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PRECISION MEASUREMENT CENTRAL

BUMPER SUMMER ISSUE 2003

Remote Dimmer

Mini Test Chart Generator

Building RF Circuits

RTC for Flash Micro Board

PHILIPS

more than 60 small circuits, tips, design ideas and web pointers

Precision Measurement Central (1)

With an MSC1210 Development Platform

Design by J. Wickenhäuser   www.wickenhaeuser.com

Elektor is proud to present a Texas Instruments MSC1210 based microcontroller board complete with its first application: a versatile, high-end, compact and accurate measurement module. Thanks to the state of the art controller used, the module can be programmed to suit many measurement tasks.
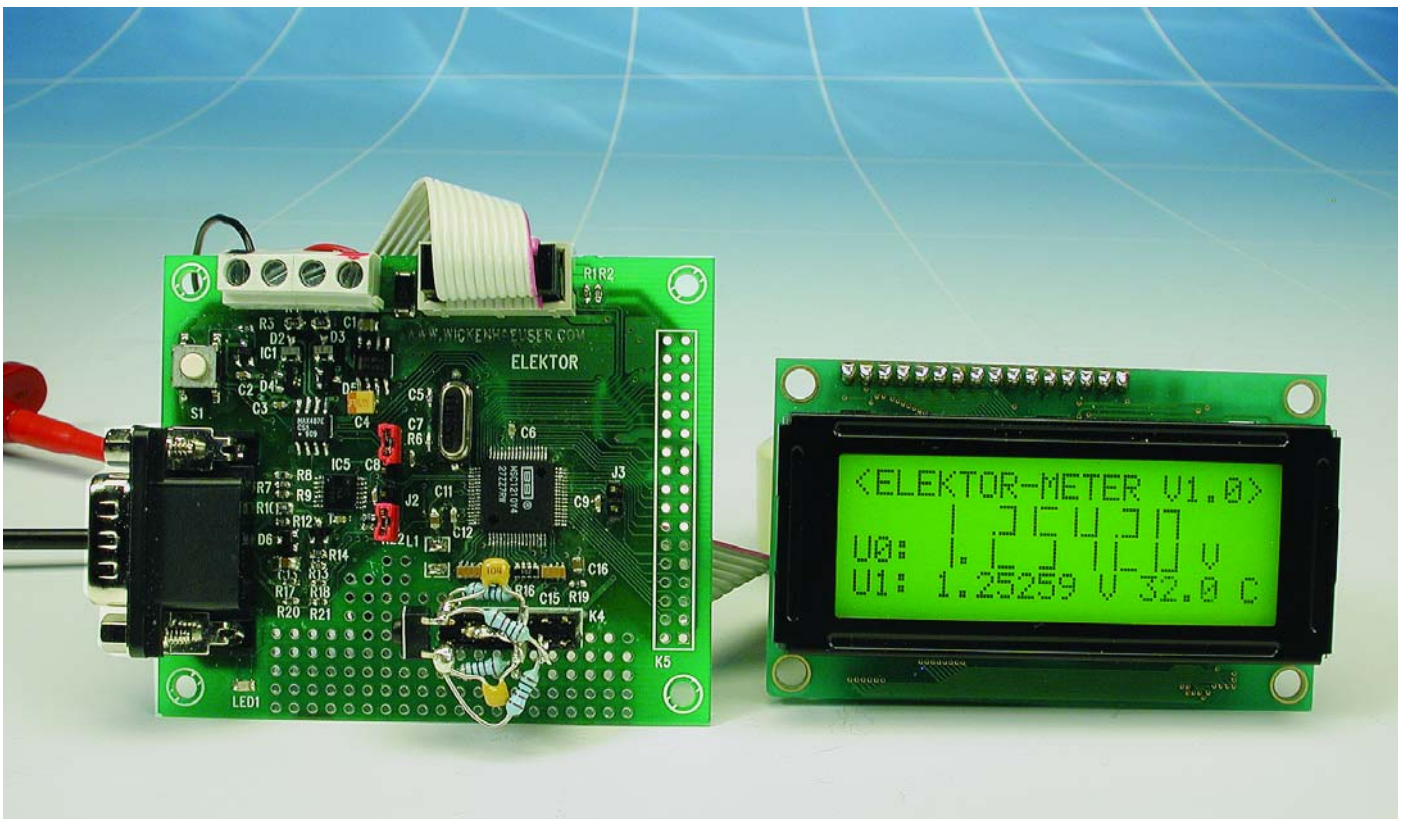
On today's microcontroller market you'll come across a plethora of 8051-compatible CPUs with on-chip analogue extensions. Texas instruments (TI) recently jumped the band-

wagon by employing the popular 8051 core in a very special product, the MSC1210. Even after just a couple of tests we were won over to

using the MSC1210 in the Elektor Precision Measurement Central.

The project comprises a small controller board that can be

attached to the rear side of an LCD module, the combination acting as a **5¹/₂-digit (!) digital multimeter with eight channels**. Besides the microcontroller the board contains number of SMA (surface mount assembly) parts.

Obviously, the versatility and accuracy of the Precision Measurement Central could not be achieved with hardware only, and that is why we include an **ANSI-C programming platform complete with a number of libraries**. The latter come complete with their source code files for smooth connection to the resources offered by the MSC1210 controller. Even complex floating-point operations are possible!

A new controller family

The functionality of the MSC1210 is illustrated in **Figure 1**. The first member of this new microcontroller family consists of an 8-channel 24-bit A-D converter, a voltage reference with extremely low temperature drift and a high-speed 8051 microprocessor core. In addition to these functional blocks we find a large number of special features like a second UART and extra RAM. The CPU itself has available 4 to 32 kbytes of Flash memory for program code or data, besides a bootstrap loader.

Apart from the MSC1210 micro, all you need to make your own development system is a handful of birdseeds (a.k.a. SMA parts). Downloading programs into the MSC1210 requires no additional hardware. Only two jumpers have to be installed and *hey presto* the Precision Measurement Central can be programmed and controlled by way of its RS232 interface. If you are satisfied with the operation of the program, you simply remove the two jumpers. The program will then remain in the on-chip memory for at least 100 years (say TI) if it is not erased on purpose.

The MSC1210 and its peripherals

The circuit diagram of the Precision Measurement Central is given in **Figure 2**. At the heart of the circuit sits the MSC1210 micro, which is powered by two voltage regulators.
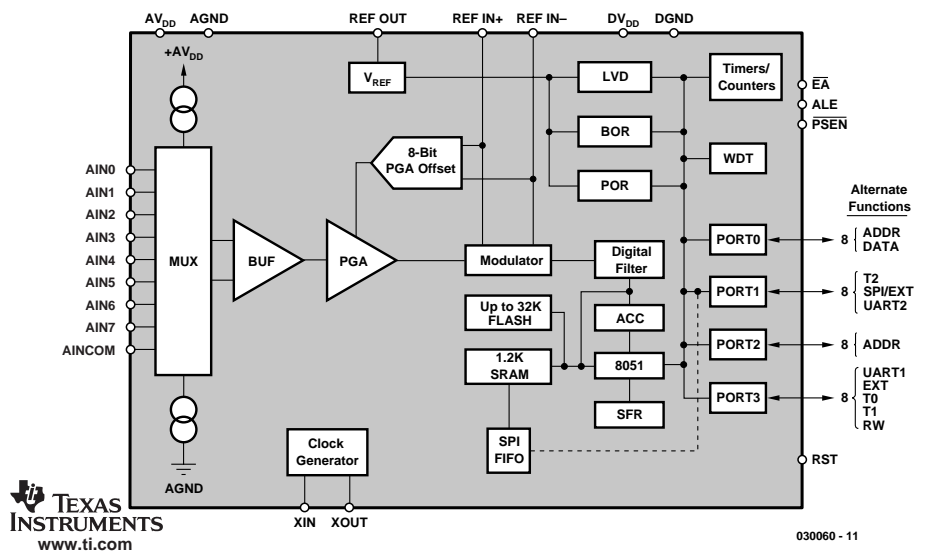

Figure 1. MSC1210 internal organisation.

Main technical data of MSC12lx series

CPU	8051 compatible high-speed core (4 cycles)
Clock	max. 33 MHz
Supply voltage	2.7 to 5.25 V
On-chip memory	4-32 kB Flash, 1.2 kB RAM
Programmability	In-Circuit and In-Application (CPU capable of programming itself)
Security	Watchdog, Internal Brown-Out detection
Main digital peripherals	2 UARTS

Analogue Peripherals:

A-D converter	8 full differential channels, 24 bit resolution
Reference	0, 1.250 V, 2.500 V (±0.2 %, drift: 5 ppm/K)

**Family members:**

MSC1210	basic model
MSC1211	4-channel 16-bit D/A converter, Multi-Master I²C
MSC1212	4-channel 16-bit D/A converter

IC2 is responsible for the digital section, IC6 for the analogue sub-circuits. A strict separation of the two supply rails is essential to be able to exploit the high accuracy of the ADC inside the MSC1210. Decoupling capacitors in all the right places and a generous 'copper pour' ground plane contribute to the supply decoupling. The CPU is clocked at 11.0592 MHz which makes it about twice as fast as a regular 8051 (depending on the instructions used; the timing being slightly different). According to TI, if the MSC1210 were clocked at its maximum rate of 33 MHz, it would be just as fast as a

regular 8051 ticking at 82.5 MHz.

All analogue inputs are protected to some degree by R-C filter sections. The reference supply line of the MSC1210, too, has a resistor inserted (R19). The reference voltage proper may be loaded with up to 8 mA. In case of extremely accurate measurements, the voltage drop across R19 may have to be taken into account. The reference voltage is digitally controllable — more about this under the software description.

At first blush the RS232 interface of the Precision Measurement Central may appear a bit of an oddball. The relevant circuitry operates as a passive interface, stealing its negative transmit voltage from the receive line (using T1 and IC5.B).
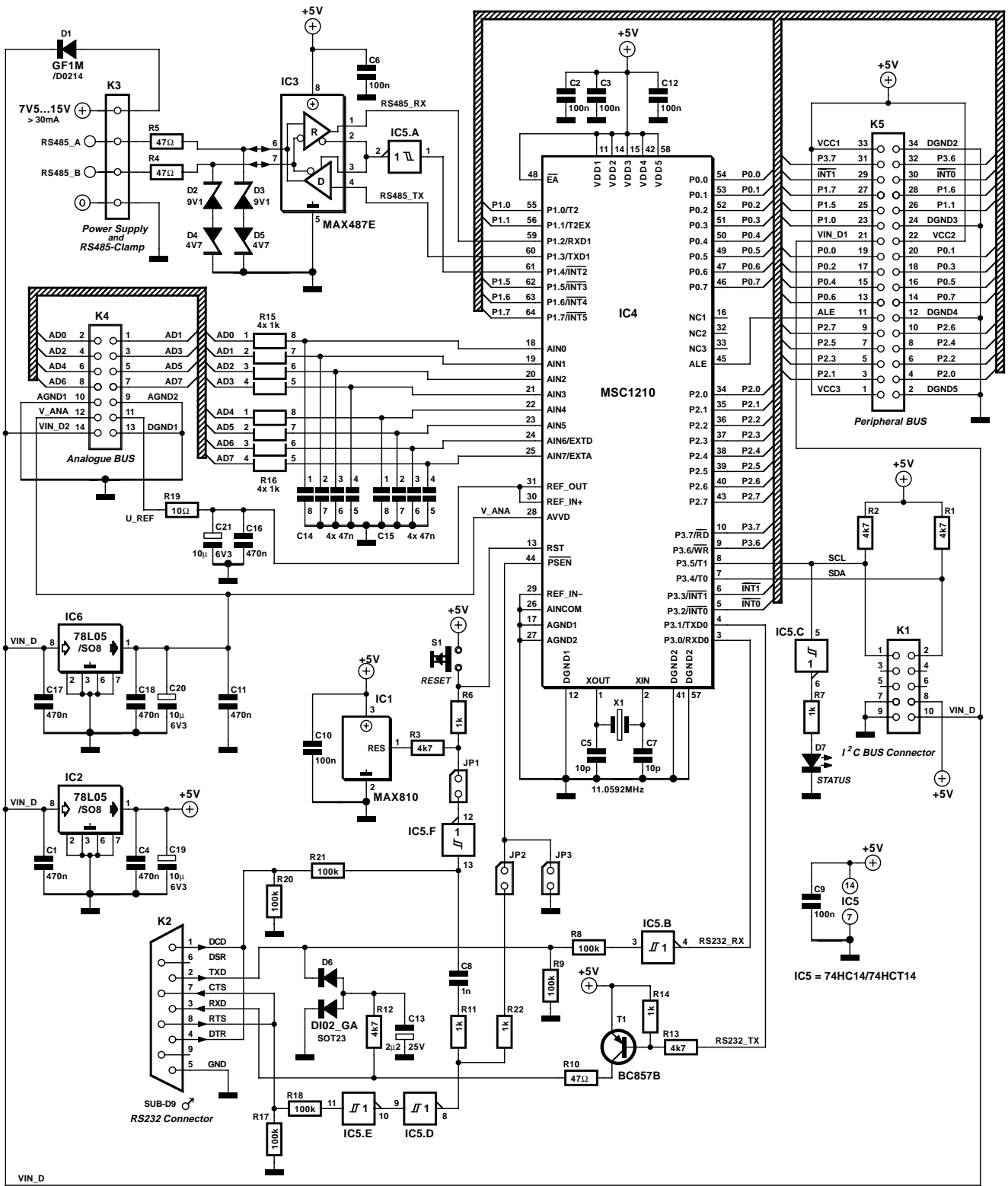
Figure 2. Circuit diagram of the Elektor Precision Measurement Central.

The bootstrap loader needs two helper signals, which are generated via IC5.D, IC5.E and IC5.F — these signals are only active when jumpers J1 and J2 are installed. Of these, J1 allows the PC to reset the MSC1210, while J2 causes the bootstrap mode to be selected on a reset. The remaining gate, IC5.C, is used to drive an LED.

The second interface of the MSC1210 controls an RS485 driver. This allows networks of anything between 32 to 256 junctions to be set up (depending on IC3), which can extend over several kilometres. The two RS485 signals are also protected against light voltage surges as they typically occur in cables installed in homes and offices. A

practical application of the RS485 interface will be discussed in a follow-up instalment.

Last but not least, the project includes an I²C bus. Because the MSC1210 requires a dedicated driver, this bus can only be used in Master mode.

All analogue signals are 'bonded out to pins' on analogue bus connector K4. The printed circuit board has plenty of free space for your own circuit extensions. The complete processor bus is available on K5. Here, you can connect add-on RAMs or an Ethernet driver, to mention but two examples. The latter extension allows the Precision Measurement Central to send e-mails or store measurement values for remote retrieval using an Internet browser.

Please be careful with VIN_D1 and VIN_D2 on K4 and K5 as these pins convey the circuit supply voltage. The controller must never be allowed to 'see' voltages lower than 0 V or exceeding 5 V.

A look at the software

In case you already had a look at the MSC1210 datasheets published by Texas Instruments, you may have been overwhelmed or even put off by the staggering number of features offered by the CPU. To make life a little easier (in this respect) we supply a software driver, complete with source code, for the essential MSC1210 functions.

Fortunately, Craig Steiner's 360-page *User Manual* makes much lighter reading than the dry datasheets. The manual may be downloaded from www.8052.com, a url that should be familiar to dyed in the wool 8051 and 8052 programmers.

All you need in the way of drivers, downloaders and compilers for this project may be downloaded from www.wickenhaeuser.com. The uC/51 Compiler has been listed by TI as an official 3rd party product. All you need to do is install the compiler in its demo version. Because the uC/51 features an extremely powerful code optimiser, the available 8 kbytes of object code is sufficient even for larger projects employing floating-point arithmetic. Alternatively the MSC micros may be programmed in higher languages like BASIC. A link to Robin Kucera's adaptation of the famous AH-BASIC may be found in the MSC Newsgroup Download section. The same author produced a free code-downloader utility that forms a good alternative to the original TI downloader because it comes with a HEX editor.

As we write this, a couple of interesting add-on tools are being developed to complement the uC/51 Compiler. For example, we can look forward to having a Flash debugger that allows C programs in EPROM/Flash memory to be debugged at the source text level, while doubling as a downloader. Have a look at the author's homepage to check the availability of this downloader by the time you read this article.

The source code files for the Precision Measurement Central ('Elektor Meter') may be found in the directory

SRC\MSC1210\ELMET

of the uC/51 installation. For your own projects, you will only need two software functions:

init_msc1210()
which initialises all essential elements: the serial RS232 interface at 9,600 bits/s, the watchdog and the peripheral circuitry.

adval_dif(uchar mux. uchar kali)
which allows you to access the ADC. The variable **mux** contains the two input channels, each coded to 4 bits. Values from 0-7 identify inputs AD0-AD7; value '8' equals AGND and '15' the internal temperature sensor. The rest of the numbers is not used. The value 0x34, for example, would indicate the difference between inputs AD3 and AD4.

When **kali** (calibration) is not equal to 0, the MSC1210 executes a self-calibration action. Although it takes some extra time, it is recommended to run the calibration after a reset or a change of the operating parameters

Useful Internet addresses:

www.ti.com/msc
Texas Instruments MSC Homepage wit general information on the MSC micros as well as current datasheets.

www.wickenhaeuser.com   For the uC/51 ANSI-C Compiler.

http://groups.yahoo.com/group/TI-MSC
The MSC Newsgroup with numerous files for downloading.

www.lightplanet.com/TI-MSC
MSC Newsgroup Download with topical info on CD distributions of development kits, datasheets, AH52-BASIC, etc.

www.8052.com
Craig Steiner's 8052 Forum (author of the MSC User Manual).

www.sys.cz/msc1210
Robin Kucera's MSC web page with the MSC Downloader.

Hardware & Software

The Precision Measurement Central described in this article, as well as various spin-off MSC1210 projects to follow, are almost impossible to build using commonly available solder tools. Manual soldering of pins with a distance of 0.5 mm will be beyond the capacity of many of our readers and that is why we offer the board pre-stuffed, that is, ready-built an tested. Availability, prices, and supply conditions are not known at time of writing but will be announced in due course on our website at www.elektor-electronics.co.uk

Meanwhile, all software relating to this article instalment may be downloaded from this month's Free Downloads section. The relevant files not only include the development environment but also the Gerber/CAM data of the double-sided through-plated printed circuit board. After publication of this article, updates and breaking news on the Precision Measurement Central may be found on the author's website.

(temperature, preamplifier, etc.).

The temperature sensor is a rather unusual feature. In order to actually measure temperature, a formula from the *User Manual* is employed (also in one of the demo programs).

The ADCON0 register in the MSC1210 is used to adjust the level of the reference voltage (1.250 V or 2.500 V) as well as activate the A-D converter buffer. This is recommended in all cases! Also, the converter's voltage window may be adjusted with the aid of the three lower bits, the available range being [Vref/1] to [Vref/128)]). The relevant constants may be found in the header file **ELMET.H**. Using the initialisation
ADCON0 = EVREF│EBUF│VREFH│GAIN_1;
the reference voltage is set to 2.500 V, the buffer is enabled, and the window size is set to 2.500 V.

After this, a period of just over 100 ms elapses, whereupon the system is ready to start measuring. Variable **adval_dif()** supplies a raw value between 0xFF800000 and 0x007FFFFF, which, as a 32-bit integer, equals the 'size' of the ADC window. Because the reference can deviate up to 0.2% of the ideal value, the following scaling operation is necessary to determine the exact voltage at the input (at a window size of 2.500 V, 1 digit of the raw value corresponds to 298.023 nanovolts):

Voltage =
  raw value * 298.023e-9*U_REF/2.500)

(at U_REF = 2.500 V ±0.2%).

In the demo **ELMET.C** supplied for this project, the above scaling is used for two inputs plus the chip temperature. Even if you do not have the I^2C LCD module pictured in the introductory photograph, measurement values may be obtained by using a terminal (emulation) program. Install jumpers J1 and J2, power up the Precision Measurement Central (supply voltage 7.5 V to 15 V), then connect the RS232 port to COM1 on your PC **using a null-modem cable with sockets at both ends**. Start by launching the program **Umshell** of the uC/51 Compiler. Next, open the file ELM_VOLT.MAK and press the F9 key (**Figure 3**). The compiler will then build the MSC program for you, generating the file **ELM_VOLT.HEX**. Next, set the Target run in the Combo box (see **Figure 4**).

Now, if you press F9 again the file **ELM_VOLT.HEX** is copied (downloaded) to the Precision Measurement Central board. Also, a Terminal window is opened in which you can view the levels of the analogue voltages at inputs AD0 and AD1 with respect to
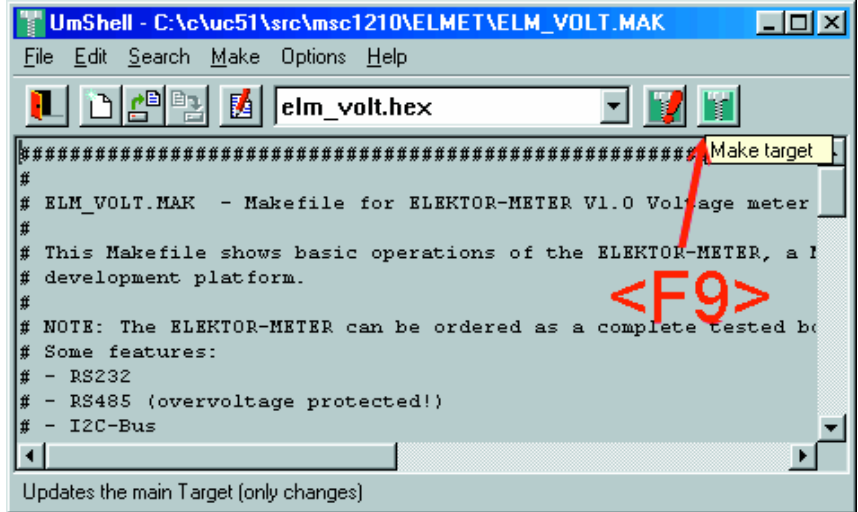

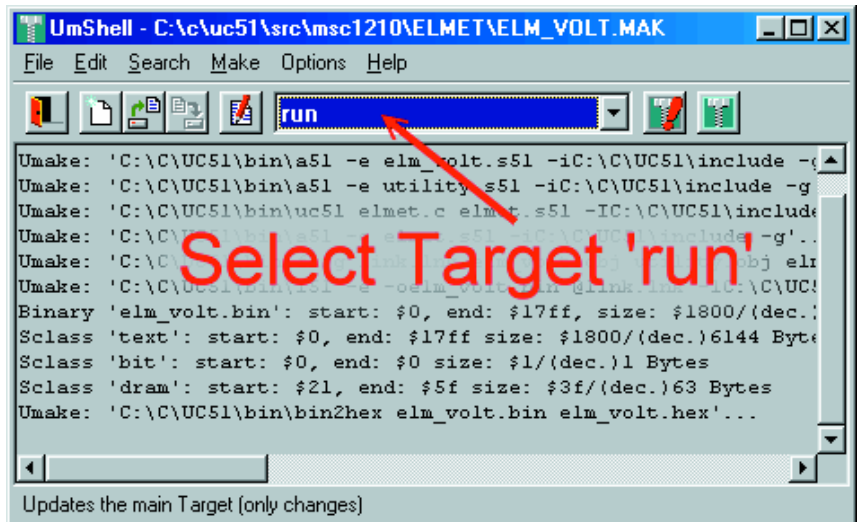
Figure 3. Umshell handling ELM_VOLT.HEX
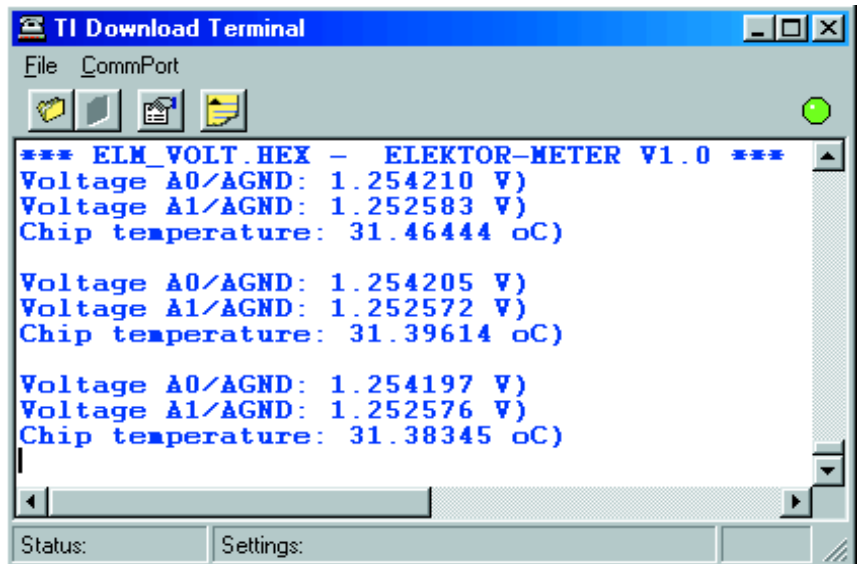

Figure 4. Umshell handling Target RUN.

