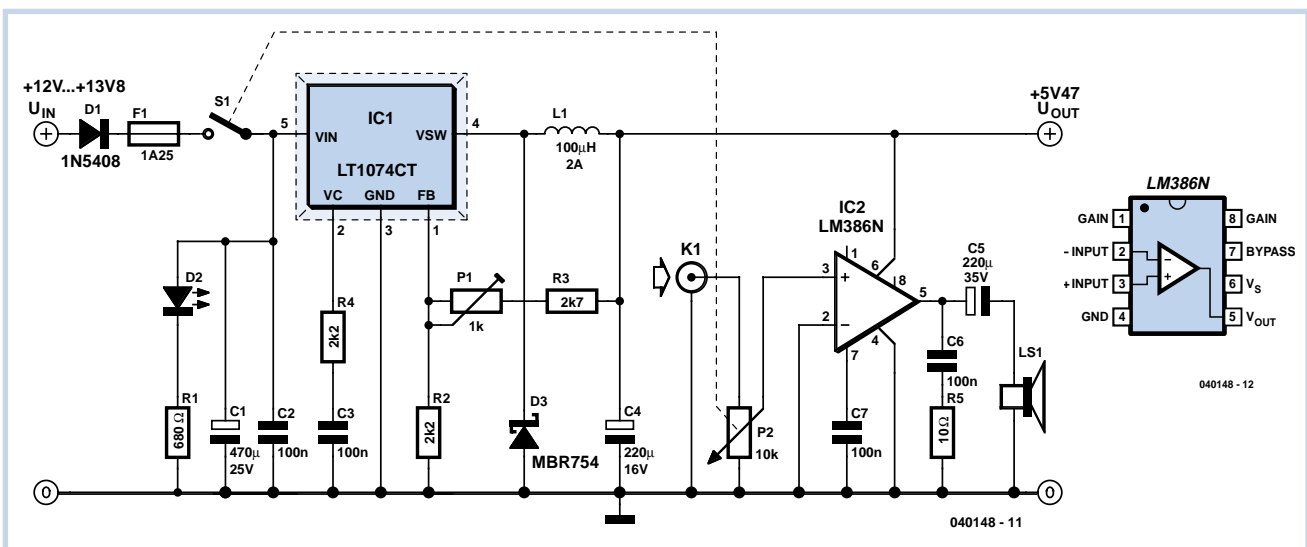
René Bosch

These days it is quite common that a

hand-held computer (PDA) is used in a car as a navigation system. The author uses,

for example, a Dell Axim X5 with TomTom navigator. The PDA is installed in a holder

in such a way that the screen is clearly visible to the driver. Such holders do not normally have power and audio connections for the PDA. This circuit offers a solution to both problems: a regulated power supply and an audio power amplifier.

The author originally used an LM350 IC, but it proved to be barely capable of coping with the dissipation when the battery was nearly completely discharged. That is why, in the end, a switching power supply was used. The power supply is designed around an LT1074, a bipolar switching regulator that contains just about all the components required for a so-called buck-regulator. The IC operates at a switching frequency of 100 kHz and can deliver up to 5 A. Coil L1 and diode

D3 form part of the flyback circuit. Make sure that these are capable of dealing with the maximum desired output current. Potentiometer P1 is used to adjust the output voltage to the value that is optimum for the PDA that is being used. LED D2 indicates the presence of the input power supply.

The second part, the audio amplifier, is an equally simple design. The circuit really speaks for itself. This is an LM386 in a standard configuration. P2 adjusts the volume.

The amount of power that the LM386 can deliver is about 300 mW. The best results are obtained of you use a special communications loudspeaker. The navigation messages are then very easy to understand.

The gain of IC2 is set to 20. This will usually be sufficient, but you can also

increase the amplification. At a gain of 50, it is necessary to connect a series network consisting of a 1k2 resistor and 10-µF electrolytic between pins 1 and 8 of the LM386 (the negative of the capacitor connects to pin 8).

Finding the correct power supply connector for the PDA can be a bit of a problem. So look for a suitable connector before you start to build this circuit. Also be very careful about the correct polarity of the connector.

The circuit can be wired directly to the car's power circuit or connected to the cigarette-lighter socket. In either case a fuse (F1) can be connected in the power supply lead or the plug.

(040148-1)

QUIZZ'AWA

In line with this month's Summer Circuit edition of the magazine we once again present a circuit design problem.
Figure 1 shows the circuit diagram of an amplifier. A 1 kHz, 12 mV$_{pp}$ input signal produces an output signal of 2 V$_{pp}$. Consequently the ac signal gain works out at about 170. This is surprising, because the signal does not seem to have a way of reaching the output in the first place, because the collector of T1 is heavily decoupled by capacitor C1,

hence cannot reach IC1 either, let alone its output. If you don't believe it, feel free to convince yourself (and your fiends) with a practical realisation of the circuit like the one pictured in **Figure 2**.