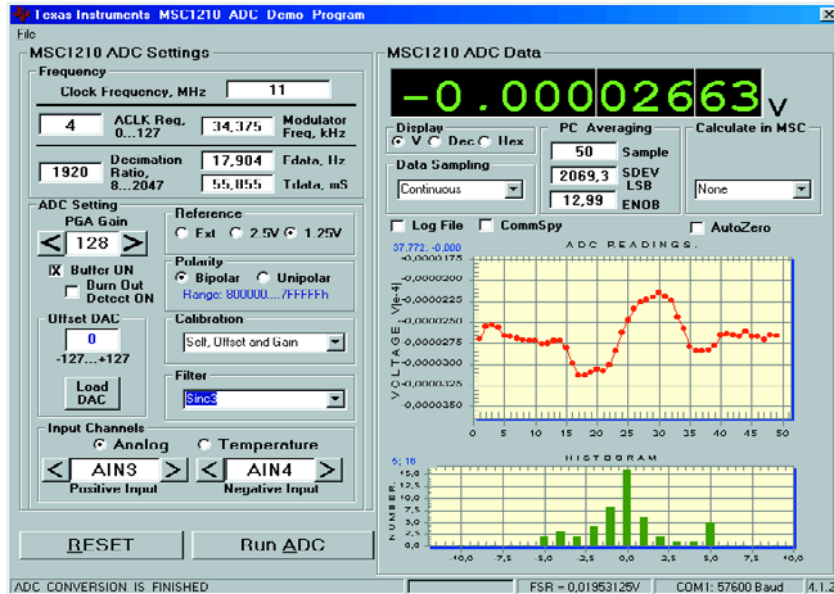Figure 5. Measurement values being output by the ELM_VOLT demo program.

Figure 6. Texas instrument's ADC Demo for the MSC1210 in action.

reset it.

If necessary, the source test **ELM_VOLT.C** may be edited. All you need to do in **Umshell** is change between the **Targets** and then press F9 to start the compilation.

Finally, a few words about the nice demo 'MSC 1210 ADC-Demo' which may be downloaded from the Newsgroup pages at TI. The demo exhausts nearly all possibilities of the ADC in the MSC controller (see **Figure 6**). The program is automatically downloaded when the MSC 1210 ADC-Demo is started. Please note that the reference voltage buffer needs to be activated for the Elektor Meter project.

The source code for the high-resolution scales you may already have read about is found with the uC/51 Compiler.

(030060-1)

ground (**Figure 5**). Then, if you remove the jumpers, your Precision Measurement Central will faithfully execute this program every time you

Note:

Projects based around the Precision Measurement Central to be described in future instalments of this series include high-resolution scales using strain gauges, an ultra-versatile LCD for the I^2C bus and long-distance data transmission using the RS485 bus.

Remote Light Control with Dimmer

Responds to RC5 infrared commands

Design by A. Oyrer

The microcontroller-driven switch described in this article allows one lamp to switched on and off as well as dimmed, all using an RC5-compatible infrared remote control.

There is a great deal of lavishness in being able to switch a lamp on and off without getting out of your chair, and even more in brightness control from the same comfortable position! A small microcontroller circuit makes it all possible. As a bonus, the circuit provides a soft start / soft turn off function, which means that the lamp is switched on and off gradually rather than abruptly.

Zero crossing

Like nearly all dimmer circuits, the project described here relies on phase angle control of the alternating voltage applied to the lamp. The process not only improves the life expectancy of the lamp, but also prevents (within limits) unnecessary electromagnetic 'pollution' in the direct vicinity of the dimmer and/or the lamp. To be able to dim a lamp using phase angle control, it is necessary for the circuit to detect when the instantaneous level of the mains voltage equals zero volts. **Figure 1** illustrates how the microcontroller is able to detect this instant called 'zero-crossing'. The mains voltage is applied to the LED inside an optocoupler. Resistance R1+R2 limits the current through the LED (during the positive half cycle of the mains voltage) as well as through D1, which quasi shunts the negative half wave across the LED. Only the positive half waves will arrive at the microcontroller input, the negative halves are missing. To prevent the microcontroller from firing the triac every second half wave only (which
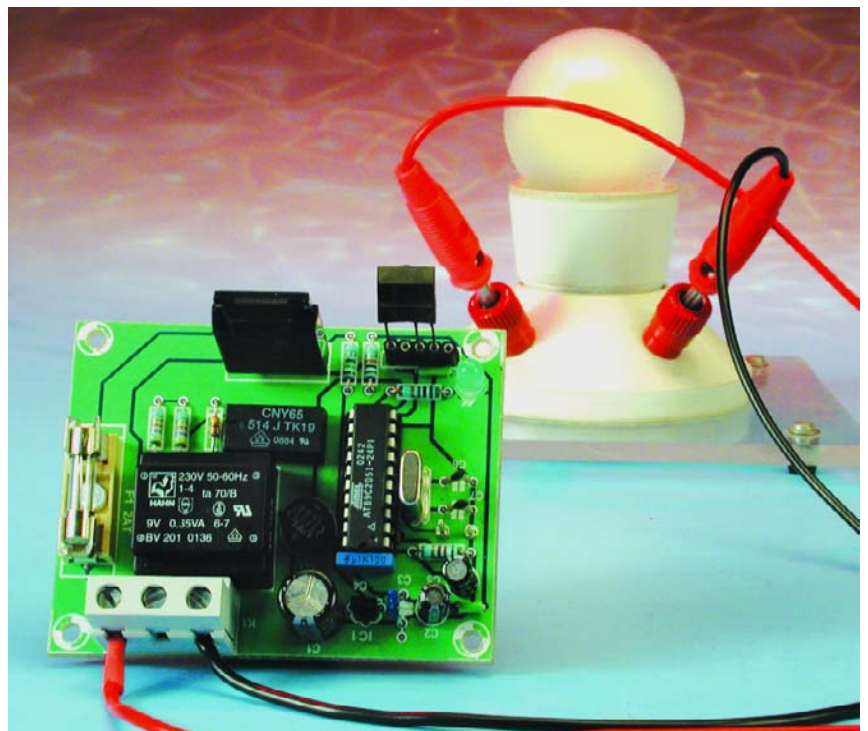
would cause the lamp to flicker), a software trick is used to ensure the triac is fired a second time, with a delay, during the second half wave.

It would have been possible to 'tap' the zero-crossings from the secondary of the mains transformer by connecting a diode between the rectifier and the smoothing capacitor.

Arguably, the 100-Hz signal at this point appears useful. However, we would easily run into problems with the phase shift caused by the transformer, hence the first solution (direct detection of the mains voltage) is preferred.

Not so long ago, the functionality and performance expected from a

dimmer like the one described here could only be realized using esoteric, purpose-designed integrated circuits. Today, a job is done by a low-cost common or garden microcontroller like the AT89C2051 with a minimum of hardware around it: a power-on reset (POR) network, a zero-crossing detector (described above), a 5-volt power supply using a miniature transformer, an infrared detector/decoder on connector K2, an on/off switch, a status LED (which lights when the lamp is off) and, finally, a triac which governs the voltage applied to the lamp.

Triac IC4 contains a TLL-compatible input that can be controlled from a microcontroller output with just one series resistor inserted in the drive line. The circuit has been designed with electrical isolation and safety in mind. When fitted with a heatsink, the S202S11 is capable of supplying lamp currents of up to 8 A. Note, however, that fuse F1 protects the copper tracks on the board by melting if the load (lamp) current exceeds 2 A.
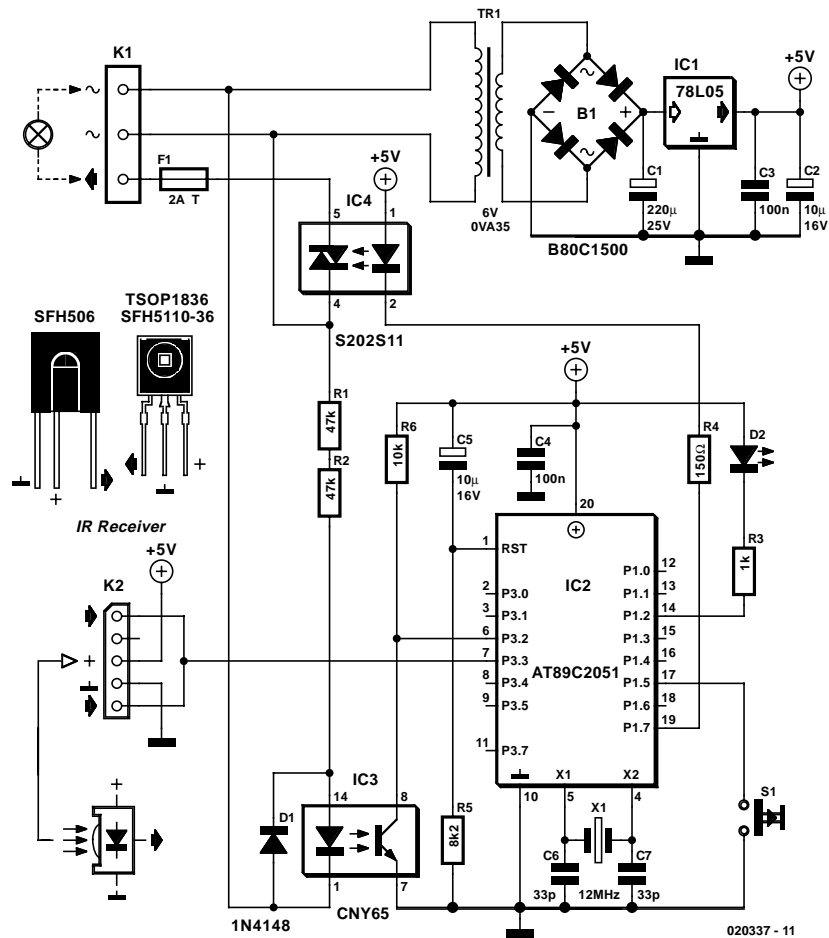
Other switches

The dimmer has three remote controlled functions. The lamp is switched on and off (also possible using S1) by pressing the Sound A/B pushbutton; Vol+ to raise lamp brightness and Vol– to dim it. These default pushbutton functions may be

Figure 1. A dimmer circuit based on a microcontroller means that there are very few parts indeed.

changed (by reprogramming) to suit your requirements. To get into programming mode, keep S1 pressed for about 2 seconds **when the lamp is off**. The lamp will come on briefly. The microcontroller now waits for a signal from your RC5 compatible IR remote control, and the pushbutton you press will act as the on/off

Software operation

Whenever the software is not busy processing a received RC5 code, it is constantly measuring the period duration of the mains voltage. The measured value is divided by two to enable the software to 'know' when the triac is to be fired (triggered) during the missing half wave. The zero crossing detector employs an external interrupt (EX0Interrupt) triggered by a falling edge at pin P3.2 (pin 6) of the controller. When such an interrupt is signalled, Timer 1 is started. When an overflow occurs, a Timer1Interrupt is generated which leads to the triac being fired. Next, Timer1 is set to the previously measured value of the half period length and then restarted. After 10 ms (at 50 Hz) the second fire pulse occurs. In this way, the phase angle control takes place every half cycle of the mains voltage.

The timer inside the 89C2051 operates as a counter clocked at a frequency equal to fosc/12 (here, 1 MHz). The counter register is incremented at the seconds rate. An overflow of the 12-bit timer causes an interrupt.

The Reload value is calculated in the Timer1 interrupt routine. Besides, a bit is available that toggles at each Timer overflow:

Bit = 0: Timer being loaded for shifted triac firing instant;

Bit = 1: Timer being loaded with 10 ms (at 50 Hz) for triac firing during negative half wave.

The Reload value for Timer1 may be decreased or increased by pressing the remote control keys.

When the lamp is switched on or off the Reload value is changed cyclically. This automated process can not be affected using the remote control. If you want a different behaviour, other increments, or other intervals then you'll need to edit the software using the source code file. You will also need a suitable assembler and a programmer.
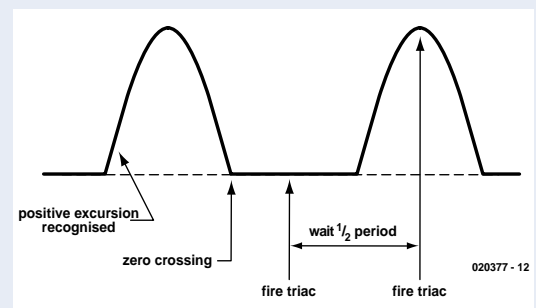
Figure 2. Copper track layout and component mounting plan of the PCB designed for the remote controlled dimmer (board available from The PCBShop).

control in the future. Press S1 again, and the lamp will light up twice. Now program the pushbutton for the 'raise brightness' control. A third press on S1 (three flashes from the l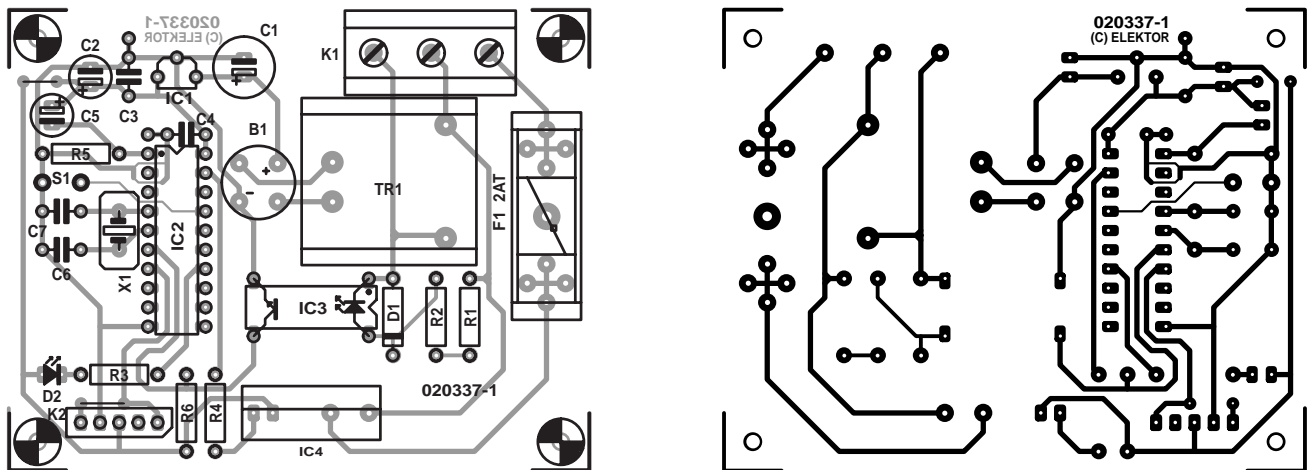amp) and you can program the pushbutton you want to use for 'lower brightness'. After successful programming of the new pushbutton functions, the lamp will come on.

When the remote control is switched on or off with S1, the lamp is not switched on and off abruptly. Rather, it comes on gradually (within approx. 1.5 s) and is slowly quenched (within approx. 3 s). The switch-on period was purposely shortened to ensure the room is quickly lighted. When the lamp is switched on by means of the remote control the brightness is not maximum but the last adjusted value.

Printed circuit board

The layout of the printed circuit board shown in **Figure 2** is generous because there was no need to make the circuit as compact as possible. None the less, the dimensions of the board should allow the circuit to be built into a surface pattress, a dry line box or a switch and socket box.

The construction should start with the mounting of the two wire links beside C2/C5 and K2. Next, the components may be fitted in the usual order: from small to large. **Do not attempt to replace R1 and R2 by a single resistor**, because its voltage rating would be insufficient. The microcontroller should be mounted in a socket, if only to be able to reprogram the device.

It should be noted that the circuit board is connected to the **lethal** mains voltage, hence an approved enclosure with protective earthing must be used, and every precaution taken that no parts can be touched when the circuit

is in operation. If you need to work on the circuit when it is being powered, always use a safety transformer. The fuse on the board should be covered with a cap to eliminate the risk of an erring test probe or, worse, a finger touching the mains voltage.

Finally, a few words on the infrared receiver module. Several types currently available on the market may be used without problems, as long as they are specified for a frequency of 36 kHz. Unfortunately, there is no such thing as pin compatibility in this area, so if necessary consult the datasheets before connecting your module to the circuit via K2. Starting at pin 1, the pin functions are:

Signal; not used; +5 V, Ground; Signal.

which should allow various IR receiver/detector modules to be connected without too much bending of connecting wires. The optics of the module should be the only parts that protrude from the housing in which the circuit is built.

(020337-1)

Free Downloads

Microcontroller software (Hex and source code files).
File number: **030337-11.zip**
PCB layout in PDF format.
File number: **020337-1.zip**
www.elektor-electronics.co.uk/dl/dl.htm, select month of publication.

COMPONENTS LIST

Resistors:
R1,R2 = 47kΩ
R3 = 1kΩ
R4 = 150Ω
R5 = 8kΩ2
R6 = 10kΩ

Capacitors:
C1 = 220µF 25V radial
C2,C5 = 10µF 16V radial
C3,C4 = 100nF
C6,C7 = 33pF

Semiconductors:
B1 = B80C1500 (round case, 80V piv, 1.5A)
D1 = 1N4148
D2 = LED, low current
IC1 = 78L05
IC2 = AT89C2051-12 (order code **020337-41**)
IC3 = CNY65
IC4 = S202S211

Miscellaneous:
K1 = 3-way PCB terminal block, lead pitch 7.5mm
K2 = SFH110-36, TSOP1836 (see text)
S1 = pushbutton, 1 make contact
Tr1 = mains transformer, 6V 0.35VA (e.g., Hahn BV2010106)
X1 = 12MHz quartz crystal
F1 = fuse, 2AT (time lag), with PCB mount holder and cap
Disk, HEX and source code files, order code **020337-11** or Free Download.

We can only answer questions or remarks of general interest to our readers, concerning projects not older than two years and published in *Elektor Electronics*. In view of the amount of post and email received, it is not possible to answer all correspondence, and we are unable to respond to individual wishes and requests for modifications to, or additional information about, *Elektor Electronics* projects.

Capacitor ESR Tester

Dear Editor — I have built this circuit from the article in your September 2002 issue and the instrument seems to work as described. In the section about adjusting the instrument, you say that an accurate voltage source of less than 200 mV is required for the adjustment of P5. However being a hobbyist on a limited budget I do not have access to precision test instruments of the kind that's likely to supply or indeed measure such a voltage. Can you indicate how I should proceed? I was thinking along the lines of a low-impedance potential divider (100 ohms to 1 ohm). I was hoping to use the ESR Tester to locate faulty capacitors in a number of valve radios I am in the process of restoring to their former glory.
M. Faulkner

An excellent idea — use new technology to restore the old! Leaky capacitors are a common source of problems in vintage radios. Regarding the 200-mV test voltage, your own suggestion is usable in principle: 0.2 V is obtained from 20 V by means of a 100:1 potential divider. The divider may also be dimensioned for a higher impedance, the aim is not so much a stable voltage, but to get the LCD to indicate the same voltage as a reasonably accurate DVM.

Hard Disk Interface for the Printer Port

Dear Editor — when I run the program I2L4.exe mentioned in the article (January 2002) under plain DOS, I am treated to the following error message:

Parallel Port: 0378 – I2L-adapter detected

HDD: xtor 82560A4

Error: unsupported partition type

Whatever type of hard disk I attempt to use, the program detects the interface and the HD, but the combination remains useless. Am I missing something (I think I have it all properly connected up)?
F.D. Burgess

Congratulations, the interface you have built is working properly. The problem is not the hardware but the partitioning of the hard disk. The DOS version of the driver is only capable of accessing disks using a FAT16 partition. By contrast, the Windows version will happily talk to FAT32 disks as well.

Year Volume 2002 CD-ROM

Mr. Finch of Aylesbury kindly advised us that at least two articles on the Elektor 2002 CD-ROM could not be opened from the archive program. In these cases a different article is opened.
The problem is caused by incorrect links in the article database. However, the relevant articles are contained on the CD-ROM and may be opened (using Acrobat Reader) by selecting the file n[production number].pdf found in the folder Articles/N on the CD-ROM.

Crescendo Millennium Edition

Dear Editor — I have a query on the Crescendo Millennium Edition published in the April 2001 issue of your magazine. I am measuring a direct voltage of –5 volts at the amplifier output. In an attempt to eliminate this voltage, I replaced the 2SK792 by a 2SK537, unfortunately, to no avail. I now suspect that the problem is caused by the MJE340 and MJE350. Since the h_{FE} specs of these two transistors are different, I started to search for a matched pair. I telephoned a number of suppliers only to be told I had to come up with a different type number before a matched pair could be ordered. Do you have suitable type numbers for me?
M. Kenyon

It is by no means necessary to replace the MJE340/350 pair by other types. With complementary transistors there is always a difference in their exact hFE specification. In audio amplifiers, that difference is typically compensated by the overall feedback. You need to look deeper into the circuit to find what's causing the

offset voltage, a likely source is major differences between the input transistors. If you measure at the output of opamp IC1, very likely you will see almost the supply voltage of +20 V. If so, try better matched input transistors, or modify the offset control — lower R4 and R5 to 1 MΩ and increase C3 to 330 nF. The amplifier output should then stabilise at 0 V.

USB Audio Codec

Dear Editor — congratulations on the publication of projects that can be connected to the USB bus, these prove that Elektor is miles ahead of your competitor EPE which seems stuck somewhere in the late 1980's as far as the technology of most of their projects is concerned. I would like to build he USB Audio Codec (December 2002) but modified with a coaxial S/PDIF input. Can I simply replace the TosLink input on the card by a cinch socket and a 75-Ω terminating resistor? Also, in view of this modification, I would prefer to build the circuit on veroboard, do you think that will work? Finally, a question about the copybit. I would like to use the card to copy a number of recordings on DCC cassette to CD, using my PC. Will I be able to transfer private recordings made using the analogue input on my DCC player?
J. Grymonprez

No, a 75-Ω resistor only is not sufficient for the purpose. You are referred to the article 'Opto-to-Coaxial Audio Converter' published in the April 1997 issue. There is no reason why the circuit would not work when built on veroboard, provided the component placement does not differ too much from that on the PCB we designed. The recording activities you describe should not cause problems.

Week/Month Timer

Dear Editor — You will perhaps be amused to know that this article (April 2003) potentially makes your readers liable to 10 years in prison in the UK!

The UK Terrorism Act 2000 says: "Section 58. - (1) A person commits an offence if
(a) he collects or makes a record of information of a kind likely to be useful to a person committing or preparing an act of terrorism, or
(b) he possesses a document or record containing information of that kind.
(2) In this section "record" includes a photographic or electronic record.
(3) It is a defence for a person charged with an offence under this section to prove that he had a reasonable excuse for his action or possession.
(4) A person guilty of an offence under this section shall be liable-
(a) on conviction on indictment, to imprisonment for a term not exceeding 10 years, to a fine or to both, or
(b) on summary conviction, to imprisonment for a term not exceeding six months, to a fine not exceeding the statutory maximum or to both. "

Clearly, an accurate long-term timer is invaluable to someone planting a bomb such as the one that blew up the Conservative Party conference in Brighton some years ago. The "reasonable excuse" defence might be enough to get us all off, of course.......
M. Thomas

Thanks for the information, we are indeed amused rather than impressed. An interpretation of the law as suggested by you could equally be construed to apply to the makers and owners of
- Mechanical alarm clocks
- Batteries
- GSM phones
- Electricity
- A Tourist Map of Brighton (with the Pier struck off)

By law the designers should have paperwork describing these products, plus the owners will have some kind of user manual. Should these products be banned and their designers and owners asked to file "reasonable excuses"? we think not.

Mr. Thomas replied:
I agree entirely. I have a shelf of pilot's manuals and the address of the Houses of Parliament ...
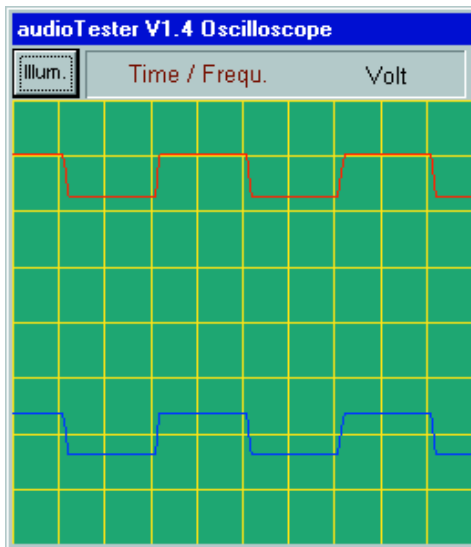
Audio Tester

001
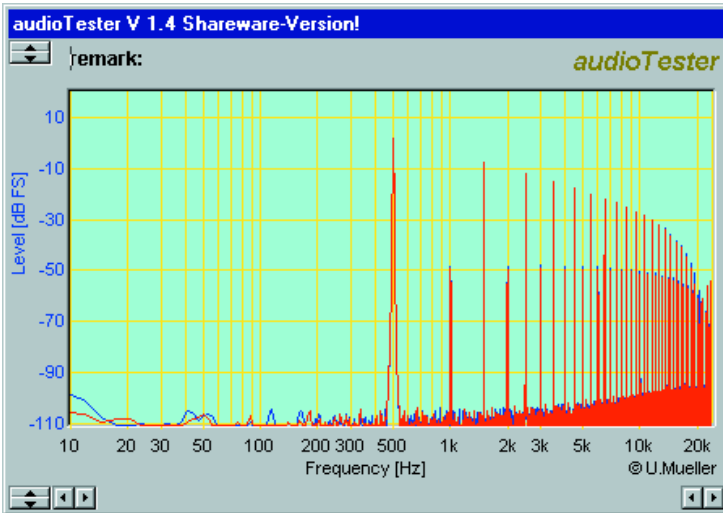
P. Goossens

Wouldn't it be nice to have an oscilloscope, spectrum analyser and function generator in one instrument without doing enormous damage to your wallet? And in addition, this instrument will not take up space on your crowded desk or workbench and does not require a separate power supply? This

sounds too good to be true! But it is possible, provided you already own a Windows-PC with a sound card. Granted, the frequency range is limited to the audio range and the accuracy depends on your sound card, but for 18 pounds or so this is certainly a very handy and desirable measuring instrument.