This month's question is:

How can the AF signal from T1 reach IC1 in spite of the collector of T1 being grounded for alternating voltages?
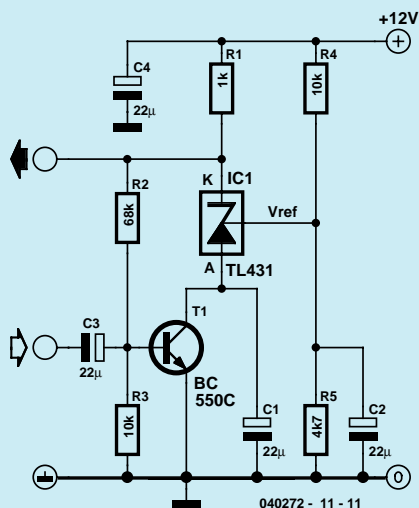
Figure 1. A rare amplifier, this.

Figure 2. Test setup.

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.

Quizz'away and win!

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

one of 10 *Design Guide: Trilogy of Inductors* books

sponsored by Würth Electronics (www.wuerth-elektronik.com). The book combines a unique reference work with a compilation of design notes and practical applications of ferrites and inductive components.

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

Please send your answer
to this month's Quizz'away problem,
by email, fax or letter to:
**Quizz'away, Elektor Electronics,
PO Box 190,
Tunbridge Wells TN5 7WY, England.
Fax (+44) (0)1580 200616.
Email: editor@elektor-electronics.co.uk,
subject: 'quizzaway 7-05'.**

**The closing date is
30 July 2005**
(solution published in the October 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.

Hint:

The TL431 is a so-called 'shunt voltage regulator', its inner structure is shown in **Figure 3**. To be able to solve this month's problem you will first need to consider how the amplifier works without the action of C1, then try to reason why C1 has hardly any effect. Initially, it is convenient to assume that the opamp inside the TL431 acts as an ideal device.
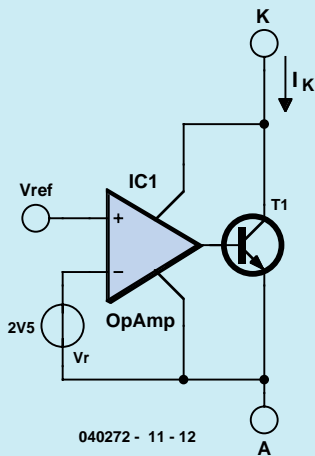
Figure 3. Inside the TL431.

Solution to the Mai 2005 problem

(p. 78; 'Blown Transistor')

To everyone's amazement, the circuit will eventually produce a negative voltage U! Typical values obtained from experiments range from $U = -0.25$ V to $U = -0.4$ V. How can we explain a single transistor reversing a direct voltage? The question and the answer are found in the literature references below.

The base-emitter junction of the transistor is reverse-biased (via a 1k resistor, see **Figure 4**). The electrolytic capacitor has about 15 V on it. At this voltage, the base-emitter junction usually breaks down, the diode starting to act as a zener and emit light (usually in the infrared range). The light is incident on the collector, base junction, where the photoelectric effect causes a small but reversed (negative) voltage between terminals A and B.

Literature:
Pease, Bob: Pease Porridge, Electronic Design, March 18, 1996, pp 123.
Pease, Bob: Bob's Mailbox, Electronic Design, April 1, 1996, pp 95.
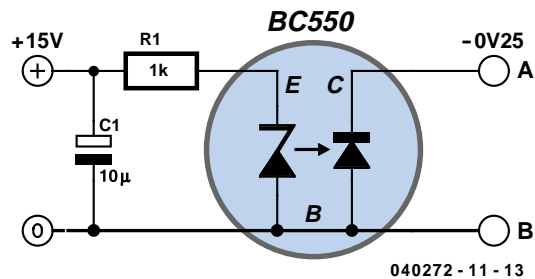
Figure 4. Blown transistor as an unexpected optocoupler/voltage inverter.

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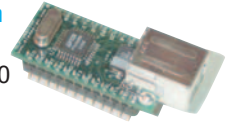
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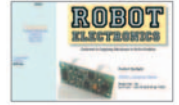
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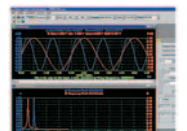the Readers Services section in this issue.*