You have probably realised by now that this is not a build-it-yourself circuit, but a program that is available as shareware on the Internet. You can register the program for 25 euros (approx. £18) and use it is much as you desire.

The (2-channel!) oscilloscope is rather Spartan by design, but that is logical, since the input of a sound card does not possess as many bells and whistles as a normal oscilloscope. It is possible however, to adjust the time base and change the sensitivity of the input channels. This oscilloscope is also fitted with a trigger function, which allows a nice 'stationary' picture to be displayed on the screen. The oscilloscope is quite usable in practice, pro-

vided the limited bandwidth and maximum input voltage don't become a problem.

The function generator has the option of generating various waveforms such as sine, rectangle and triangle. White noise and pink noise can also be produced with this generator. A final option permits a wave-file to be played, so that, in principle, any arbitrary waveform is possible (provided it can be generated by the sound card). The generator also has a second function, namely as a sweep generator. In this case the generator produces different sine waves of increasing frequency. At each frequency, the level at the input is measured. These values are then displayed in a nice Bode-plot. This is very useful when measuring filters, amplifiers, etc.

The final instrument is a spectrum analyser. This makes use of FFT-analysis, which gives the analyser a fast update rate. The adjustments provide, among other things, different windowing options that can be applied to the input signal. The number of samples that are used for analysis is also adjustable.

Being able to carry out a good measurement with this program is entirely dependent on the quality of the sound card. Currently, the average sound card is good enough to make reasonable measurements possible, but they are not really ideal, of course. It should be clear, that the inside of a PC enclosure is hardly a desirable environment for analogue signals. There are manufacturers who, for these reasons, make sound cards available where the A/D and D/A converters are fitted in a separate enclosure from the PC. To reiterate, a standard soundcard is good enough to perform measurements, but you should not expect miracles from it!
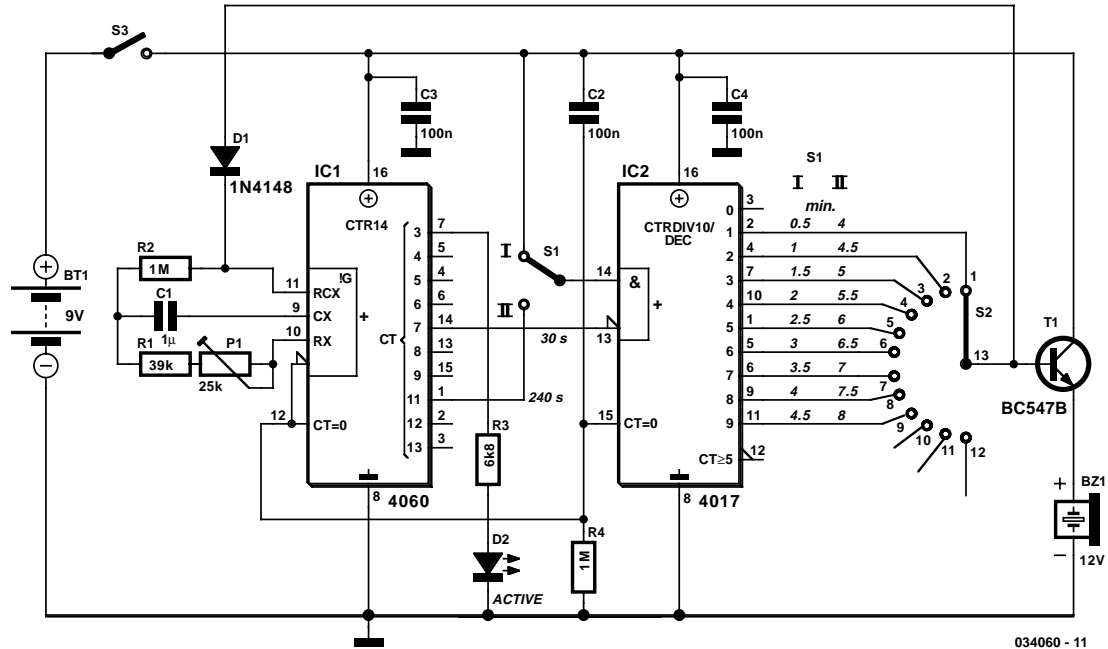
The program can be downloaded from the designer's website: http://www.sumuller.de/audiotester/

(030027-1)

Egg Timer

002

034060 - 11

T. Giesberts

This egg timer, which is both simple and functional, shows once again that it is not essential to use a microcontroller for everything these days. The circuit consists of only two ICs from the standard 4000 logic family, a multi-position rotary switch and a few individual components. The combination of a 4040 oscillator/counter and a 4017 decimal counter is certainly not new, but it is an ideal combination for timers that are required to generate long intervals that can be programmed in steps. The circuit can be directly powered from a 9-V battery, without using a voltage regulator. The signalling device is a 12-V buzzer, which generally works quite well even at a much lower voltage.

We won't explain the operation of the two ICs here; if you would like to know more about this, we recommend consulting the device data sheets. The RC configuration has been selected for the oscillator circuit of the 4060, since the frequencies of standard crystals and resonators would be too high (even 32.768 Hz is much too high), making it impossible to achieve the desired times. With an RC oscillator, it's also easier to modify the times to suit our purposes. For instance, if the oscillator frequency is reduced by a factor of two, we obtain a range of 1 to 16 minutes in steps of 1 minute.

The range is split into two by taking advantage of the fact that the 4017 has an AND gate at its input (with an inverted input). The two ranges overlap by two steps. The oscillator has been dimensioned such that the 2^3 divider output (pin 14) has a period of 30 seconds, so IC2 receives a clock pulse every 30 seconds. This means that the oscillator frequency
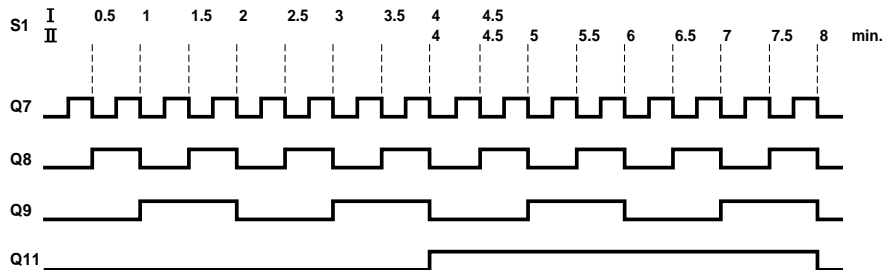
034060- 12

must be set to 8.5333 Hz.

The first output of IC2 is active after a reset, so it cannot be used. If S1 is in position I, pin 14 of IC2 is connected to the positive supply line. This input is used as an enable input. Directly after the first pulse from the 4060, the second output of IC2 goes high (which means after exactly half a minute). The subsequent outputs become active in turn at intervals of one clock pulse, and thus generate the states for 1 to 4.5 minutes.

In the second range (II) of S1, the 'enable' pin of IC2 is connected to the 2^{12} divider output of the 4060 (pin 1). This output goes high 4 minutes after the reset (which is why it is labelled '240 s', instead of the period time of 480 s). Since the 4060 is an asynchronous counter, this output goes high a short time after the 2^3 output goes low. This delay provides the proper condition for an extra clock pulse for the 4017. The outputs of the 4017 will thus count upwards once. This means that the second output will become active after 4 minutes, with the rest of the outputs becoming active after 4.5 to 8 minutes.

The desired timing interval is selected using switch S2. The output of S2 is connected directly to emitter follower T1, which energises the buzzer when the level on the wiper of the switch

is high. At the same time, the counter of IC1 is disabled via diode D1 by forcing the oscillator input high. The buzzer thus remains active until the circuit is switched off.

The first counter output of the 4060 is connected to an LED (D2), which indicates that the circuit is active and the battery not yet exhausted. The blinking rate is approximately 0.5 Hz. The current through the LED is set to a modest 1 mA, since this current represents the majority of the current drawn by the circuit. This ranges from 0.5 to 1.5 mA, with the average current consumption being approximately 1 mA while the timer is running. The buzzer used in our prototype increases the current to around 13 mA when it is energised, but this naturally depends on the actual type used.
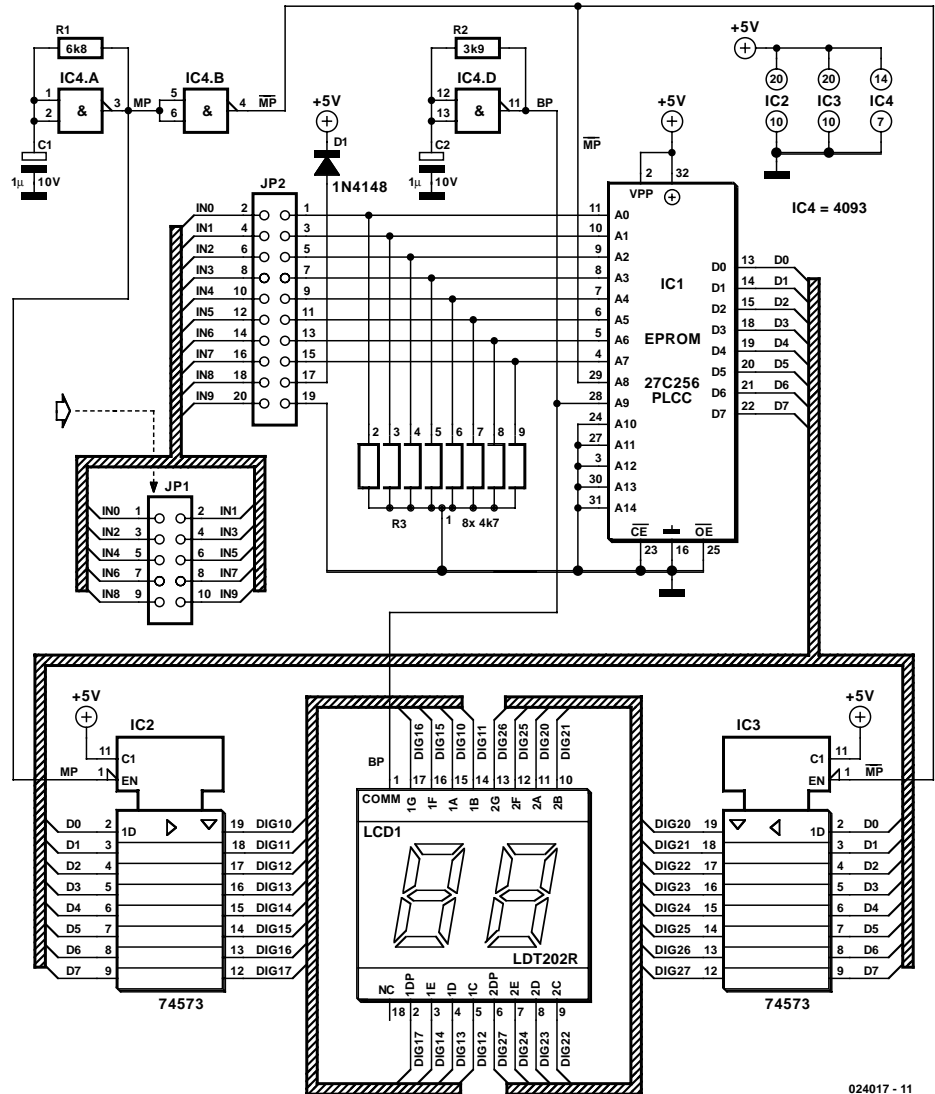
In principle, the circuit will work with any supply voltage between 3 and 16 V. However, the actual supply voltage should be taken into account in selecting the buzzer. The value of the supply voltage also has a small effect on the time interval, but in practice, the deviation proved to be less than 5 percent — which is not likely to matter too much to the eggs.

(034060-1)

HEX Display

003

A. Barthel

When experimenting with digital and microcontroller-based circuits it is often more convenient to display a value as a number and not as a bit pattern on a row of LEDs. This circuit is designed for exactly that purpose. Thanks to its low current consumption (a little under 10 mA) and its compact construction it can be plugged directly into a header on a microcontroller board, taking its supply from that board. An EPROM, which stores all the required values for display, is used as the decoder. The 256 kbit EPROM is considerably larger than strictly necessary for this job — 1 kbit would be enough — but the type shown is much easier to obtain.

The binary data (and power, if available) are taken from JP1 to one side of JP2. The binary data and power signals can be permuted using a suitably-wired plug fitted into JP2. Also, power can be provided at this point, if it is not available from JP1. The data are now taken directly to address signals A0 to A7. The incoming data byte is viewed as two 4-bit values. The clock generator consisting of IC4.A and IC4.B switches between banks in the memory using address line A8. At the same time this signal provides a multiplex clock for IC2 and IC3. At any given moment the outputs of exactly one of these latches are enabled while those of the other are put into a high-impedance state. In this way the high and low halves of the input byte are separated and switched through to the correct digit.

Oscillator IC4.D produces the backplane signal for the LCD. An LCD segment only 'lights' when its front and rear electrodes are driven with signals of opposite phase. The backplane signal is therefore also taken to A9 on the EPROM as a further bank-switching signal (we can afford to be generous with memory space!). This memory bank stores mask values for each possible input value.

The author has designed a printed circuit board for this circuit. The layout, in Eagle format, is available for download from the *Elektor Electronics* website, along with the HEX file for the EPROM. The file numbers are **024017-1** and **024017-11** respectively.

(024017-1)

024017 - 11

Flip-Flop Using CMOS NAND Gates

L. Libertin

Using just two NAND or inverter gates its possible to build a D type (or 'toggle') flip-flop with a pushbutton input.

At power-up the output of gate N2 is at a logical '1', ensuring that transistor T2 is switched off. When the pushbutton is pressed the output of N2 changes to a logical '0' and transistor T2 conducts. The coupling between N1 and N2 ensures that the output of N1 will always be the inverse of N2 so T1 and T2 will always be in opposite states and will flip each time the pushbutton is pressed.

In some cases it is possible to omit T1 and T2 and use the outputs of N2 and N1 to drive external circuitry directly but only if the loading on these outputs is low enough. The 4000 series CMOS family can source/sink a maximum of 0.5 mA (at 5 V) so for the sake of safety its best to use these open-collector configured transistor buffers.

This circuit is particularly useful if you have some unused gates left over in a circuit design, avoiding the need to add a dedicated flip-flop IC. It is worth remembering that all other unused CMOS gates must have their inputs connected to either the positive or ground rail.

The supply voltage can be in the range 3 V to 15 V for CMOS ICs and the current taken by this circuit is between 0.2 mA and 5 mA (no load).

(034010-1)

034010 - 12

034010 - 11
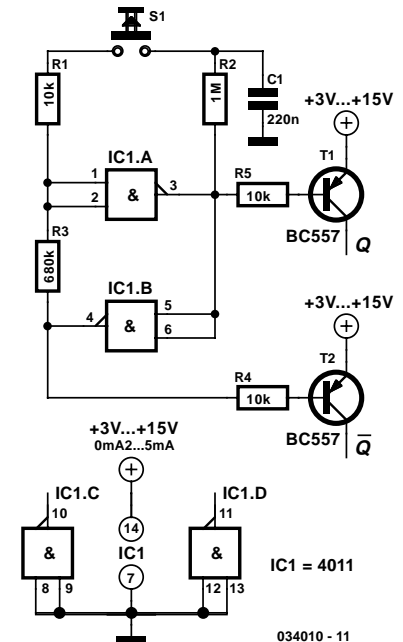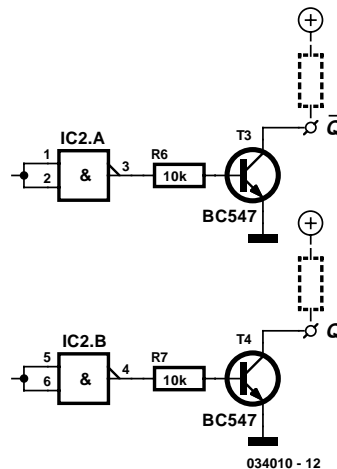
RIAA Phono Preamplifier 005

H. Riegstra

Since modern sound systems usually lack inputs for record players, separate MD preamplifiers are becoming increasingly popular. They are needed not only by people who still regularly like to listen to vinyl records, but also by those who want to finally transcribe their LP collections to CD using a CD recorder. The author has built innumerable phono preamplifiers for friends and acquaintances. In many cases, for the sake of simplicity these were based on an old circuit design with two μA741s, which was originally described by B. Wolfenden in a 1976 issue of *Wireless World*. In that simple design, the first 741 simply amplified the full range of the frequency spectrum, while the second one was fitted with RIAA frequency compensation — a fairly common configuration at that time.

However, a variant on this classic design was recently born after a bit of experimenting. It also uses two opamps, with the difference that the RIAA frequency compensation is distributed over both opamps. The accompanying figure shows the schematic diagram of this preamplifier. The first opamp attenuates the signal at 6 dB/octave starting at 2.2 kHz, while the second opamp looks after the other corner frequency. The objective of the new design was to keep the feedback factor as high as possible in both stages.

To the considerable surprise of the developer, this modifica-

034023 - 11
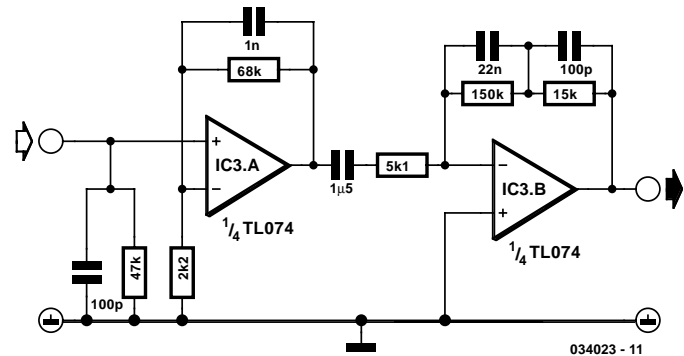
tion turned out to have an unexpected side effect: when records were played, certain scratches were no longer audible! The difference between the new and old preamplifiers could be clearly heard; it was certainly not just imagination. What could be the cause of this? A quick calculation showed that a 0.05-mm scratch in a record groove moving past a needle at a speed of 0.5 m/s produces a square-wave pulse with a frequency of 10 kHz. Evidently, there is a lot to be gained by attenuating such pulses with a low-pass filter as early as possible, which means in the first stage, in order to prevent them from overdriving the rest of the circuit.

(034023-1)

Control Box with Status for Märklin Railway Points

N. Körber

006

The model rail manufacturer Märklin produces the turnout mechanism (or points) type 74490 for C track, the 7549 for K track (H0 gauge) and also the 5625 (1 gauge) all fitted with limit switches. The circuit here shows a control box to interface to these mechanisms and also display the status of the turnout using LEDs.

All these turnouts are fitted with two actuating coils, when energy is supplied to coil L1 the turnout moves to the 'straight ahead' position while energising L2 moves them so that the train 'turns out' onto a branch line. The standard Märklin control box for controlling these devices is fitted with a green push button to activate L1 and a red push button for L2. This colour convention is also used here for connections. Yellow indicates the power supply connection and brown the earth connection. The limit switches interrupt power to the coils when the turnout reaches the end of its travel. These ensure that the coils do not become overloaded and also divert the supply to the other coil, enabling the points to be moved back later.

When the pushbutton is pressed, current flows through the coil and also the status LED. The only other additional components are the LED current limiting resistors, protection diodes and a rectifier.

The low-current LEDs require an additional 2 mA (red) or 4 mA (green) from the transformer. Series resistors R1 and R2 limit current through the LEDs while D1 and D2 protect the LEDs from the back-emf generated when current through the coil is interrupted.

Diode D3 rectifies the supply to both LEDs and can also supply additional LEDs if more than one turnout control is built. A feature of the circuit is that the status LED will illuminate when its corresponding pushbutton is pressed even if power to its coil is not connected through the limit switch. This does not affect operation but can be remedied if necessary by fit-

020039 - 11
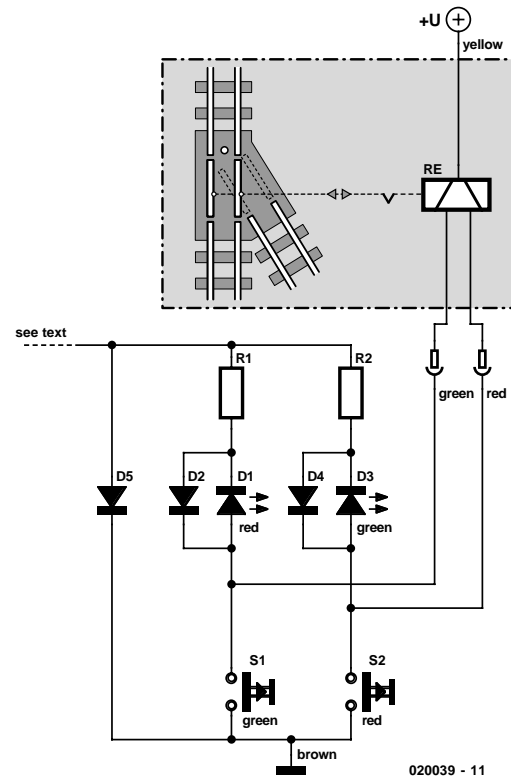
ting separate rectifiers for each coil.

Additional low-current or standard LEDs or even optocouplers can be added in series with the LEDs if more status indicators are needed but it will be necessary to change the value of the series resistors to suit. A conventional control box like the Märklin 7272 can be substituted for the pushbuttons shown in the circuit and the LEDs can be fitted to provide visual positional feedback.

(020039-1)

EL Lamp Driver using HV832MG 007

D. Prabakaran

An EL lamp is a solid state, low power, uniform area light source. Because of its thin profile (as thin as 0.3 mm) and the fact that it can be built into almost any size and shape, EL lamps are an ideal way to provide backlighting for LCD displays, membrane keypads and a variety of other applications. Electroluminescent (EL) lamps offer significant advantages over point light sources such as LEDs, incandescent, and fluorescent lighting systems. As a result of these advantages, EL lamps are seeing growing use. Many wireless phone and pager manufacturers are converting to EL lighting systems in keypads and displays. The typical lamp consists of light emitting phosphor sandwiched between two conductive electrodes with one of the electrodes transparent so allowing light to escape. As an AC voltage is applied to the electrodes, the electrical field causes the phosphor to rapidly charge and discharge, resulting in the emission of light during each cycle. Since the number of light pulses depends on the magnitude of the applied voltage, the brightness of EL lamps can generally be controlled by varying the operating voltage.

Because EL lamps are a laminate, they exhibit a capacitance of the order of 2.5 nF to 3.5 nF per square inch. When high voltage is applied across the electrodes, the resulting electric field excites the phosphor atoms to a higher energy state. When the electric field is removed, the atoms fall back to a lower energy state, emitting photons in the process. The wavelength of the emitted light is determined by the type of phosphor used and the frequency of the excitation voltage. With most phosphors, the spectrum of emitted light will tend to shift towards blue with an increase in excitation frequency. Colour is usually controlled, however, by selecting the phosphor type, by adding fluorescent dyes in the phosphor layer, through the use of a colour filter over the lamp, or a combination of these.

EL lamp brightness increases approximately with the square of applied voltage. Increasing frequency, in addition to affecting hue, will also increase lamp brightness, but with a nearly linear relationship. Most lamp manufacturers publish graphs depicting these relationships for various types of lamps. Excitation voltages usually range from 60 V_{PP} to 200 V_{PP} at 60 Hz to 1 kHz. Increased voltage and/or frequency, however, adversely affects lamp life, with higher frequencies generally decreasing lamp life more than increased voltage. EL lamps, unlike other types of light sources, do not fail abruptly. Instead, their brightness gradually decreases through use. For intermittent use, lamp life is seldom a concern. For example, if a lamp is used 20 minutes per day, over the course of 10 years the lamp will be activated for a total of 1,216 hours, well within the useful life of almost any EL lamp available. When designing a drive circuit, a balance needs to be struck between lamp brightness, hue, useful life, and supply current consumption. To generate the high voltages needed for driving EL lamps, dedicated ICs like the Supertex HV832MG employ switch-mode converters using inductive flyback. By integrating high

020433 - 11
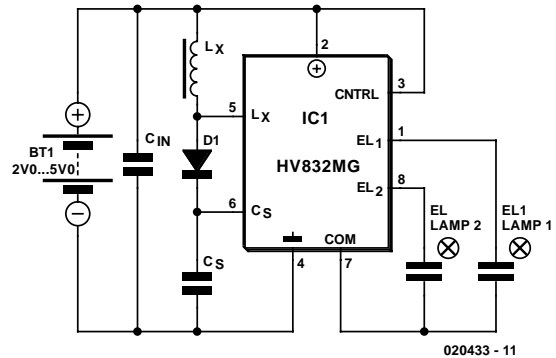
voltage transistors on-chip, this driver avoids the need for expensive, bulky, and noisy transformers to generate high output voltages. The HV832MG employs open-loop conversion. This EL driver incorporates a lamp drive oscillator that is separate from the power conversion oscillator. This allows setting lamp drive frequency independently from the power conversion frequency and so optimise overall performance.