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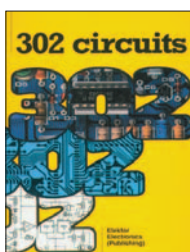
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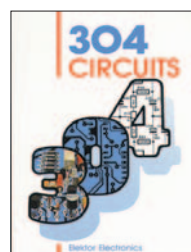
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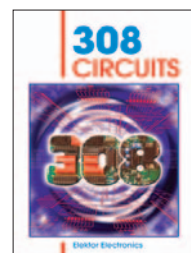
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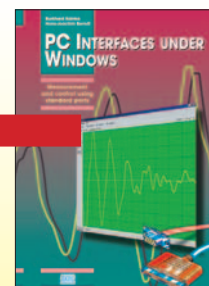
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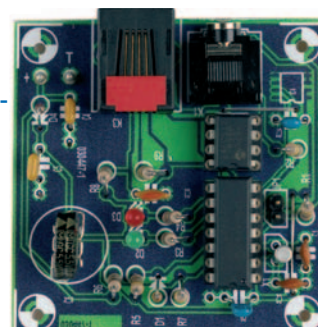| READY-BUILT PROJECTS		£	$
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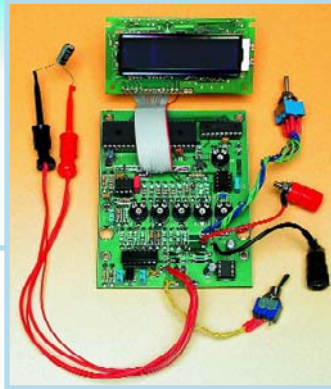
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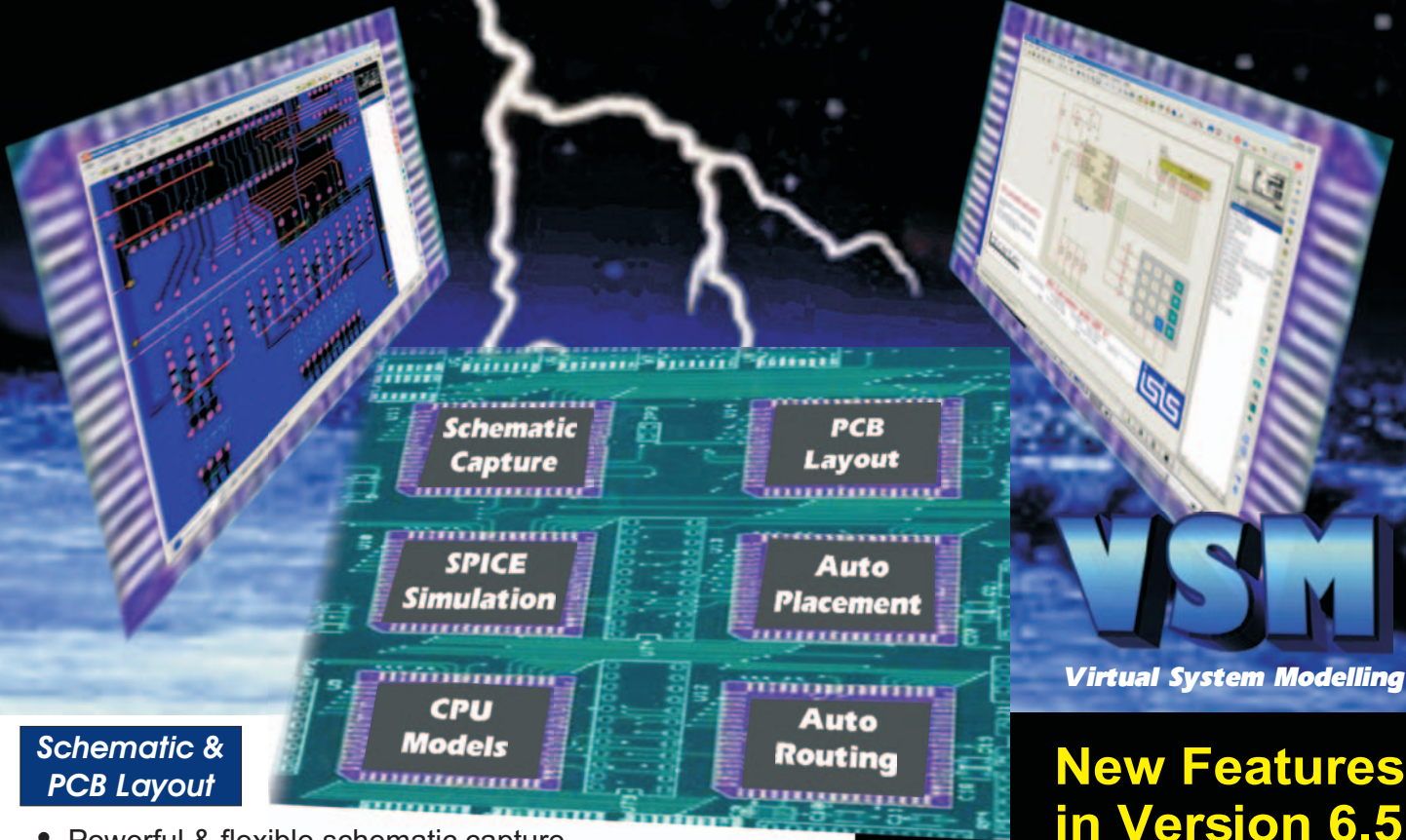a free 128 MB USB 2.0 Flash drive

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