The power conversion cycle begins when a MOSFET switch in the HV832MG is turned on and current begins to rise in inductor Lx. When the switch is turned off, inductive flyback causes the voltage across the inductor to reverse polarity and rise until it reaches the level of the storage capacitor C_S, (plus diode drop) at which point the rectifier conducts and the energy contained in the magnetic field of the inductor is transferred to C_S. When all the inductor energy is transferred and inductor current drops to zero, the rectifier stops conducting and inductor voltage drops to zero, ready for the next cycle. Output power is simply the amount of energy transferred per cycle multiplied by the number of cycles per second.

It is important to select the inductor and conversion frequency to provide the required output voltage while assuring that the inductor current does not approach saturation levels. If the inductor saturates, excessive current will flow, potentially leading to device failure. Ideally, the inductor current should be allowed to return to zero between cycles. If inductor current is not allowed to return to zero, a higher average current will be needed to meet output power requirements, increasing I^2R losses, and decreasing conversion efficiency. On he other hand, if too much time is allowed between zero inductor current and the start of the next cycle, more energy will need to be transferred each cycle to maintain output power, thus risking inductor saturation and increasing I^2R and core losses. This circuit provides an output of 130 volts at 300-450 Hz, draws just 30 mA current, yet is capable of driving EL lamps with a surface area of up to 9 cm^2.

This design has excellent drive capability and provides a symmetrical bipolar drive, resulting in a zero-bias signal. Many lamp manufacturers recommend a zero-bias drive signal to avoid potential migration problems and increase lamp life. The supply voltage should be bypassed with a capacitor located close to the lamp driver. Values can range from 0.1 μF to 1 μF

depending on supply impedance.
For very large lamps representing much larger capacitances, a FET follower circuit may be employed to boost the output drive capability of the lamp driver.

The HV832MG may be obtained from Supertex Semiconductors, USA, www.supertex.com.

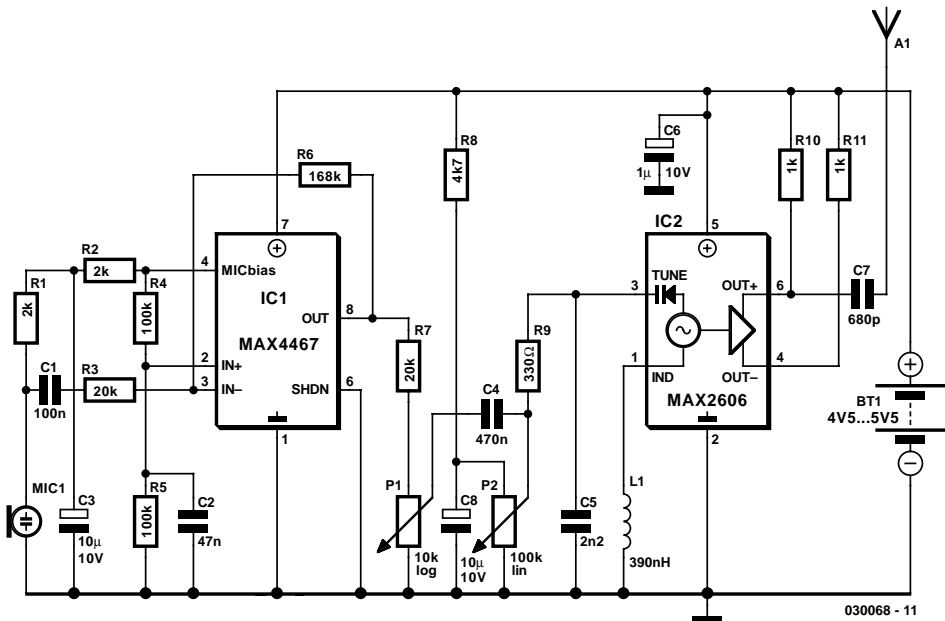(020433-1)

FM Wireless Microphone   008

D. Prabakaran

Here is a very simple, inexpensive and interesting project which provides lot of fun to a home experimenter or hobbyist. This simple transmitter can transmit speech over a short range. It can be used as a simple cordless microphone. The circuit uses two integrated circuits from Maxim. IC1 a MAX4467, is an amplifier raising the microphone signal to a level suitable for frequency modulation (FM). IC2 is a voltage-controlled oscillator (VCO) with integrated varactor (a.k.a. varicap diode). Its nominal frequency of oscillation is set by inductor L1. The inductor value 390 nH provides an oscillation frequency of about 100 MHz. For best performance, L1 should be a high-Q component. L1 may consist of 4 turns of silver-plated wire wound around a 10-mm drill bit, and stretched to a length of about 1.5 cm. The wire diameter can be anything between 26 SWG (0.5 mm) and 20 SWG (1 mm). No core is used.

The MAX4467 is a micropower opamp for low voltage operation and providing 200-kHz gain bandwidth at a supply current of just 24 μA. When used with an electret microphone, some form of DC bias for the microphone capsule is necessary. The MAX4467 has the ability to turn off the bias to the microphone when the device is in shutdown mode. This can save several hundred microamps of supply current, which can be significant in low power applications particularly for battery powered applications like cordless microphones. The MICBias pin provides a switched version of Vcc to the bias components.

Resistor R1 resistor limits the current to the microphone element. The output impedance of the MAX4467 is low and well suited to driving cables over distances up to 50 m.

The MAX2606 intermediate-frequency (IF) voltage-controlled oscillators (VCO) has been designed specifically for portable wireless communication systems. The IC comes in a tiny 6-pin SOT23 package. The low-noise VCO features an on-chip var-

actor and feedback capacitors that eliminate the need for external tuning elements. Only an external inductor (here, L1) is required to set the oscillation frequency and produce a properly operating VCO.

To minimize the effects of parasitic elements, which degrade circuit performance, place L1 and C5 close to their respective pins. Specifically, place C5 directly across pins 2 (GND) and 3 (TUNE).

Potentiometer P2 then lets you select a free channel by tuning over the FM band of 88 MHz to 108 MHz. Output power is about –21dBm (approx. 10 μW) into 50 Ω. P1 serves as a volume control by modulating the RF frequency. Signals above 60 mV introduce distortion, so the pot attenuates from that level. To decrease stray capacitance, minimize trace lengths by placing external components close to IC1's pins.

Using a wire antenna of about 75 cm the transmitter should have a range of about 35 m. Try to keep all leads as short as possible to prevent stray capacitance.

The transmitter operates on a single supply voltage in the range 4.5 V to 5.5 V from any standard battery source.

The transmitter must be housed in a metal case, with shielding installed between the two stages (AF and RF). Try to keep all leads as short as possible to prevent stray capacitance.

(030068-1)

Rolling Shutter Control

009

T. Knipa

An electrically operated rolling shutter usually has a standard control panel with a three-position switch: up, down and stop. If you would like to automate the opening and closing with a time controlled switch, a few additional wires will have to be connected. Typically, the controls are implemented as indicated in the schematic 'Normal Situation'. If this is indeed the case, then you can see in 'New Situation' how the shutter can be automated with a timer. There is only one method to determine the actual schematic of your control circuit, and that is to open the control box and using an ohmmeter, pencil and paper to check out and draw the circuit. Make sure you turn the power off first though!

Connect a 230-V relay (with both the contacts and the coil rated 230 VAC) to the timer. The changeover switch between automatic and manual control needs to be rated 230 VAC as well and may not be a hazard for the user. The relay and switch are preferably fitted in a plastic mains adapter enclosure with built-in plug, which is plugged into the timer. It is a good idea to check first if this will actually fit.

Because of the manual/automatic-switch, the operation is completely fail-safe and misunderstandings are out of the question. The switch prevents the issue of conflicting commands (with disastrous consequences) when, for example, the shutter is being automatically raised and manually lowered at the same time.
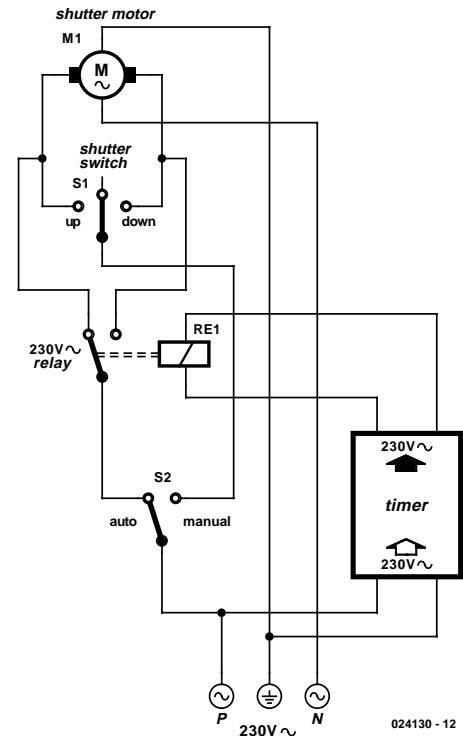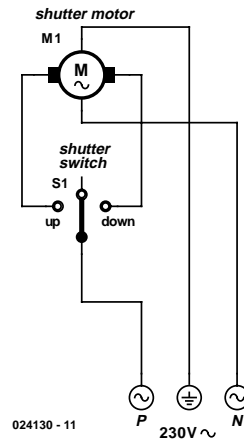
(024130-1)

RMS to DC Converter

010

G. Kleine

In order to measure the RMS value of an alternating voltage an accurate converter is required to produce the true RMS value of its alternating input as a DC output. With simple sinewave inputs the RMS voltage can simply be calculated as 0.707 times the peak AC voltage, but with complex waveforms the calculation is not nearly as straightforward. The RMS value is defined as the DC voltage that would give the same heating effect in a resistor as the alternating voltage.

The LTC 1966 from Linear Technology (www.linear-tech.com) uses a new form of delta-sigma conversion and is designed for battery operation, drawing only 170 µA from the supply. The new technique is accurate to 0.02 % between 50 mV and 350 mV and is highly linear. It can operate from 50 Hz to 1 kHz (with an error of 0.25 %) and up to 6 kHz with a 1 % error. The input voltage range on the differential inputs IN1 and IN2 extends to the supply rails, and so in the non-symmetrical circuit shown here the voltage on IN1 can swing between 0 V and the supply voltage. If the signal to be measured is AC only, then another coupling capacitor will be required. The input impedance is many megohms. The output voltage at the OUT

pin can be offset by applying a DC voltage to the OUTRTN pin. This is particularly helpful when using the device with LCD multimeter ICs such as the 7106. A further capacitor is connected to the output which is charged up to the required voltage by the switched-capacitor circuit in the converter. The capacitor required is ten times smaller than that demanded by previous RMS to DC converter designs.

The LTC1966 is not temperature sensitive and is available in an 8-pin MSOP package. It allows a tiny RMS to DC converter to be constructed using just four components.
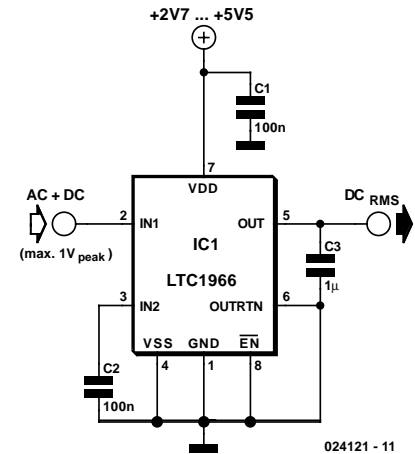
Multisound for Guitars

011

P. Goossens

Electric guitars use coils (guitarists call them pickups or elements) to convert the vibrations of the strings into an electrical signal. Usually, a guitar has more than one element built-in, so that the musician can select with a switch which element or elements are used to generate the signal. Because of the differences in construction of the elements and the varying positions of where they are mounted, each element sounds different.

The elements can be roughly divided into two categories. There are the so-called 'single-coils' and 'humbuckers'. Single coil elements are elements that contain one core and coil for each string. Humbuckers can be regarded as two elements that are connected in series.

Many humbuckers have four connections (actually two single-coils with two connections each). These two individual coils are usually interconnected with fixed wiring so that they are always used in series.

The circuit proposed here offers the possibility of using a humbucker with four connections in no less than four different modes, each of which having its own sound. The only things that have to be changed on the guitar are the wiring and the addition of a four-position switch. The latter requires drilling holes in the guitar of course, but if there is a control cover plate (along the lines of a Fender Stratocaster, for example) then it makes sense to put the switch there. This avoids the need for drilling holes in the wood while keeping an (expensive) guitar reasonably unmarred.

original
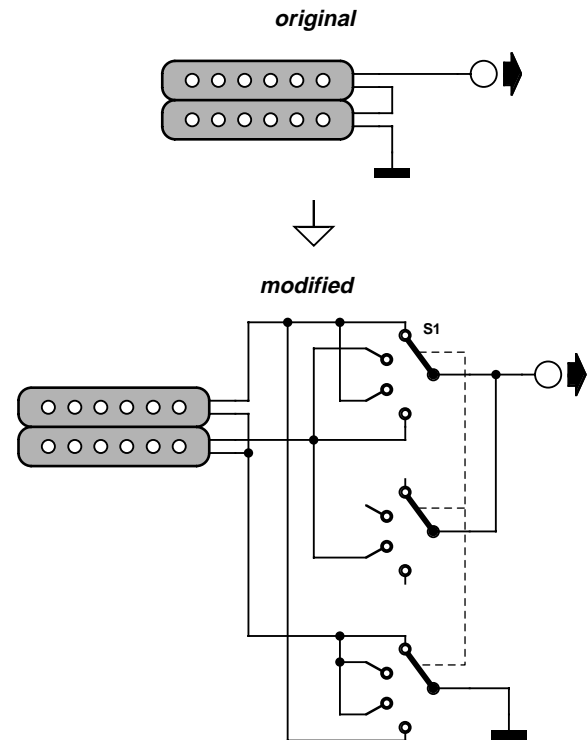
modified

034014 - 11

The schematic shows what the various things look like, electrically speaking, before and after the multisound modification.

(034014-1)

Three Hour Timer

012

020208 - 11
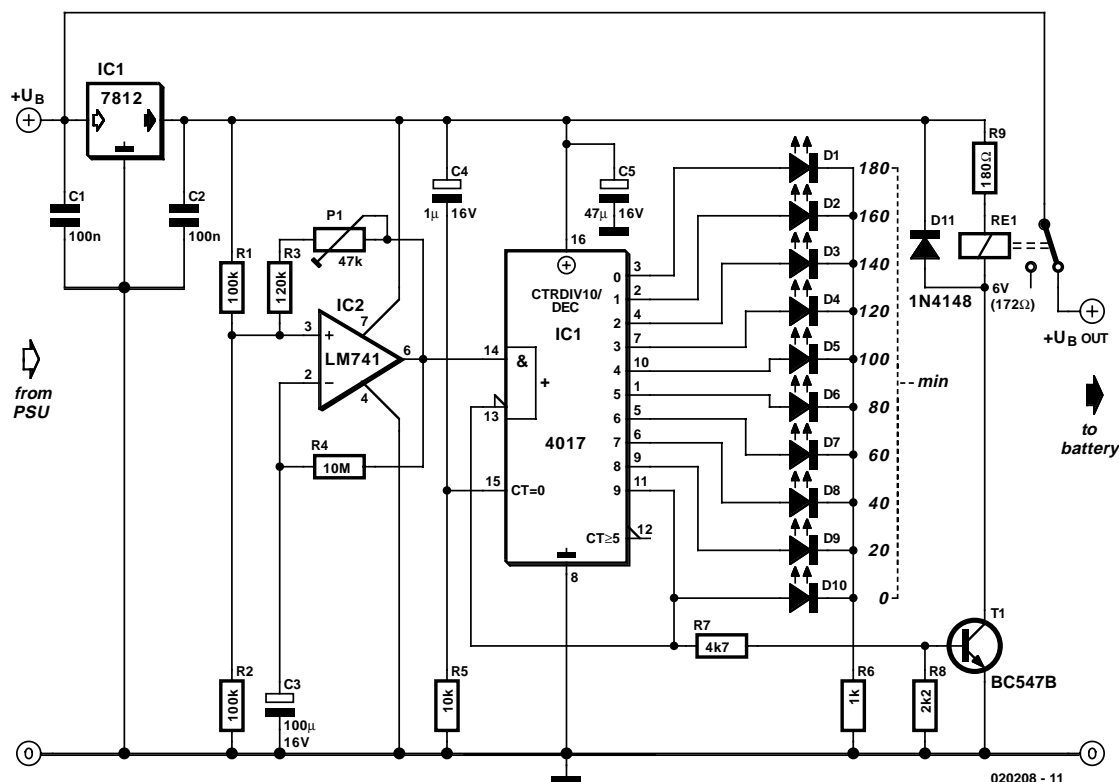
L. Libertin

Manufacturers of cordless drills generally recommend a battery charging time of three hours. Once the charging time is up the battery must be disconnected from the charger: if you forget to do this there is a danger of overcharging the battery. This circuit, which sits between the charger circuit and its battery socket, prevents that possibility: the contact of relay Re1 interrupts the charging current when the three hours are up. Ten LEDs show the remaining charging time in steps of 20 minutes. The timer is reset each time power is applied and it is then ready for a new cycle.

When power is applied IC3 is reset via C4 and R5. When the charging time has elapsed, Q9 (pin 11) goes high, which turns

the relay on and interrupts the charging current. Since Q9 is connected to the active-low EN (enable) input, the counter will now remain in this state. The charging time can be adjusted from about 2 hours 15 minutes to 4 hours 30 minutes using P1. The author set P1 to 30 kΩ, giving a charging time of 3 hours 7 minutes. The greater the resistance of P1, the shorter the charging time. The timing of the circuit is not particularly precise, but its accuracy is entirely adequate for the job.

When adjusting the charging time it is worth noting that the first clock cycle after the circuit is turned on (from Q0 to Q1) is longer than the subsequent ones. This is because initially capacitor C3 has to be charged to around half the supply voltage.

(020208-1)

DC Control for Triacs

L. Libertin

If a circuit is to switch a mains voltage, a relay is a simple solution in cases where switching times are long and high currents are involved. However, at lower currents, and in particular where rapid switching is required, such as in sound-to-light systems, a relay no longer fills the bill. Electrical isolation is often a requirement, which rules out driving a triac via a transistor. Here we use the MOC3041 optocoupler, which is specially designed for such applications, to drive a power triac. The control circuit therefore remains galvanically isolated from the mains.

The internals of the optocoupler are somewhat more complex than appears from the circuit diagram. A special zero-crossing detector circuit in the optocoupler ensures that the connected triac is only triggered when the alternating mains voltage goes through zero. This has the advantage of generating less interference compared to switching the triac at arbitrary phase in a cycle. Indeed, it means that we can dispense with the suppressor choke at the output that would otherwise be necessary. If very brief pulses are likely to be present at the input to the optocoupler, a 220 nF capacitor should be connected between the input of the circuit and the emitter of T1 to lengthen the drive pulses. This ensures that the triac will be triggered even with very short input pulses, which might otherwise miss the zero-crossing point of the mains waveform.

020279 - 11
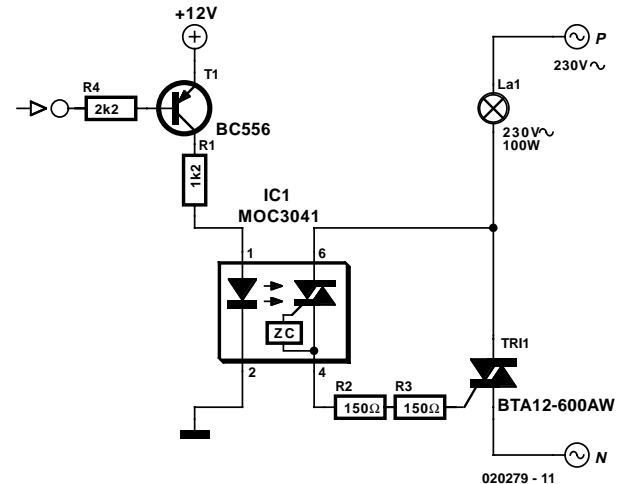
The triac should be an AW-suffix type. These types are less sensitive, but have higher dv/dt and di/dt specifications. The gate resistance must be constructed from two resistors connected in series, since normal resistors are not suitable for direct use with mains voltages. It is also necessary to exercise care around the optocoupler. In order to guarantee Class II isolation the solder pads on the input and output sides must be separated by at least 6 mm. The leads may therefore need to be bent outwards when soldering.

(020279-1)

Automatic Mains Disconnect 014

A. Brandon

Downloading and CD-burning programs usually provide the option of automatically shutting down the PC on completion of their tasks. However, this energy-saving feature is of little benefit if even after the PC has been switched off, all of the peripheral equipment remains connected to the mains and happily consumes watt-hours. The circuit shown here provides a solution to this dilemma. It is connected ahead of the power strip and connects or disconnects mains power for all of the equipment via a power relay. A connection to a 12-V PC fan (which may be the processor fan or the fan for the chipset, if the latter is present) indicates whether the PC is switched on. If you are certain that the 12-V power supply voltage is switched off when the PC is in the sleep mode, you can use this connection instead.

To switch everything on, press the Start button to cause the power relay to be energised and provide mains voltage to all of the equipment. If the PC has an ATX board, its Power switch must be pressed at the same time to cause the PC to start up. When the PC fan starts to run, low-power relay Re1 engages and takes over the function of the Start switch, which can then be released. This state is stable.

If the PC switches to the sleep state, the 12-V voltage drops out. The electrolytic capacitor ensures that Re1 remains engaged for a short time, after which it drops out, followed by the power relay. D1 prevents the electrolytic capacitor from discharging through the connected fan, and D2 is the usual freewheeling diode. The system is disconnected from both mains leads and is thus completely de-energised.

Be sure to select components that are suitable for their tasks. Naturally, the contacts of Re2 should be rated to handle the total current drawn by all of the peripheral equipment and the PC, and the relay coil must be suitable for use with mains voltage (6 mm minimum separation between coil and contacts). A low-power 12-V relay that can switch mains voltage is adequate for Re2. The Start pushbutton switch is connected to the mains voltage, so a 230-V type must be used. The circuit board layout and enclosure must also be designed in accordance with safety regulations. A separation of at least 6 mm must be maintained between all components carrying mains voltage and the low-voltage components, and the enclosure must be completely free of risk of electrical shock. With a bit of skill, the circuit can be fitted into a power bar with a built-in switch, if the switch is replaced by a pushbutton switch having the same mounting dimensions.
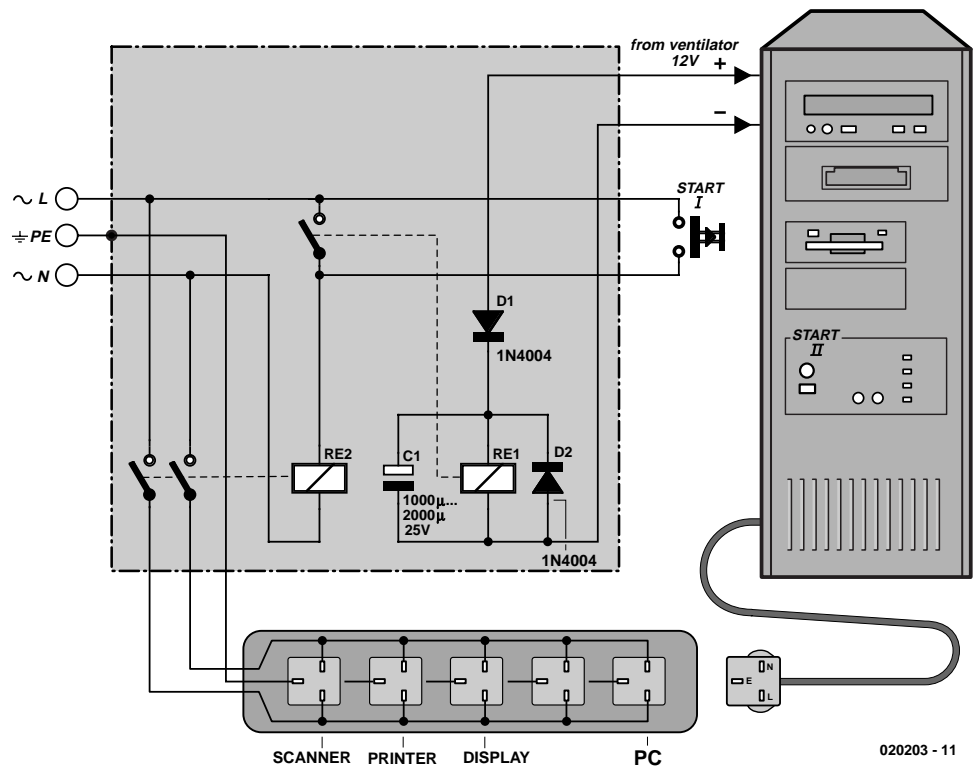
Note that the circuit is not suitable for use with deskjet printers that can only be switched on and off by a front panel button.

(020203-1)

Overvoltage Protection

015

G. Kleine

When a sensitive circuit must under no circumstances have too high a supply voltage applied, then some means of disconnecting the supply must be provided. One way to achieve this is to trigger a thyristor to blow a fuse. A less destructive alternative possibility is to use a MOSFET to disconnect the supply.

An overvoltage protection IC, the LTC1696 from Linear Technology (www.linear-tech.com), has recently become available, which is suitable for triggering and driving such a device. It operates from a power supply in the range 2.7 V to 27 V and can be connected to the unregulated input of a voltage regulator. Two voltages can be monitored using feedback pins FB1 and FB2, suitably divided down using potential dividers. The trigger threshold for both FB1 and FB2 is +0.88 V. The value of the upper resistor in the potential divider can be calculated using the following formula:

$$R1 = 33\,k\Omega \times [(V_{LIMIT} - 0.88\,V)/0.88\,V]$$

The value of the capacitor connected to the TIMER/RESET pin sets the delay before the protection is triggered. The charging current for this capacitor depends non-linearly on the amount by which the voltage exceeds the threshold value. The greater

024118 - 11

the overvoltage, the faster the IC triggers. Once triggered the IC remains in that state until either the input voltage is removed or the internal latch is cleared using the MOSFET connected to the TIMER/RESET input.

(024118-1)

Tube Box Upgrade

016

M. Graeber

The Tube Box published in the June 2002 issue of *Elektor Electronics* opens up many new expressive sonic possibilities for the electric guitarist. The Tube Box can replace Hall, Echo, Pitch Shift, Phaser and the like: it offers so many possibilities that you may not need any other effects units.

The author has adapted and extended the Tube Box circuit, building it into the existing electronics compartment of a guitar. What was missing was the ability automatically to switch the unit on when the jack is plugged in. The usual method used in effects units is to connect one battery terminal to the middle pin of a stereo jack socket and so connect that terminal to ground when the jack is inserted, thus switching on the power to the circuit. This method cannot be used here, however, because ground in the Tube Box circuit is not connected directly to the battery. The small additional circuit shown here solves that problem by switching the supply voltage as the jack is inserted using a transistor, connected as a switch. The battery, a 9 V PP3 type, is fitted inside the guitar and powers the circuit. The negative terminal is connected to K3 while the positive terminal is taken to transistor T1 via an optional bypass switch. If no cable is plugged in the transistor is turned off. Only a tiny current (in the region of a few microamps) flows.

If a cable is now plugged in, a small current flows through R1, R2 and the internal resistance of the Tube Box circuitry, turning on T1. T1 goes into saturation. C1 prevents interference from mechanical contact noise on the jack socket as well as when the circuit switches on and off.

The bypass switch can be connected in a different way from the original circuit, namely directly between the pickup and the jack socket. This is a particularly good idea for stage use, since it means that in case of 'emergency' (severe interference or a flat battery) one can still play without the Tube Box circuit. In the 'bypass' position the battery is disconnected and the signal from the pickup appears directly on the output socket. With the switch in the 'on' position, the output signal comes from K2 of the Tube Box circuit. The input to the Tube Box circuit is in any case connected directly to the pickup.

In the author's case the 'original' signal that appeared on the output jack of the instrument before it was modified was used. The tone control capacitors (in parallel with the pickups via a potentiometer) are removed. Instead, the three new potentiometers are fitted to the guitar. The following controls:

– the potentiometers for each of the two pickups (to control the mixing of the signals)
– the switch to select between the two pickups, or to switch them in parallel

020369 - 11

remain connected as before, whereas the following are new:

– bypass/on switch
– Tube Box tone switch
– Tube Box 'Mid Cut/Boost' switch (existing 'tone' switch can be used)
– Tube Box drive control potentiometer
– Tube Box volume control potentiometer
– Tube Box tone control potentiometer

A file containing photographs of the modifications made to the author's guitar can be downloaded from www.elektor-electronics.co.uk/dl/dl.htm, reference number **020369-11**, under month of publication of this article. Great care was taken in construction to ensure adequate shielding. Self-adhesive copper foil (available, for example, from Conrad Electronics) was used and the enclosure for the electronics was completely screened, the individual pieces of copper foil being soldered together. This is very important, as the Tube Box has a high gain and is very sensitive to external interference. Conductive spray can also be used around the switches, potentiometers and pickups: the effort is definitely worthwhile.

D1 and R4 are provided to connect the battery to the outside world. The battery can be charged via connector X1 and D1. R4 allows the battery voltage to be measured without having to dismantle the instrument. D1 and R4 prevent a short on X1 from damaging the battery. An old mains adaptor can be used as a charger: a 150 mAh battery can be charged at around 20 mA.

US-Style Siren

L. Libertin

The circuit described here can create three different 'US-style' siren sounds: police, ambulance and fire engine. The desired sound can be selected using switch S1.

The circuit can be used in toys (such as model vehicles), as part of an alarm system, and in many other applications. For use in a toy, a BC337 is an adequate device for driver T5, since it is capable of directly driving a 200 mW (8 Ω) loudspeaker. In this case the current consumption from a 9 V power supply is around 140 mA. If a louder sound is required, a BD136 is recommended: this can drive a 5 W (8 Ω) loudspeaker. The current consumption from a 12 V supply will then be about 180 mA.

If still more volume is desired, then T5 (a BD136) can be used as a first driver stage, and a 15 W (8 Ω) loudspeaker can be connected via output transistor T6. Here an AD162 or an MJ2955 can be used, which, for continuous operation, must be provided with cooling. The peak current
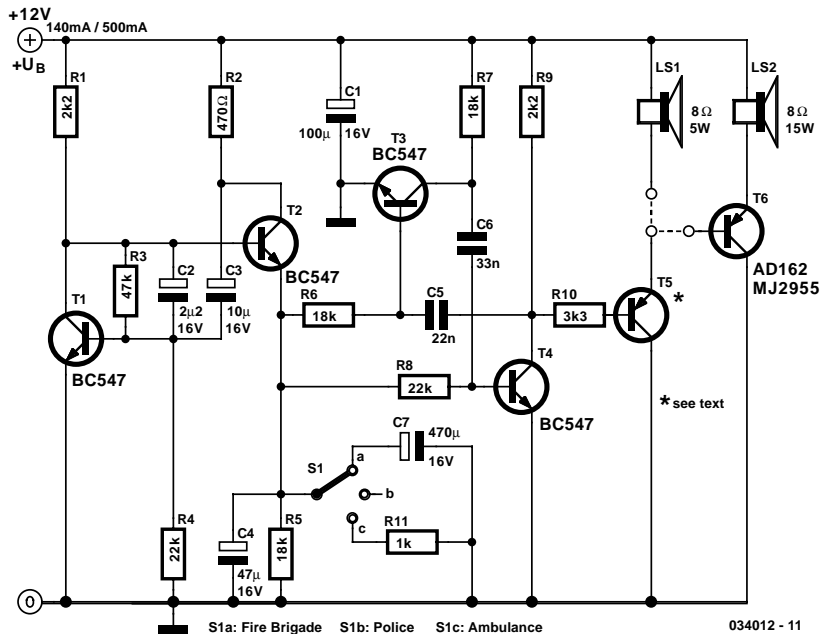
consumption of the circuit will now be about 500 mA with a 12 V power supply. Capacitor C1 is not required for battery operation.

(034012-1)

Isolated Fuse Fail Indicator 018

G. Kleine

This circuit uses standard components and shows a method of indicating the fuse status of mains powered equipment while providing electrical isolation from the mains supply.
A standard miniature low power mains transformer (e.g. with an output of around 6 V at 1.5 VA) is used as a 'sense' transformer with its primary winding (230 V) connected across the equipment's input fuse so that when the fuse blows, mains voltage is applied to the transformer and a 6 V ac output voltage appears at the secondary winding. The 1N4148 diode rectifies this voltage and the LED lights to indicate that the fuse has failed. The rectified voltage is now connected to an RC low-pass filter formed by the 10 kΩ resistor and 100 nF capacitor. The resulting positive signal can now be used as an input to an A/D converter or as a digital input to a microcontroller (make sure that the signal level is within the microcontroller input voltage level specification). The 1 MΩ resistor is used to discharge the capacitor if the input impedance of the connected equipment is very high.
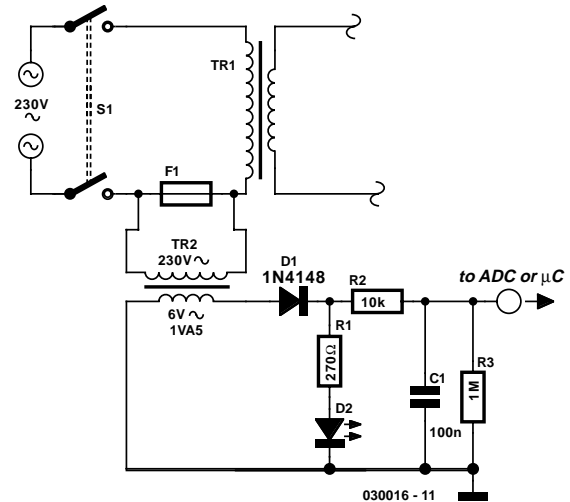
As long as the fuse remains intact it will short out the primary winding of the 'sense' transformer so that its secondary output is zero.

(030016-1)

Lambda Probe Readout for Carburettor Tuning

019

P. Goossens

A lambda probe (or oxygen sensor) can be found on the exhaust system of most cars running on unleaded fuel. Having reached its normal operating temperature (of about 600 degrees Celcius!) the lambda probe supplies an output voltage proportional to the amount of residual oxygen measured in the exhaust gas. This information is indicative of, among others, the air/fuel ratio supplied by the carburettor(s) and hence the combustion efficiency. In modern car (and motorcycle) engines, this information is used to (electronically) adjust engine parameters like ignition timing and fuel injection.

The indicator described here is intended for permanent installation on a motorcycle of which the air/fuel ratio needed to be watched, with the obvious aim engine power tuning after fitting a different set of carburettors. Apart from this obvious technical use the unit's bright LEDs will no doubt attract the attention of curious motorcyclists.

At the local junkyard a single-wire lambda probe may be salvaged from a wrecked car. Once a suitable nut has been found, the probe can screwed into the exhaust pipe of the motorcycle, at about 30 cm from the cylinders. Since we're talking of welding and drilling in an expensive (chrome-plated) exhaust pipe, you may find that actually fitting the probe is best left to specialists!

The starting point for the design of a suitable electronic indi-

034052 - 11
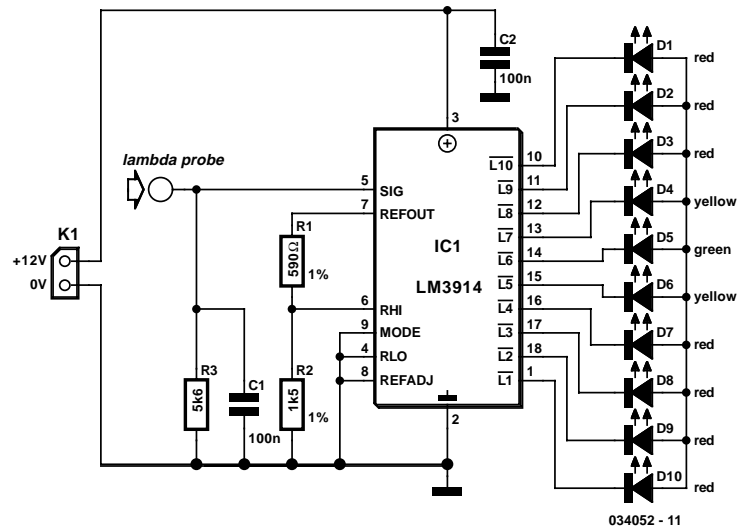
cator is that in the noble art of carburettor tuning an air/fuel ratio of 14.7 to 1 is generally considered 'perfect', the range covering 16.2 to 1 ('lean') to 11.7 to 1 ('rich'). The perfect ratio typically corresponds to a probe output voltage of 0.45 V. Referring to the circuit diagram, that is the input level at which 5 of the 10 LEDs will light, including the green one, D5. If one of the red LEDs lights, the mixture is definitely too rich. Note that in general it is better to have a mixture that is a little to rich than one that's on the lean side, hence a yellow LED lights between the green LED and the first red one. Also note that the engine needs to be at its normal operating temperature before a meaningful indication is obtained.

(034052-1)

Isolated 1-Hz Clock

020

M. Myo

One of the author's physics projects required an accurate 1-Hz (seconds) clock signal. Unfortunately, precision 10-MHz quartz crystals are expensive, while another problem was found in the inability of most common or garden 40xx CMOS logic chips to work at such a high frequency. However, a typical CMOS counter like the 4017 has such a high input resistance that its clock input has 'radio' properties. The effect is exploited here to convert the stray magnetic field picked up from a mains transformer into a clock signal. Here, the signal is induced in a short piece of wire (approx. 5 cm) connected to the clock input of a CD4017 decade counter for division by 10. The resulting 5-Hz signal is then divided by 5 by a second 4017 (IC2) to give an output of 1 Hz. LED D1 flashes to indicate the presence of a sufficiently strong magnetic field. The pickup wire should be placed close to the mains transformer, without compromising electrical safety. Always use the greatest distance at which a clock signal is reliably generated.

030105 - 11
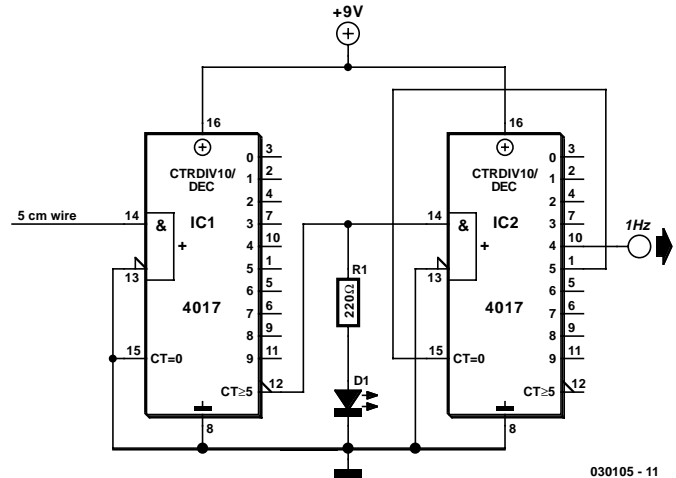
For 1-Hz output from 60-Hz power systems, use output 6 of IC2 (pin 5).

(030105-1)

12-V Glow Plug Converter 021

P. Goossens

Most small internal-combustion engines commonly used in the model-building world use glow plugs for starting. Unfortunately, glow plugs have an operating voltage of 1.5 V, while fuel pumps, starter motors, chargers and the like generally run on 12 V. This means that a separate battery is always needed to power the glow plug. The standard solution is to use an additional 2-V lead storage battery, with a power diode in series to reduce the voltage by approximately 0.5 V. However, this has the annoying consequence that more than 30 percent of the energy is dissipated in the diode. Naturally, this is far from being efficient.

The converter presented here allows glow plugs to be powered from the 12-V storage battery that is usually used for fuelling, charging, starting and so on. A car battery can also be used as a power source. Furthermore, this circuit is considerably more efficient than the approach of using a 2-V battery with a series power diode.

The heart of the DC/DC converter is IC1, a MAX 1627. The converter works according to the well-known step-down principle, using a coil and an electrolytic capacitor. Here the switching stage is not integrated into the IC, so we are free to select a FET according to the desired current level. In this case, we have selected a 2SJ349 (T1), but any other type of logic-level FET with a low value of R_{DSon} would also be satisfactory. Of course, the FET must be able to handle the required high currents.

Diode D1 is a fast Schottky diode, which must be rated to handle the charging currents for C2 and C3. This diode must also be a fairly hefty type. The internal resistances of coil L1 and capacitors C2 and C3 must be as low as possible. This ensures efficient conversion and prevents the components from becoming too warm.
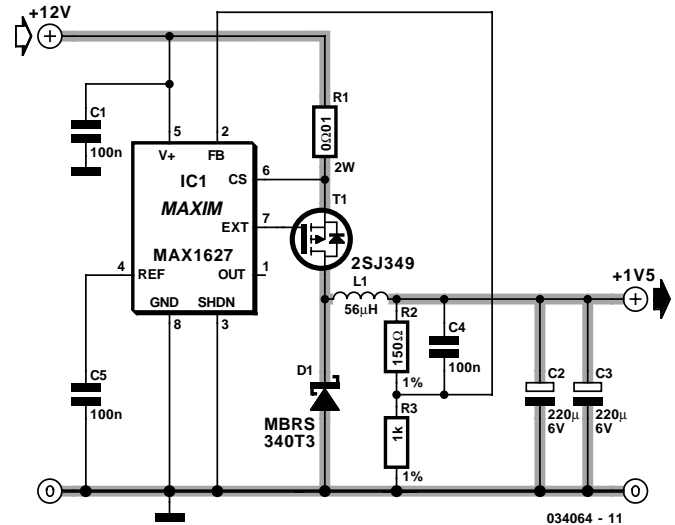
ing too warm.

The resistor network R2/R3 causes 87 percent of the output voltage to be applied to the FB pin of IC1. This means that an output voltage of 1.5 V will cause a voltage of approximately 1.3 V to be present at the FB pin. The IC always tries to drive the switching stage such that it 'sees' a voltage of 1.3 V on the FB input. If desired, a different output voltage can be provided by modifying the values of R2 and R3.

When assembling the circuit, ensure that C5 and C1 are placed as close as possible to IC1, and use sufficiently heavy wiring between the 12-V input and the 1-5-V output, since large currents flow in this part of the circuit. A glow plug can easily draw around 5 A, and the charging current flowing through the coil and into C2 and C3 is a lot higher than this!

(034064-1)

Light Gate with Counter

022
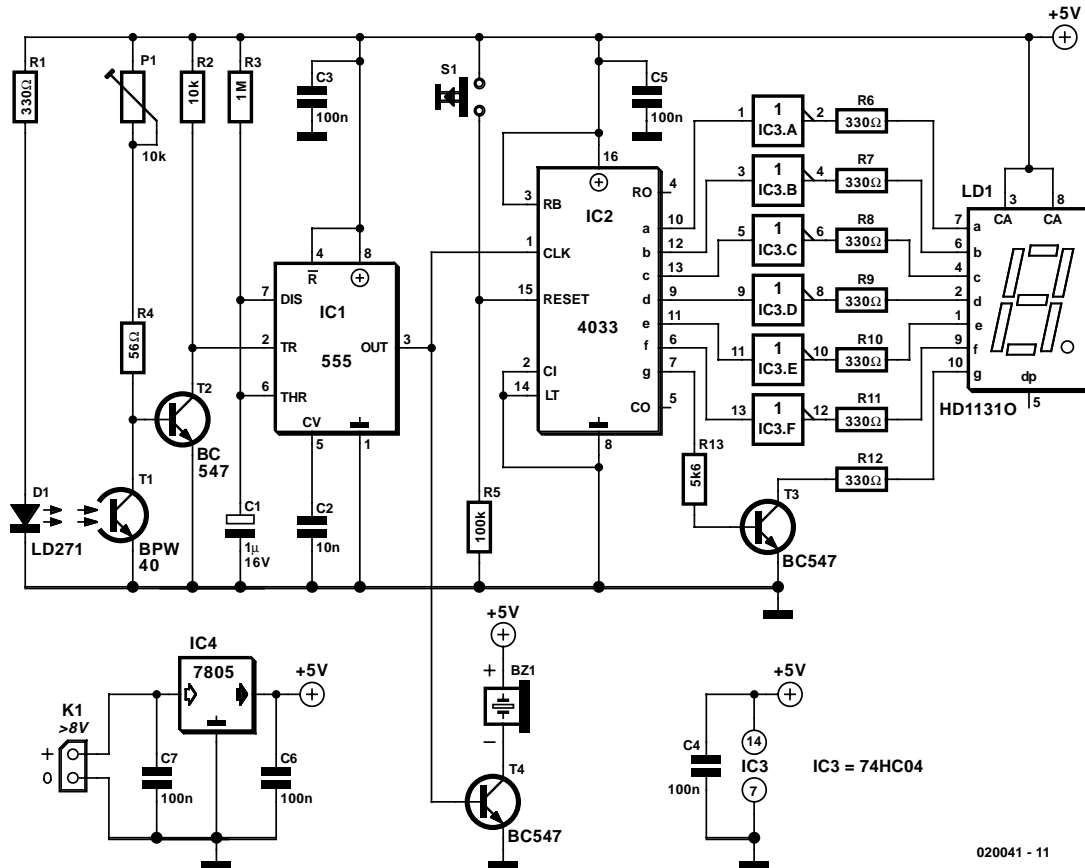
020041 - 11

T. Hareendran

The circuit described here counts the number of times that an infrared beam is interrupted. It could be used to count the number of people entering a room, for instance, or how often a ball or another object passes through an opening (handy for playing shuffleboard).

The heart of the circuit consists of —you guessed it — a light gate! Diode D1 is an IR diode that normally illuminates IR transistor T1. The light falling on T1 causes it to conduct to a certain extent. The resulting voltage on the collector of T1 should be just low enough to prevent the following transistor (T2) from conducting. This voltage can be adjusted within certain limits using P1.

As soon as an object comes between D1 and T1, the light shining on T1 will be partially or fully blocked, causing the IR transistor to conduct less current. As a result, the voltage on its collector will increase, producing a brief rise in the voltage on the base of T2. This will cause T2 to conduct and generate a negative edge at IC1. This negative edge will trigger the monostable multivibrator, which will then hold the output signal on pin 3

'high' for a certain length of time (in this case, one second).

At this point, two things will occur. First, a buzzer will be energised by the output of IC1 and produce a tone for approximately one second. When the buzzer stops, a negative edge will be applied to the clock input of IC2, causing the counter in IC2 to be incremented by 1. IC2 is conveniently equipped with an internal binary-to-BCD decoder, so its outputs only have to be buffered by IC3 and T3 to allow the state of the counter to be shown on the 7-segment display. Switch S1 can be used to reset the counter to zero.

If a one-second interval does not suit your wishes, you can modify the values of R3 or C1 to adjust the time. Increasing the value of R3 lengthens the interval, and decreasing it naturally shortens the interval. The same is true of C1.

When building the circuit, make sure that T1 is well illuminated by the light from D1, while at the same time ensuring that T1 'sees' as little ambient light as possible. This can best be done by fitting T1 in a small tube that is precisely aimed toward D1. The longer the tube, the less ambient light will reach T1. The sensitivity of the circuit can be adjusted using P1.

(020041-1)

78xx Voltage Regulators

023

K. Walraven

The voltage regulators from the 78xx-series are found in many analogue power supplies. It seems, then, somewhat superfluous to say much more about them. But on the other hand, it can be very useful to highlight the important points, just because they are so ubiquitous.

The 78xx is almost always used 'bare', because additional components are almost unnecessary. In fact, only one additional component is required, and that is capacitor C2. Based on the manufacturer's recommendation, this capacitor should be 220 nF in order to prevent oscillatory behaviour. In practice, you will almost always see that a 100 nF capacitor used here. This is a value that does not cause problems.

C1 is the smoothing (reservoir) capacitor, its purpose is to reduce the ripple of the rectified AC voltage and is not actually related to voltage regulation. If the DC voltage is provided by a mains adapter, then this electrolytic capacitor is usually already part of the adapter, although the value is rather small sometimes.

C2 may only be omitted if C1 is close to the 78xx and C1 is of good quality (low ESR). But there is nothing wrong by playing it safe and always fitting C2.

Rule of thumb: always place a 100 nF capacitor on the input as close to the regulator as is practicable.

Strictly speaking, there is no need for a capacitor on the output. However, a capacitor of at least 100 nF (C3) ensures much-improved regulation with fast (several microseconds) changes in load current. In practice, a decoupling-capacitor is placed close to the power supply pins of many ICs. These can provide the same function, provided they are placed not too far away. An electrolytic capacitor (C4) can be added for similar reasons: to catch slow (and fast, if it is a good capacitor) variations in load current. There is actually no compelling reason to deal with slow variations, because the IC is fast enough of regulating these on its own.

Rule of thumb: always place an output capacitor of at least 100 nF preferably as close as possible to the IC with the greatest current consumption (read: greatest changes in current
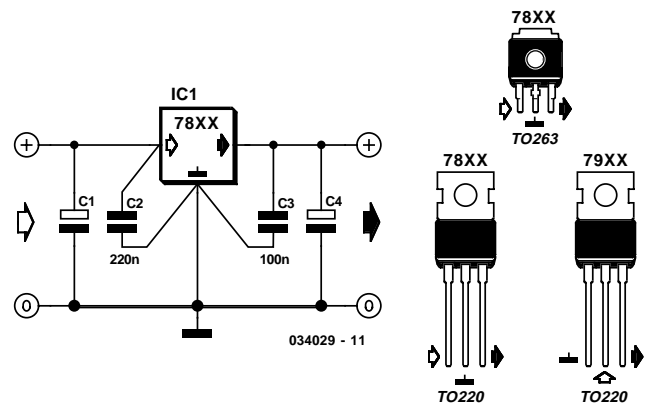
consumption).

When building the circuit, it is important to connect the capacitors via the shortest possible path. So don't use long wires or make large loops. Obtain the input voltage for the regulator directly from the connections of the smoothing capacitor, because the ripple is smallest there.

Finally, a few remarks about the temperature that a 78xx may run at. As a first approximation, if seem to burn your fingers when touching the regulator, the temperature of the regulator is above 60°C and a (small) heatsink is definitely recommended. It is not really a problem when the IC gets too hot, because it was designed in such a way that it will turn itself off when the temperature is too high. It doesn't actually turn off, but the output current reduces when the temperature increases. When the internal temperature has reached 150°C, the output current will be only a little more than half the current delivered at 25°C. That is why it is possible that the output voltage of the regulator has dropped even though the output current is less than the rated current for the IC. A heatsink is the obvious solution.

Rule of thumb: you should be able to touch the regulator (or the heatsink) without burning yourself. If not, then the heatsink has to be larger.

(034029-1)

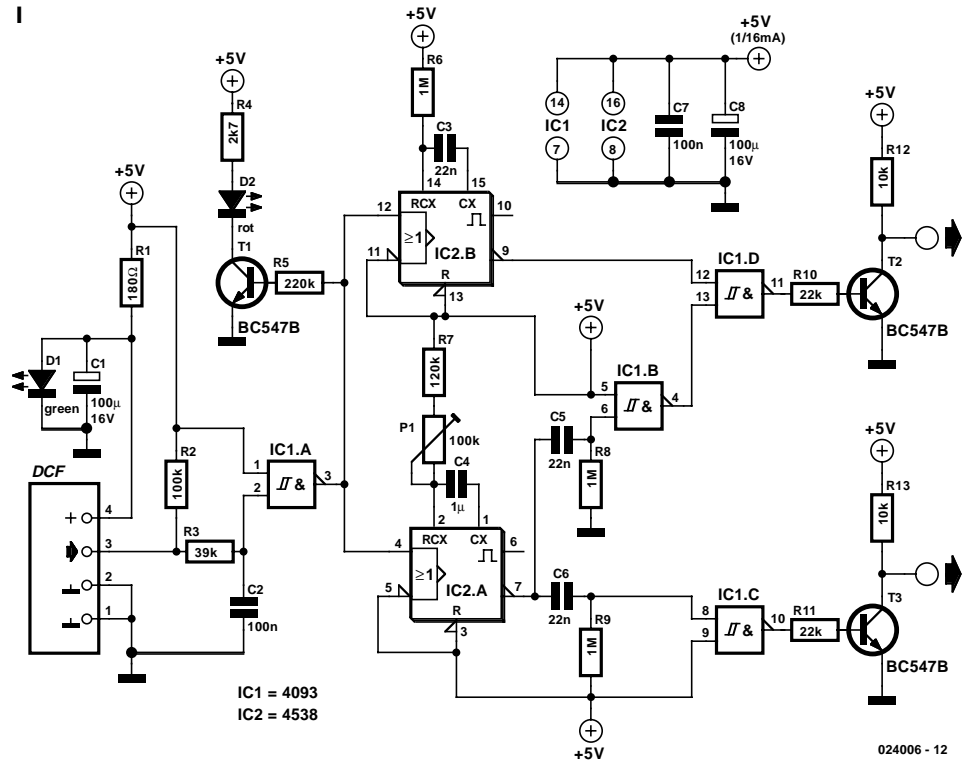# Seconds and Minutes Clocks from DCF77

024

W. M. Köhler

Nowadays, the availability of inexpensive receiver components makes it attractive to use the DCF77 signal at 77.5 kHz (transmitted from Mainflingen, Germany) for trivial applications. The circuit shown in **Figure 1** can relatively easily extract seconds and minutes clocks from the DCF77 signal. As is well known, the 59th second pulse is missing every minute in the DCF77 signal, with the missing pulse marking the minute. To obtain an uninterrupted seconds clock, we must first generate minutes pulses from these gaps and then derive the missing seconds pulses from the minutes clock.

The circuit input is suitable for use with DCF77 receivers providing negative output pulses. The pin assignment of the receiver corresponds to the Conrad Electronics HK 009 module; other modules may use different arrangements. After passing through a low-pass network that attenuates any residual high-frequency components, the signal arrives at gate IC1a, which is wired as an inverter and serves as an input buffer. Following this gate, the signal branches to the two monostables of IC2. IC2b is triggered by the positive edges of the 100-ms or 200-ms pulses of the DCF77 signal and generates 20-ms pulses at a one-second rate. However, the 59th pulse is still missing!

IC2a acts as a missing-pulse detector. This monostable is also triggered by the positive edges of the DCF77 signal, but it is retriggerable. The period of this monostable is approximately 1100 ms. During the string of seconds pulses, its pin-7 output remains low, but at the time of the missing 59th pulse, it jumps high for around 1100 ms. IC1b detects the leading edge of this pulse and converts it into a 20-ms pulse that is added to the seconds clock signal via logical NOR gate IC1d, in order to provide the 59th pulse. IC1c detects the trailing edge of the monostable pulse and generates a 20-ms pulse, which is applied to output inverter T2 to provide a minutes clock. If you find this all a bit difficult to follow, have a look at the timing diagram in **Figure 2** (not drawn to scale).

In practice, the monostable period is adjusted so that with 'normal' seconds pulses, the circuit just avoids adding an extra seconds pulse via the logical NOR gate.

When the circuit is operating, the low-current LED driven by T3 shows the 'ticking' of the DCF signal. The receiver is powered from the supply voltage via a series resistor. A (normal) green LED (the colour is important) limits the voltage to approximately 2.2 V. The current consumption of the circuit, excluding the DCF module, is very low at around 1 mA.

(024006-1)

1

IC1 = 4093
IC2 = 4538

024006 - 12

2

024006 - 11
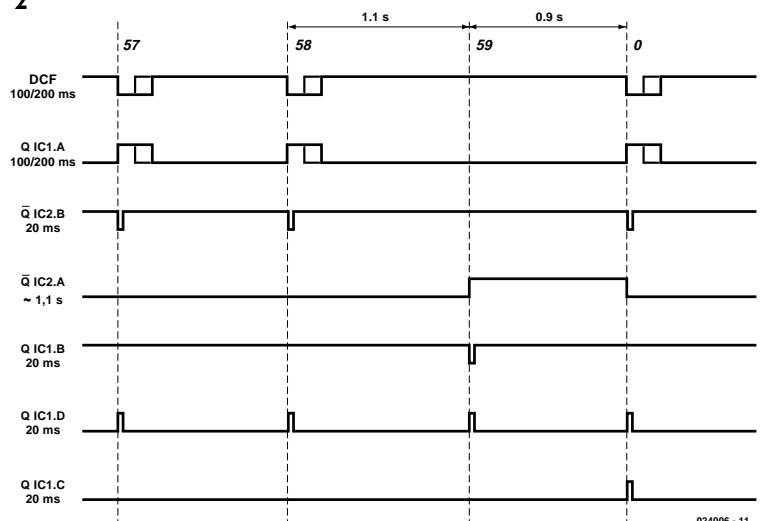
Universal Keypad

H. Kraus

Keypads are needed for a variety of applications and DIY projects. Particularly for selecting the measurement range of an instrument or setting the output voltage of a laboratory power supply, as well as for many other uses, potential-free relay outputs are desirable. In addition, break-before-make switching should be used to avoid short circuits. This cannot be guaranteed by simple relay circuits, since the pull-in speed of most relays is greater than the dropout speed!

In many cases, an expensive or hard-to-obtain special-purpose IC is used for this purpose, but most such ICs limit the number of keys that can be used, and break-before-make switching is often an unheard-of luxury! The circuit shown here, which is about as simple as possible and can be built using only a handful of parts from your 'junk box', shows that that there are other ways to solve this problem.

This design has the following advantages:
– break-before-make operation
– potential-free relay outputs
– any desired number of keys
– any desired operating voltage
– well-defined initial state (all relays disengaged)
– only one stage switches if multiple keys are pressed

Each of the relays must have a spare working contact for the changeover function. The pushbutton switches must have changeover (double-throw) contacts that can switch the coil currents of the relays. If the current rating of the pushbutton switch contacts is insufficient (particularly with high-power circuitry), a small relay can be connected in series with the switch to supply power to the load relay.

Operating power is supplied to the switching stages via a series connection of the normally-closed (nc or 'break') contacts of all of the pushbutton switches. When any one of the switches is actuated, the supply voltage to all stages is interrupted, causing all of the relays to drop out, and the base capacitor associated the actuated switch is charged. When the switch is released, power is again applied to all of the relay stages, but only the capacitor of the selected switching stage provides sufficient energy to drive the connected transistor into conduction and engage the relay. The working contact of the relay latches the relay. LEDs with series resistors connected in parallel with the relay coils indicate their switching states.

When a different key is pressed, the above process is repeated. First, the supply voltage is disconnected from all of the relays, which ensures break-before-make operation. When the key is released, the relay whose capacitor has been charged is actuated.

If several keys are pressed at the same time, only one capacitor receives a charging voltage. This is the capacitor for the only pushbutton switch in the series circuit that is still connected to the positive terminal, which means the first switch
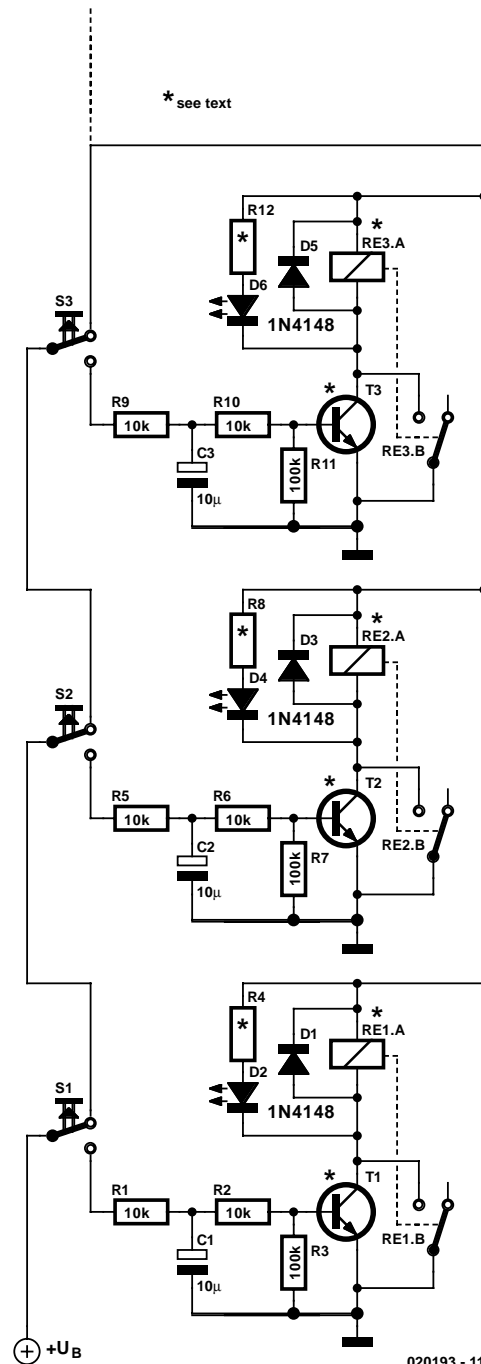
in the series. This ensures that only one stage can switch. The values of the components marked with a * must be chosen to match to the supply voltage used or the required switching current. If power relays are used, Darlington transistors with suitable power ratings should be used. The number of switching stages can be extended to almost any desired limit to allow you to fit your equipment with a convenient, reliable keypad.

(020193-1)

020193 - 11

Optical Serial Interface

026

R. Schüler

It is sometimes necessary to install microcontrollers quite far away from data processing systems, such as in temperature measurement systems, security systems and other situations. An interference-free connection between the two parts of the system is thus an absolute 'must'. This simple optical interface is excellent for this sort of application.

The system consists of two parts: a transceiver (**Figure 1**) using a MAX323, which is connected to the serial bus of a PC, and an even simpler transceiver (**Figure 2**) at the microcontroller end. Both circuits can easily be built so small that they can be fitted into the shell of a Sub-D25 or Sub-D9 connector, respectively. The link between the two optical modules is provided by two standard optical cables. The author had no difficulty bridging distances of up to 25 metres using this optical interface.

It will probably be relatively easy to power the circuit shown in Figure 2 from the microcontroller power supply. In many cases, the required 5-V voltage will already be present on pin 9 of the 9-way Sub-D connector. For the circuit in Figure 1, it may be possible to take the supply voltage from the PC with a bit of fiddling. If this proves not to be possible, a simple external supply with a 5-V regulator can be used.

Now for a few practical remarks. First, almost all types of optical transmitters and receivers can be used in place of the SFH250 and SFH350 devices shown here, including the popular TOTX173 and TORX173. A 9-way Sub-D connector can naturally also be used instead of a 25-way connector for connecting the circuit of Figure 1 to the PC, but in this case, it will not be possible to fit the circuit into the connector shell.

If you want to build the circuit so it can be connected directly to the PC, as with the author's prototype, you will have to use a female connector. Note that the wiring of the Rx and Tx leads (pins 2 and 3) is not always the same; there may be differences
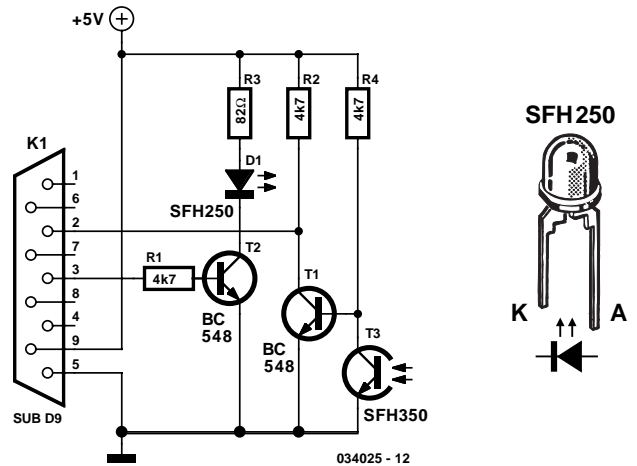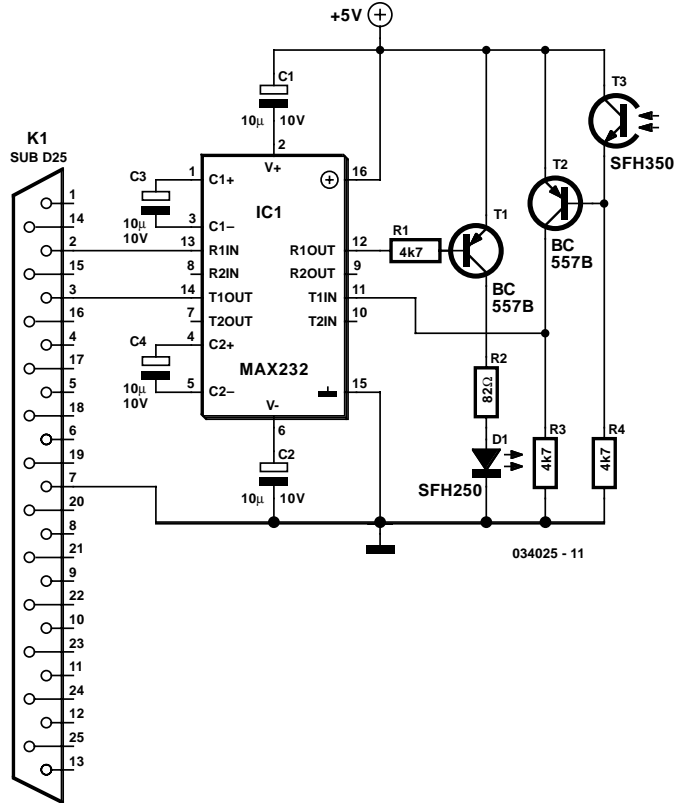
between 9-way and 25-way connectors and between male and female connectors. The only solution is to measure everything using a multimeter. The pin bearing a voltage of −10 to −12 V in the quiescent state is the Tx connection of the PC. The same problem also arises with interconnecting cables. There are extension cables with a male connector at one end and a female connector at the other end, which are connected 1:1, but there are also null-modem cables with two female connectors, which usually (!) have pins 2 and 3 cross-connected. Here again, the answer is to check everything with a meter.

(034025-1)

EEDTS Pro Budget Booster   027
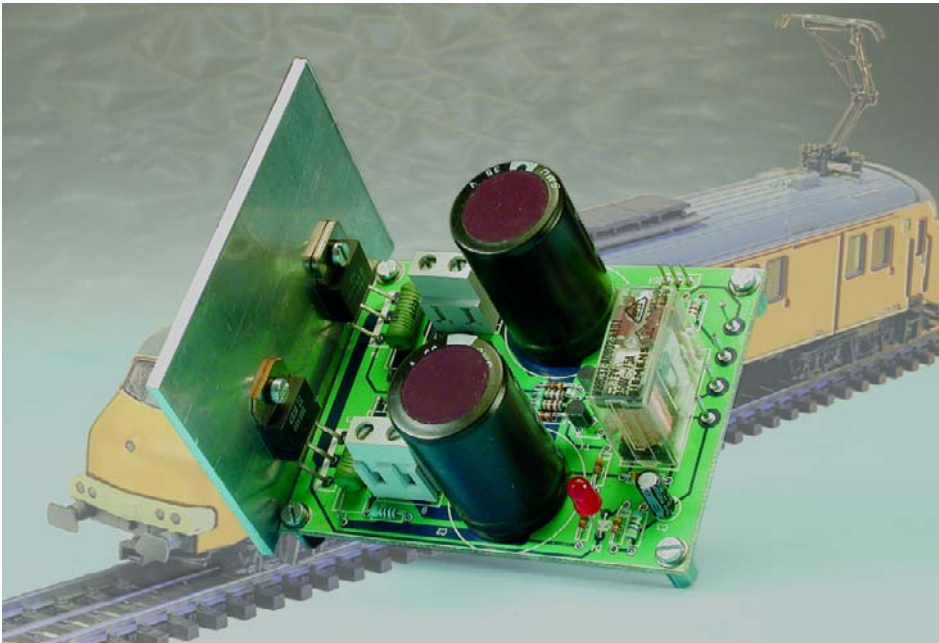
S. van de Vries

For many people, the existing EEDTS booster, which has an output current capacity of 10 A, is perhaps a bit too much of a good thing. Although the existing booster is significantly supe-

rior to the 'Budget Booster' described here in many respects, the latter booster is more suitable for making the transition from analogue to digital control for your model railway. You can even use your old reliable train transformer (AC) from the analogue era to power the new booster!

Note: although the Budget Booster can also be used with other controllers, since a symmetric signal can be connected to K1 and K2, this circuit is intended to be connected to the EEDTS Pro controller. The connectors are labelled to match the connectors on the EEDTS Pro controller board.

As can be seen from the schematic diagram, the output is driven by a complementary pair of Darlington transistors (T3 & T4). These Darlingtons are wired somewhat differently than in the 10-A booster, with the load resistors R10 and R11 being placed in the emitter leads. This has the advantage that the two collectors are connected together. Since this junction is also connected to the mounting tabs, the two Darlingtons can be fitted to a heat sink without using insulating washers.

A small aluminium plate (3×8 cm, 3 mm thick) provides a more than adequate heat sink.

The combination of R10/R11 and diodes D7–D12 provides current limiting for the booster. Current limiting will take effect at a voltage drop of approximately 0.6 V, which means at a current of approximately 2.5 A with the resistor value used here (0.22 Ω).

The Darlingtons are driven by a complementary pair of normal transistors (T1 & T2). In the absence of an input signal, both of these transistors will be cut off, and the Darlingtons will also not conduct, causing the output to be in a high-impedance state.

Besides current limiting, the booster also features a disable circuit built around relay RE1. As long as a negative voltage is present at the output of the booster, this circuit will allow the booster to be driven (the Motorola format is negative most the time, so the input signal will cause the output to be almost continuously negative). If the output is shorted, the relay drops out, disconnecting the control signal and causing the output to assume a high-impedance state. Once the short has been removed, the relay can be re-energised by briefly applying a negative input voltage (by pressing S1, the 'Go' button). After this, the input signal can again drive the booster.

Capacitor C3 provides a certain amount of delay to prevent the relay from dropping out too quickly. An LED in series with diode D5 is provided as a short-circuit indicator. This LED will be illuminated when the booster is out-

014098 - 11
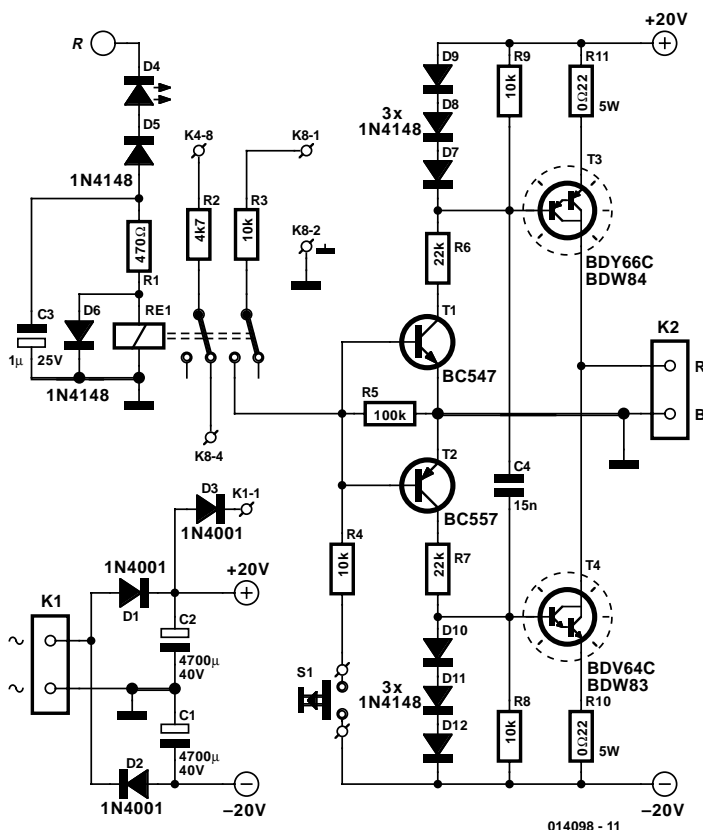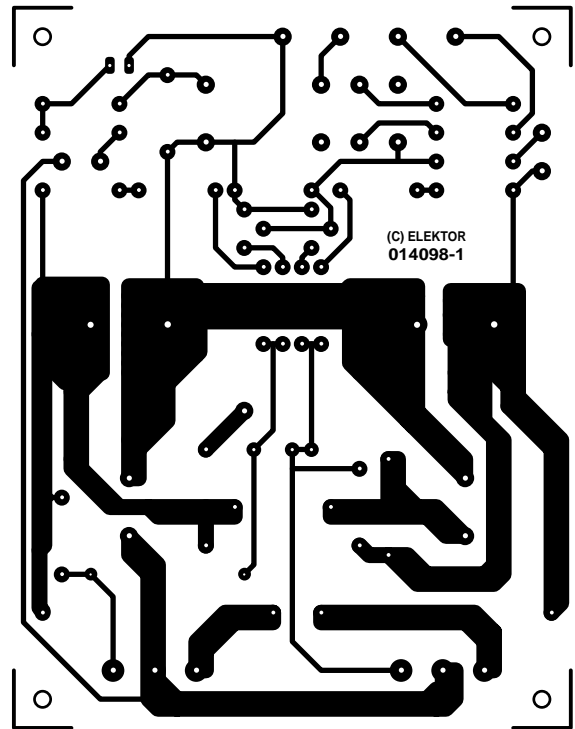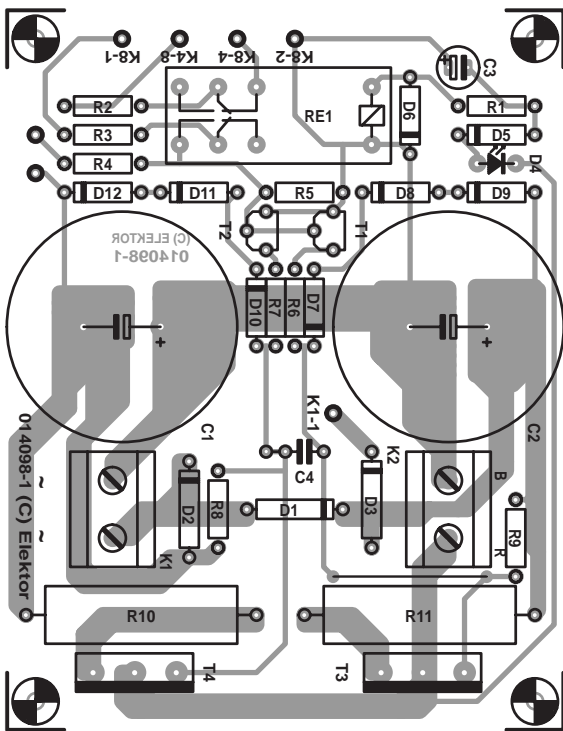
COMPONENTS LIST

Resistors:
R1 = 470Ω
R2 = 4kΩ7
R3,R4,R8,R9 = 10kΩ
R5 = 100kΩ
R6,R7 = 22kΩ
R10,R11 = 0Ω22 5W

Capacitors:
C1,C2 = 4700µF 40V radial
C3 = 1µF 25V radial
C4 = 15nF

Semicondcutors:
D1,D2,D3 = 1N4001
D4 = LED
D5-D12 = 1N4148
T1 = BC547
T2 = BC557

T3 = BDY66C
T4 = BDV64C

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead
pitch 7.5mm
S1 = on/off switch
RE1 = 12V, changeover contacts, e.g.,
Schrack V23037
PCB, order code **014098-1**

putting a signal and extinguished when there is a short.
If desired, a pushbutton switch can be wired in series with R1
to serve as an emergency stop switch. This addition can be
easily made by fitting R1 vertically on the circuit board. In
accordance with an unwritten convention, you should use a
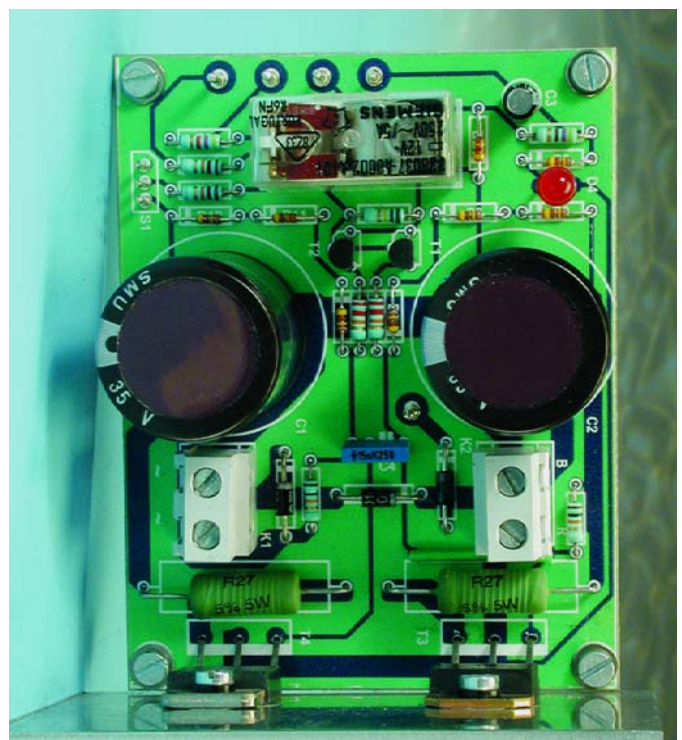green pushbutton for the Go switch and a red pushbutton for
the Stop switch.

The circuit has a remote short-circuit indicator in the form of
resistor R2 connected to relay RE1. This allows the new con-
troller to sense whether there is a signal on the track.

A 16 V / 32 VA train transformer connected to K1 provides an
excellent source of power. Symmetric DC supply voltages are
derived from the transformer secondary in a simple manner
using D1, D2, C1 and C2.

With a small modification, the EEDTS Pro controller can also
be powered from the train transformer by fitting a small heat
sink (2 × 3 cm, 2 mm thick) to the 5-V regulator IC on the con-
troller board and tapping off the supply voltage via D3.

Most of the space on the printed circuit board for the booster
is taken up by C1, C2 and RE1. Since the actual circuit consists
of only a few components, the board can be built relatively
quickly.

(014098-1)

Electronic Die

L. de Hoo

The simplicity of a traditional die makes it exceptionally difficult to create a fully equivalent electronic version, if only because an electronic version requires a power supply and a collection of electronic components that occupy a much larger volume than a normal die. This article describes an electronic die that can be built using normal components or SMDs as desired, and which comes very close to having the same format as a traditional die in the latter case.

Despite its simplicity, this electronic die incorporates several interesting features. For instance, the range of 'spots' can be increased from 1–6 to 0–9 using a jumper, and it has standby function that disables the display approximately 8 seconds after the die has been 'thrown', in order to save energy. The electronic die also uses energy efficiently by driving the display in pulsed mode. As a result of the latter two features, the current consumption of the circuit is approximately 25 mA in use and 12 mA in standby. This means that it can easily be powered by a 9-V battery. The circuit consists of the following parts: a free-running oscillator (IC1a), additional logic for driving the display (IC1c & IC1d), a timer (IC1b), a counter (IC3) and a display decoder (IC2).

The oscillator is very simple. Its frequency, which is determined by R1 and C1, is approximately 225 Hz, with a duty cycle of around 50–60 percent. The signal from the oscillator acts as a clock signal for the counter (via R2) and a blanking signal for the display decoder (via IC1d). However, the counter will not count as long as the 'throw' switch (S1) remains closed, since the clock input of IC3 is grounded by S1. The blanking input of the display decoder is driven by a pulse waveform, so the display is in principle illuminated only around 50 percent of the time, but it appears to be constantly illuminated due to the high clock frequency.

The standby mode works as follows. As long as there is a signal on the clock input of the counter (S1 pressed), the output of gate IC1b is low and the display is enabled. If S1 is released, the counter stops and a number will be shown on the display. However, the clock pulses will have charged C2 via D1, and C2 will slowly discharge via R4. After approximately 8 seconds, the output of gate IC1b will go high, causing the display to be blanked. The design of the counter is relatively simple. It is wired as an up counter by connecting the U/D pin to Vcc. The preset inputs (pins 4, 12, 13 and 3) are configured to binary '0001', and the counter normally has a counting range of 0–9 (pin 9 connected to ground). Diodes D2, D3 and D4, in combination

with resistor R5, act as a logic AND gate, so if the value of the counter is greater than 6, the preset value of 1 is latched into the counter and it starts to count again from 1 to 6. This only happens if jumper J1 is open. If it is closed, the preset pulse on PREN is suppressed and the counter range is 0–9.

The A, B, C and D inputs of the decoder IC (IC2) are driven directly by the counter. The series resistors normally used for the individual segments of the display are instead placed in the common-cathode lead (R7 & R8). This has the advantage of allowing the number of resistors to be reduced, although it has the drawback that the brightness of the display depends on the displayed number. If the segment current is sufficiently large, (light) saturation occurs and this brightness variation is no longer noticeable. The Blank input (BL) controls whether the display is enabled.

If you choose to build this circuit using SMD technology, that will not affect the schematic diagram, but it will naturally affect the choice of components. In this case, SMD components must be used for the resistors and C1, the diodes must be replaced by BAS32 types, and BT versions of ICs IC1–IC3 must be used instead of conventional types. An SMD version of C2 was not used in the prototype, since SMD electrolytic capacitors are expensive, and normally they are only sold in lots of 10, just like other passive components. It is also recommended to use a socket for the display of the SMD version of the electronic die, to allow the space under the display to also be used and the dimensions of the circuit board to be further reduced. Any desired DC power source providing a voltage of 5 to 15 V can be used as a power supply. Due to the low current consumption of the circuit, a 9-V battery will last quite a long time.

(030002-1)

TX Check for GSM/DECT Phones 029

T. Bulla

A fieldstrength meter is all you need for a quick go/non-go check on the transmitter section (TX) in a GSM phone (900 MHz or 1800 MHz), a DECT phone (1900 MHz), or a base station.

The antenna used here is a half-wave dipole designed for a wavelength of 32 cm (900 MHz band) or 16 cm (1800 MHz band). Theoretically, the dipole 'arms' have a length of 80 mm (900 MHz) or 40 mm (1800 MHz). However, because the conductors (1) have a finite thickness, (2) are not suspended in free space but etched on a printed circuit board and (3) are close to other objects, the actual length is not given by theory. Observing all of the above factors, a 'velocity factor' of about 0.85 was found by trial and error. Fortunately, a dipole is wideband in nature, and all we need is a relative indication of the transmitter fieldstrength. In practice, good results were obtained from a dipole with a track length of 150 mm (75 mm). A half-wave dipole has its feeder point in the middle, so that element lengths of 75 mm (38 mm) are used.

At resonance, a half-wave dipole is marked by minimum voltage between the feeder points and maximum current at the end of the elements. The current distribution along the dipole is exactly the opposite. In principle, all we need to do is insert a rectifier diode between the feeder points and shunt it with a sensitive micro-ammeter. Because of their low threshold voltage of about 0.2 V, germanium (and some Schottky) diodes are preferred over their silicon counterparts. Suitable diodes include the AA119 and AA117.

The dipole should have the same polarisation (usually vertical) as the phone you are checking. The RF signal is decoupled from the measured antenna current by two chokes inserted in the lines to the micro-ammeter. Both chokes consist of about 10 turns of enamelled copper wire. Their internal diameter is about 5 mm. The ammeter may be connected at some distance

76 mm   76 mm

D1

AA117

L2   L1

+ K1   − K2

L1, L2 = 10 turns 0.5mm Ø ECW, Ø 5mm

024040 - 11
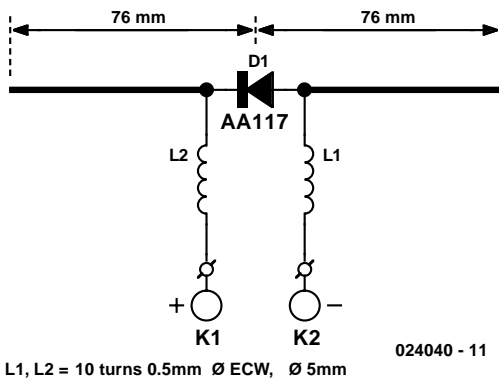
COMPONENTS LIST

Capacitors:
C1,C2 = 1nF ceramic

Semiconductors:
D1 = AA117, AA119

Inductors:
L1,L2 = choke, 10 turns, 0.5mm ECW, internal diameter 5mm
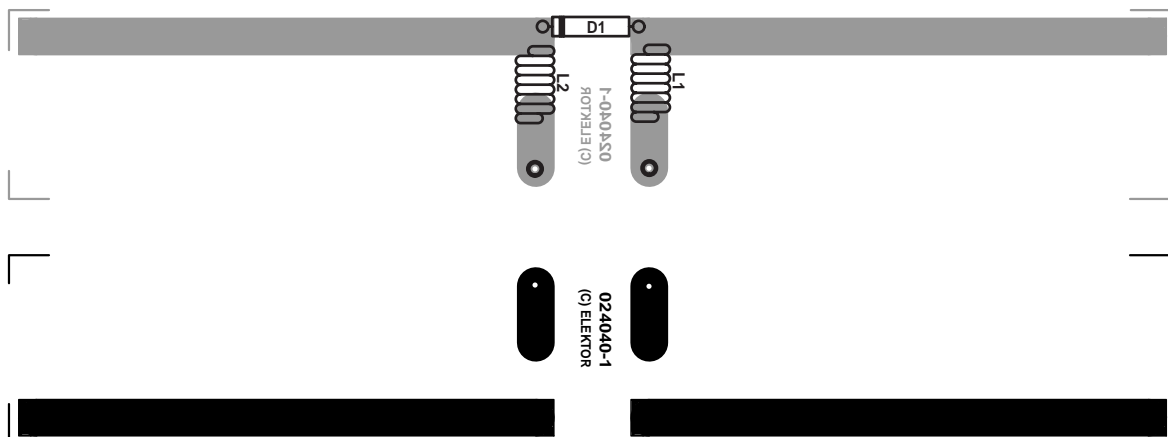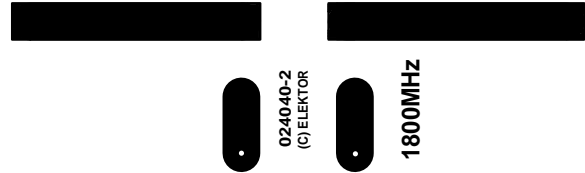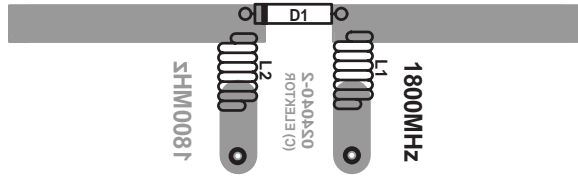
from the antenna and connected to the chokes by a (long) length of twisted wire. To prevent erroneous readings owing to the connecting cable picking up RF signals, 1-nF decoupling capacitors are connected between across the wires at both ends of the cable. In principle, the fieldstrength meter should also be capable of locating active DECT handsets and base stations operating at frequencies between 1880 and 1930 MHz.

(024040-1)

Flight Simulator Display

P. Goossens

Elsewhere in the Small Circuits Collection there is an article about connecting an LCD to a PC (see 'LCD Status Display'). There is also an article about creating your own options for the Microsoft Flight Simulator (see 'Flight Simulator Extensions'). We couldn't resist the temptation to combine these two subjects. The result is an LC display that shows essential information while you are flying with the Microsoft Flight Simulator.

The software for this article is very simple, since most of the work has already been done for us by the programmers of FSUIPC and Smartie51. The Smartie51 LCD program can be extended using DLLs, and FSUIPC allows us to read data from the flight simulator. The only thing we had to do was to write a DLL that can read the desired data from the flight simulator and pass them to Smartie51 as necessary. We did this using the FSUIPC SDK.

Naturally, to get everything to work properly you will have to install the necessary software, as described in the previously mentioned articles. You will also have to place the DLL for this article (FSSSmart.dll) in the Smartie plugins folder. The file config.cfg belongs in the main folder of Smartie51. Once everything is properly installed, you're ready to have fun.

First, start the flight simulator. After it is fully loaded, you have

to start Smartie51. If everything is OK, the LCD will now continuously display the following information: Alt (altitude), Hdg (heading), IAS (indicated air speed) and VS (vertical speed). The necessary files, including the source code, can be downloaded from the *Elektor Electronics* website (www.elektor-electronics.co.uk) under number **034056-11**, see month of publication. The design of the software is simple, so people with a bit of experience with Delphi can easily extend the program to display other flight simulator data. If you want to do this, it's a good idea to also download the FSUIPC SDK, which can be found at the following site: www.schiratti.com/dowson.html.

(034056-1)

Delphi Floating Strings 031

P. Goossens

While writing a program in Delphi, we encountered a problem in converting a floating-point variable to a string and back to a variable. The strange thing about this problem was that it only occurred on a particular PC. Further investigation was necessary to determine why this problem only occurred on this one PC, while other PCs in the *Elektor Electronics* labs ran the program without a hitch. Ultimately, it turned out that the regional settings for this PC were different from those for the others. This also turned out to be the cause of the problem.

The problem occurs when a string is converted to a floating-point variable. The Delphi programming language always uses a full stop as the decimal separator character, but the routine FloatToStr uses the character selected by the regional settings. If a floating-point value is converted to a string (using Float-ToStr) and afterwards converted back to a floating-point value (using Val), the conversion will fail if a comma (,) is configured as the decimal separator in the Windows regional settings.

An initial solution was quickly found: during program initialisation, the value of the system variable 'Decimalseparator' is set to '.'. This variable is used by FloatToStr to determine which character to use in the position of the decimal separator character. If a full stop is always used, the Val function will not have any problem converting the string back into a floating-point variable.

Still, we were not completely satisfied with this solution, since
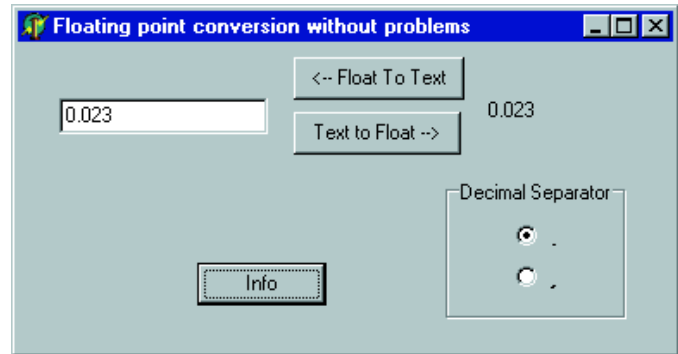
the original problem occurred again if we changed the regional settings of the system while the program was running,. Fortunately, this minor difficulty was quickly remedied by adding the following line to the project:

```
Application.UpdateFormatSettings:=false;
```

This line prevents the program from adopting any changes made to the Windows settings.

A small sample program that can convert a string to a variable and the other way around without being adversely affected by the regional settings can be downloaded from the *Elektor Electronics* website (www.elektor-electronics.co.uk), look for file number **034066-11** under month of publication.

(034066-1)

Extended Simulation Package 032

Simulation programs are often used in developing electronic circuits. They allow a variety of versions to be quickly tested and enable design errors to be detected at an early stage, even before a prototype has been built. Depending on the particular simulation package, the results can be viewed in the form of diagrams or even using virtual instruments.

However, most simulation programs have trouble simulating microcontrollers. If a microcontroller (with its associated software) is present in the circuit, most simulation packages fail. A pleasant exception to this situation is provided by the ISIS simulation package from our advertiser Labcenter Electronics. This program can simulate a variety of microcontrollers in electronic circuits. In addition to the tools commonly found in simulation packages, it thus includes debuggers for several types of microcontrollers, including the 8051/AVR/HC11 family and PIC microcontrollers. This software package also includes several components typically found in microcontroller applications, such as 7-segment displays, a keypad and (graphic) LCDs. These components can be operated using the mouse during the simulation, allowing the user interface to also be tested in the simulation package! GALs and PALs are also supported. Naturally, the program can also simulate 'normal' electronic circuits.

The supplied examples are more than worth looking at. They range from simple, standard electronic circuits, such as a transistor amplifier and oscillators, to microcontroller applications, such as a clock and even a chess computer with a touch screen! One of the noteworthy features of the simulations is their execution speed. Most of the microcontroller simulations could be run at real time on a PC with an AMD Athlon 900-MHz processor!
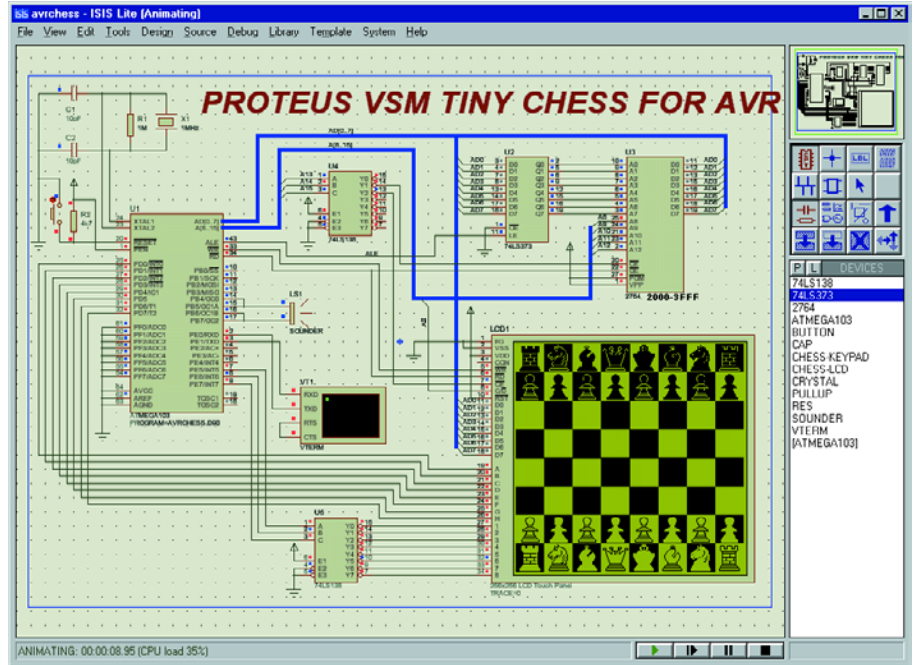
An evaluation version of the program can be downloaded from http://www.labcenter.co.uk. The restrictions of the evaluation version are that the circuits cannot be saved or printed. The 'schematic in schematic' option is also not available in the evaluation version. Otherwise, it is fully usable.

(034055-1)

Low-cost Inductance Meter   033

1

034030 - 11

2
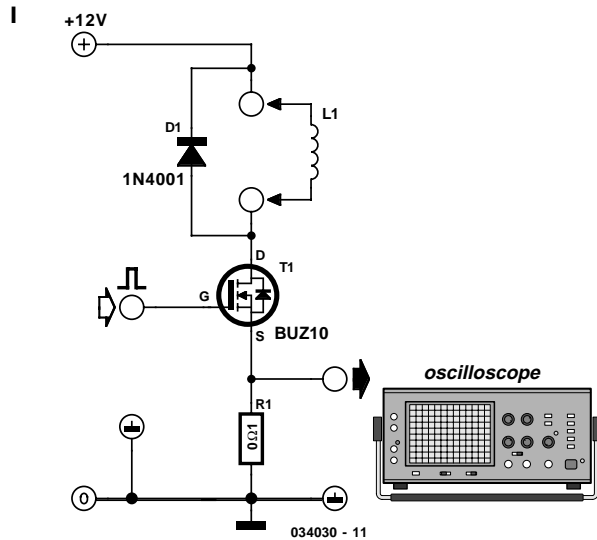
P. Goossens

This inductance meter consists, all in all, of four components that can be mounted on a small piece of prototype board in a jiffy. In order to use this meter the following are also necessary: a power supply, a pulse generator and an oscilloscope. So this is not really a complete measuring instrument, but more of a handy tool for the hobby laboratory.

Inductors

An inductor does with current what a capacitor does with voltage, namely: store and release. A constant voltage across an ideal inductor causes a linearly increasing current. Or mathematically: $dI/dt = U/L$.

This formula may look a little strange, but it is actually very simple. dI/dt indicates how quickly the current changes in one second. U is the voltage across the inductor and L is the inductance (value) of the coil. From the above equation we can deduce that the larger the value of the coil, the slower will be the rate of increase of current.

The Circuit

If we apply a constant voltage for a short period of time across the inductor, we can determine the value of the coil by measuring how quickly the current increases. In our circuit (**Figure 1**), an external pulse generator provides a pulse, which drives the gate of FET T1. This causes the FET to conduct, which in turn causes the entire power supply voltage to be applied across the inductor. We make the assumption here that there is no current flowing in the inductor the moment the FET is switched on.

The voltage across this (unknown) coil results in an increasing current through it. This current flows via the FET through resistor R1. The current will cause a voltage drop across the resistor. If you examine this voltage with an oscilloscope, you will see that it increases linearly at first. The rate at which this occurs is a measure of the value of the inductor.
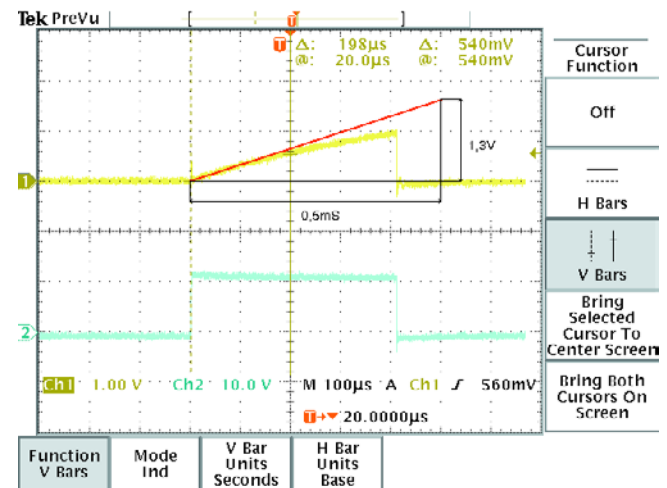
The instant the FET blocks, the inductor will continue to supply the current. That is because a negative voltage is required across the inductor for the current to fall. This is why a diode is connected in parallel with the inductor. The inductor will cause current to flow through the diode once the FET switches off. Because there is now a negative voltage across the inductor, the current in the coil will decrease. Without the diode, the coil would generate a very high voltage in an attempt to maintain constant current flow. The ignition coil in a car makes use of this property to generate a spark between the spark plug electrodes. But with electronics, sparks, smoke and fire are usually an indicator that something is wrong, hence the diode.

Calculating

If everything is correct, there will now be a nice picture on the oscilloscope. From this we should be able to calculate the value of the unknown coils, since that's what we were after in

3
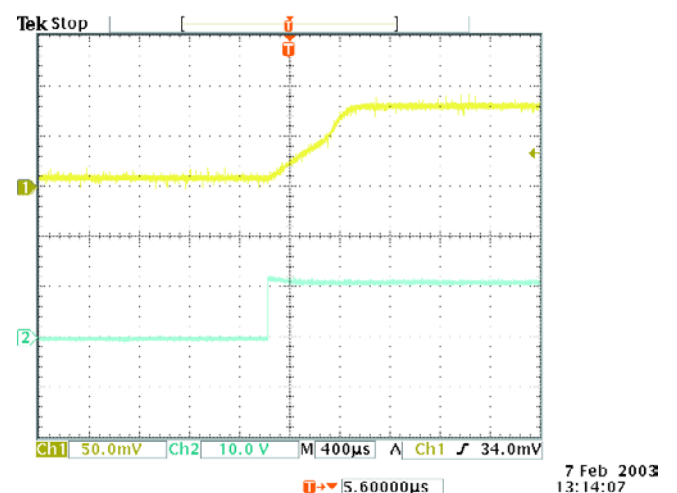
the first place! The necessary calculations are fortunately very straightforward. As mentioned before, $dI/dt = U/L$. We also remember Ohm's Law, namely $U_R = I_R R$. Since the current through the resistor is equal to the current through the coil we may replace dI_L/dt with 0.1 dU_R/dt. Also, the voltage across the coil (U_l) is known as 12 V. Substituting this in the first formula leads to: 0.1 $dU_R/dt = 12/L$. Finally, rearranging the terms gives: $L = 120/(dU_R/dt)$.

Example

An oscilloscope trace of a measurement of an unknown inductor is shown in **Figure 2**. The sloping line has been drawn in order to determine the increase of voltage per time unit. This line intersects the measurement at exactly the beginning of the measurement, since the rate of change is most accurate here. As the picture shows, the voltage initially rises at a rate of 1.3 V/0.5 ms. This corresponds with a rate of change $dU_R/dt = 2600$ V/s. The inductance is therefore: $L = 120/2600$ $\approx$ 46 mH.

In the example measurement you can see that the current does not increase linearly. This can be explained as follows: as soon as the current starts to increase, the voltage drop across T1 and R1 will also increase, reducing the effective voltage across L1. The rate of change of current is directly proportional to the voltage across the inductor. If the voltage across the inductor drops, then the rate of increase of current will also be smaller.

A second effect that can occur is when the graph curves upward. This can be clearly seen in the next measurement (refer **Figure 3**). This effect only occurs with inductors that have a core. Once the current increases to the point where the magnetic field causes the core to saturate, the core does not contribute to the magnetic field any further. From this point onwards, the inductance reduces with the consequence that the current will increase faster.

Microscope 2.5-D Lighting 034

020325 - 11
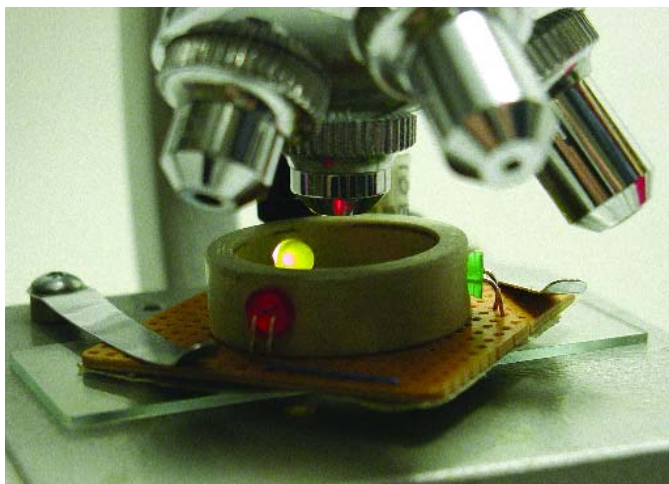
A. Bauer

Interesting, surprising as well as scientifically useful visual effects can be obtained by employing coloured LEDs instead of the normal lamp fitted in the lighting assembly in a microscope base. Of course, the lamp can be simply replaced by a white LED with appropriate changes in the supply current/voltage etc., but it is more interesting to have three colours available — here, red, green and orange (amber) which are individually adjustable for intensity.

The dashed line around LEDs D2, D3 and D4 indicates that they are fitted in a 10 mm long section of 1-inch plastic (PVC) pipe. The 5-mm holes for the LEDs are drilled at an angle so that the LED beams are pointed downwards at the centre of the holder. As ashown in the photograph, as small piece of veroboard can be fitted under the ring, with a 1-inch hole in it so
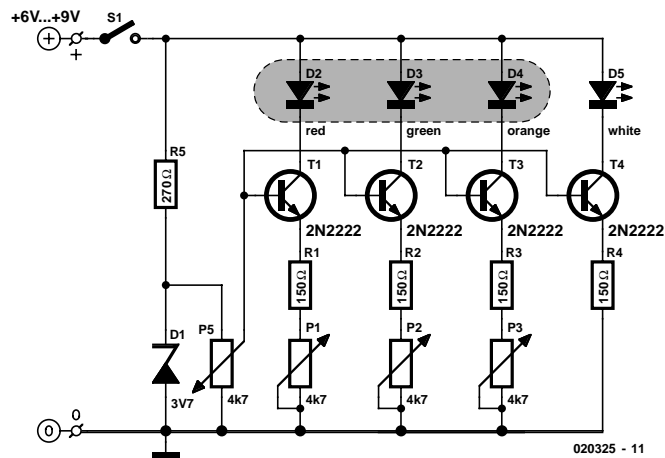
that the centre of the ring remains open, allowing the assembly to be placed on top of the glass specimen carrier. The PCB, which is held secured to the ring by the LED wires, allows wires to be run between the lighting assembly and the driver electronics fitted in the microscope base.

The white LED, D5, takes the place of the (6-V) lamp in the lamp holder, and is connected to the driver circuit by wires. The potentiometers P1, P2 and P3 allow the intensity of each colour to be individually adjusted, while P5 acts as the master intensity control. Space allowing, the pots may be fitted in the microscope base. If there are problems with reflections in the ring, paint the inside black. Finally, in most microscopes there is a need for strong lighting which pleads for high-intensity LEDs to be applied in this circuit.

(020325-1)

AT90S2313 Programmer 035
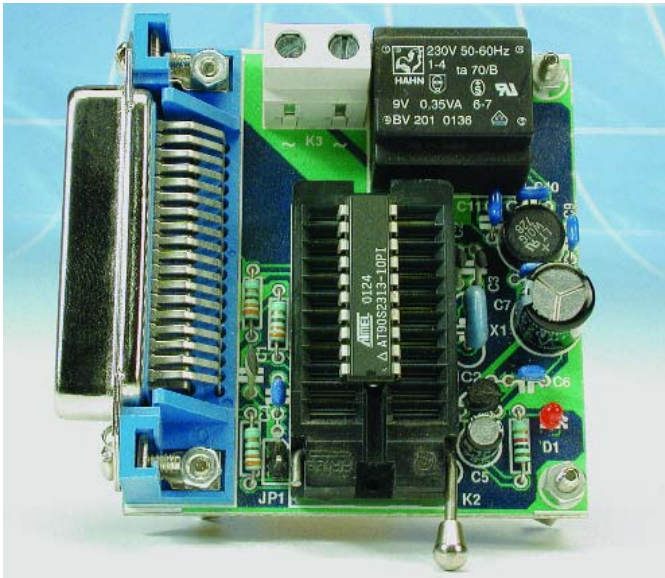
COMPONENTS LIST

Resistors:
R1,R2,R3 = 330Ω
R4 = 1kΩ

Capacitors:
C1 = 100pF
C2,C3 = 33pF
C4,C6 = 100nF ceramic
C5 = 10μF 63V radial
C7 = 220μF 25V radial
C8-C11 = 22 nF ceramic

Semiconductors:
B1 = B80C1500, round case (80V piv, 1.5A)
D1 = LED
IC1 = AT90S2313

IC2 = 78L05

Miscellaneous:
JP1 = 2-way pinheader with jumper
K1 = Centronics socket (female), PCB mount, angled pins
K2 = 24-pin ZIF-socket (e.g., Farnell # 178-235) or 20-pin IC socket with turned pins
K3 = 2-way PCB terminal block, lead pitch 7.5 mm
X1 = 4MHz quartz crystal
TR1 = mains transformer 9 V/0.35 VA (e.g., Hahn BV201 0136)
PCB, order code **034036-1**

T. Giesberts

In January 2003, we published an article about programming AVR microcontrollers using Bascom AVR. In that article and in the manual for this Basic compiler, a circuit from *Sample Electronics* is described as one of the simplest ways to program the microcontroller. This circuit provided the basis for the practical implementation described here.

For this purpose, the parallel port of the PC is directly connected to the 'Serial Interface for In-system Programming' (SPI) via resistors that protect the parallel port. The serial link to the internal Flash memory is enabled when the Reset signal (pin 1) is low. The three connections for the SPI interface are SCK, MISO (output) and MOSI (input), which are located on pins 19, 18 and 17 of the microcontroller, respectively. The 100-pF capacitor (C1) is intended to avoid potential timing problems. It can be connected between the SCK line and ground using jumper JP1. However, during our tests this proved not to be necessary.

To make building and connecting this programmer as easy as possible, a Centronics connector is located on the associated printed circuit board to allow a standard parallel printer cable to be used to connect the programmer to a PC. If you want to program multiple microcontrollers, it is highly recommended to use a zero insertion force (ZIF) socket. If you want to build a less expensive version, you can also use a normal IC socket. The design of the printed circuit board allows only one socket to be fitted.

The circuit has a small 5-V supply, consisting of a tiny 0.35-VA transformer, a bridge rectifier and a 78L05 voltage regulator (IC2). Capacitors C4, C6 and C8–C11 suppress any interference that may be present. The power indicator LED D1 also acts as a minimum load for the voltage regulator, in order to prevent the voltage
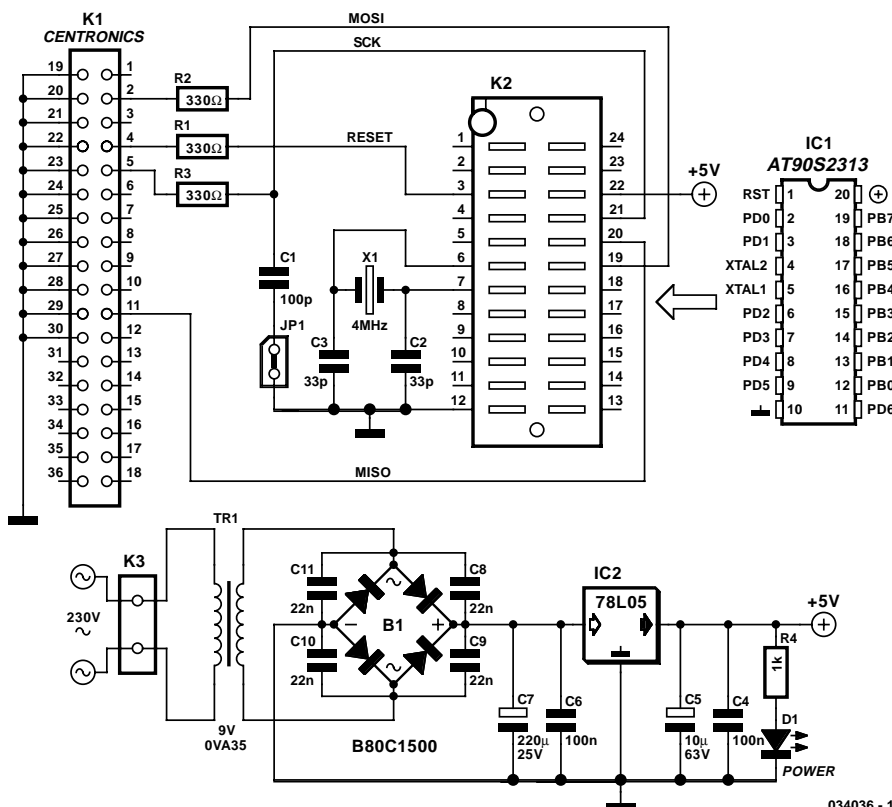
034036 - 11
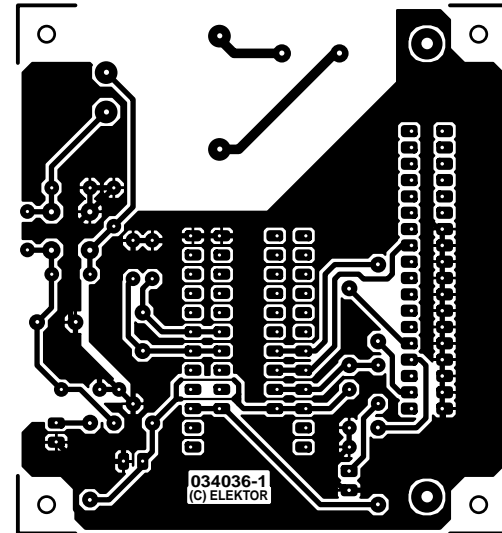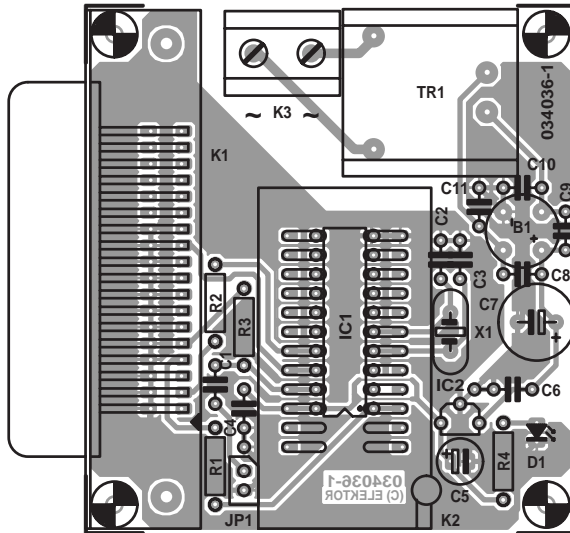
from rising excessively in the absence of a load, which is a problem with some types.

The programmer should preferably be connected while the PC is switched off. This is in any case always a good idea when connecting equipment to the parallel port of a PC, in order to avoid damage to the hardware. After the programmer is connected, switch on the PC and the programmer and start Bas-

com AVR. The program should select the *Sample Electronics* programmer by default. If this doesn't happen, look under Options/Programmer to verify that the address of the parallel port (LPT address) is properly configured.

(034036-1)

(based on an idea from *Sample Electronics*)

Resistance Calculator

036

A. Rossius

This is a project that doesn't require any soldering. It is a resistance calculator made from cardboard, which can be used to determine the value of a resistor from the coloured bands and vice versa.

Building the calculator couldn't be simpler. First scan and print this page (or cut it out), glue everything to a reasonably light piece of cardboard and then cut out the individual discs and the main body. Cut out the small windows in the body piece and then fold it along the heavy line, so that the markings are to the outside.

Secure the discs in the body using paper fasteners. The locations of the fasteners are marked on the body by dots, and the crosshatched areas must be cut out.

The first two numbers must be multiplied by the third number. The fourth ring gives the tolerance of the resistance in percent. The first two discs have coloured segments with the following colours (in the order listed): black, brown, red, orange, yellow, green, blue, violet, grey and white. Disc 3 has the following colours: black, brown, red, orange, yellow, green, blue, violet, silver and gold. The fourth disc has green, brown, red, gold, and silver. To finish everything off, fasten the edges using Sellotape, and your calculator is ready for use.
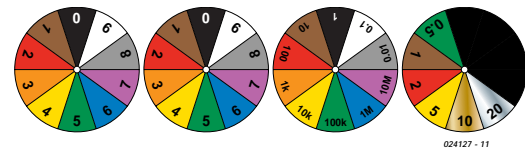
(024127-1)
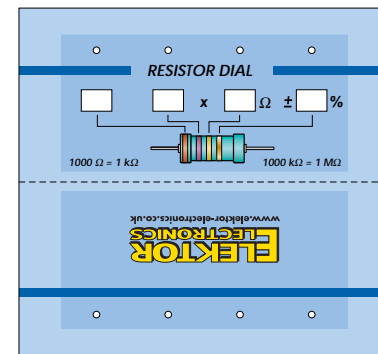
024127 - 11

024127 - 12
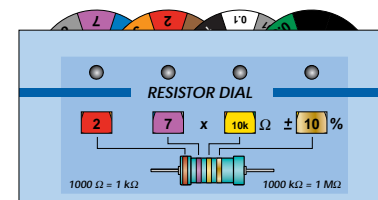
024127 - 13

LCD Status Panel

037

1

K2
PC Parallel Port

K1
LCD

+5V

1
14
2
15
3
16
4
17
5
18
6
19
7
20
8
21
9
22
10
23
11
24
12
25
13

RS
R/W
E
D0
D1
D2
D3
D4
D5
D6
D7

P1

10k

K3
3.5" Power Supply

+5V

red
black
black
yellow

C1

100n

034047 - 11

SUB D25

2

P. Goossens

PCs are currently used for just about anything. E-mail has become a standard communications tool and a network at home is no longer the exclusive domain of geeks. In many households, the stereo is connected to the PC in order to listen to MP3s, etc., etc. There is such a huge choice of software that everyone should be able to find something to their liking and be able to put it to good use. The disadvantage of much software is that it is sometimes hard to see the windows for the screen (well… trees, forest…).

Granted, it is very easy to check whether you have email, to look which track Winamp is playing or keep an eye on the current speed of your internet connection. But it often takes a little bit of hunting around to find this information and it is often obscured when another window is in focus. The end result is that displaying this information inevitably requires several mouse clicks. Not difficult really, but rather cumbersome.

Here we present a solution to this problem: an LCD screen built into the PC enclosure that displays the desired information continuously. This display can easily be mounted on a spare blanking panel of the PC. The power requirements can conveniently be fulfilled by the PC's own power supply, thanks to the low current consumption. In this case, the

plug for a 3.5"-drive has been used, of which there is usually a spare one available.

To keep things cheap, we can use the parallel port for communication between the PC and the LCD. This connector is being used less and less anyway, due to the rise of USB and network printers.

The schematic (**Figure 1**) is very simple, since the parallel port has sufficient inputs and outputs to drive an LCD directly.

Although the circuit requires very little current, it is much better of the power is not obtained from the parallel port directly. As mentioned before, we used a power connector that is normally reserved for 3.5" floppy drives (K3). That leaves potentiometer P1 and capacitor C1. P1 is used to adjust the contrast of the LCD. C1 helps provide a clean power supply without unnecessary interference. You can choose the type of LCD according to your own requirements, provided only that the display contains an HD44780 controller. The software supports the various standard dimensions (from 1×10 characters to 4×40 characters).

The entire circuit is easily built on a piece of prototype board. In our prototype we used a 14-pin header to connect the LCD module. The connection to the power supply is made with a simple 4-way pin header. Make absolutely sure you connect the power supply connector the correct way around, otherwise you run the chance that you use +12 V instead of +5 V, and the LCD is unlikely to survive that!

If the LCD module has a backlight, you may like to connect that as well. It is best to consult the datasheet for the LCD module to check how this is done. Some models require a

3

series resistor whereas other implementations have this resistor built in. To mount the LCD in a PC, an unused blanking panel is eminently suitable.

Once everything has been built, we need the software to drive the circuit. Several programs are available on the Internet, complete with all the relevant information. The nicest program we have come across so far is 'LCD Smartie 5.1'. The program can be downloaded from:
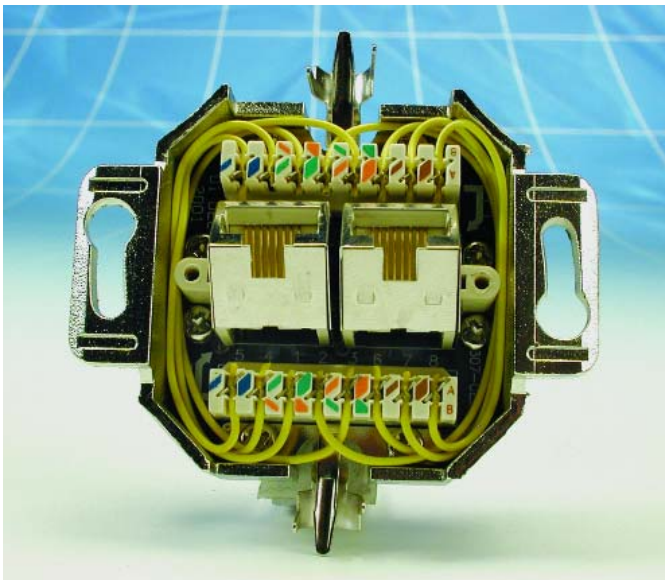
http://backupteam.gamepoint.net/smartie/

The capabilities of the program are so extensive that it is a hopeless task to detail them all. The text messages on the display are fully adjustable. The messages can include up-to-date information, such as current username, temperature of the processor, speed of the Internet connection, alerts when new emails arrive, etc. Fortunately, the program is very user friendly, so that everyone will be up-and-running quickly. **Figure 2** shows the Smartie 5.1 emulation of an LCD on the screen, while **Figure 3** shows the program's configuration screen.

(034047-1)

Cross-linking with Two Patch Cables

038

L. Lemmens

In networks, the supremacy of coax cable is a thing of the past. Nowadays, Ethernet connections are made using UTP cables. The BNC plug has yielded to the 8-way RJ45 plug. Previously, coax cables were daisy-chained from computer to computer and terminated at the two ends using 50-_ resistors, but modern networks use central 'socket boxes' (switches and/or hubs) to interconnect everything. The connections between the hubs and the computers are made using patch cables having the same sequence of leads in the RJ45 connectors at each end. For making a direct connection between two computers without using a hub or switch, a 'crossover cable' is used. Such a cable has the leads cross-linked in order to allow the two computers to directly communicate with each other.

If there are problems with the network, it can be handy to be able to directly interconnect two computers, or directly connect a computer to a cable or ADSL modem without using a hub or switch. A long crossover cable is not always available, and shoving around computers is not an attractive alternative. Consequently, we can use a dual RJ45 wall outlet box to construct an adapter, which can be used to interconnect the two patch cables coming from the equipment in question. This outlet box must be wired to create a cross-linked connection. This

is done by making the following internal connections:

$1 \rightarrow 3$
$2 \rightarrow 6$
$3 \rightarrow 1$
$4 \rightarrow 4$
$5 \rightarrow 5$
$6 \rightarrow 2$
$7 \rightarrow 7$
$8 \rightarrow 8$
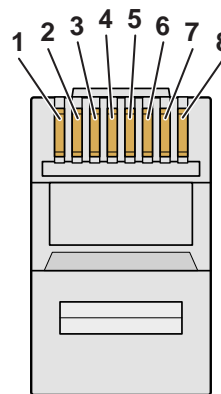
(034051-1)

034051 - 11

1: white/orange   TX+
2: orange   TX-
3: white/green   RX+
4: blue
5: white/blue
6: green   RX-
7: white/brown
8: brown
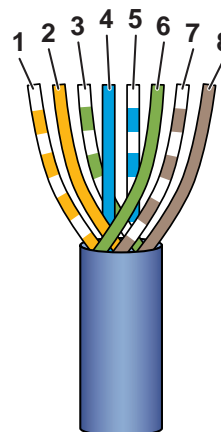
034051 - 12

Operating Life Extender for Incandescent Lamps
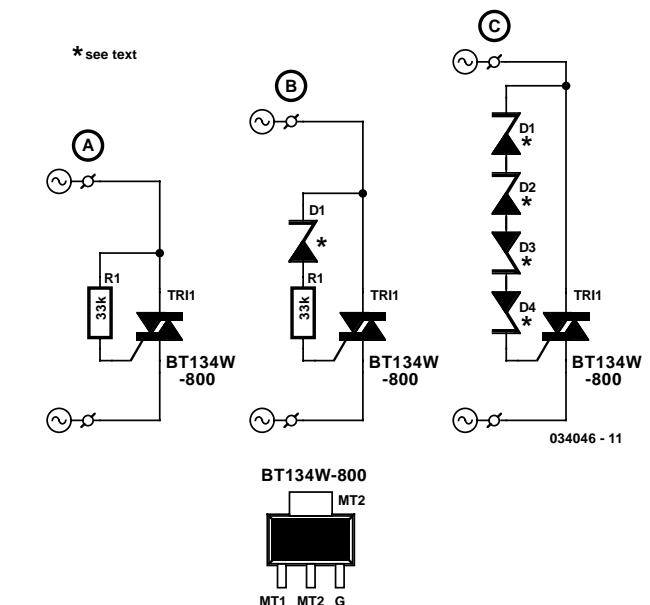
039

034046 - 11

BT134W-800
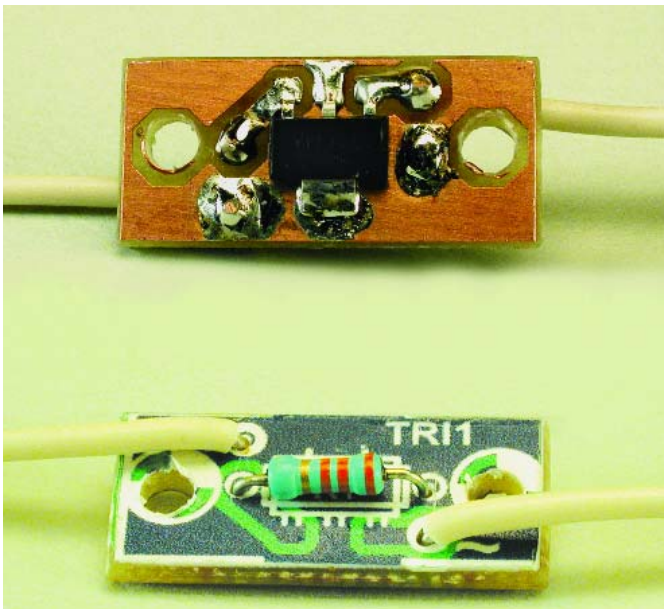
T. Giesberts

One way to extend the operating life of incandescent lamps is to reduce the voltage across the lamp by connecting something in series with it. Naturally, a series resistor is the simplest solution, but this produces unnecessary power dissipation. In order to reduce the voltage on a 100-W lamp by approximately 10 V, slightly more than 4 W must be dissipated in the resistor, and that is naturally a waste of energy. A better approach is to use a phase control circuit with a triac controller to reduce to voltage on the lamp. To reduce the voltage on the lamp by 10 V, a phase cut of approximately 44 degrees is necessary. Three ways in which this can be done are presented here.

The simplest version is a triac with a resistor in the gate circuit (**Figure A**). If the voltage on T2 is sufficiently great, the triac will start to conduct. With the indicated type of triac and a 33-kΩ resistor, the voltage is reduced by approximately 10 V. However, the drawback of this approach is that the gate sensitivity of most triacs is different in the various quadrants. For the type shown here, the gate sensitivity is typically 5 mA with T2 positively biased and a positive gate current, while with T2 negatively biased and a negative gate current, it is 11 mA! This results in a DC voltage across the lamp and a 50-Hz component that is just noticeable in the form of a slight flickering. With the tested circuit, the positive triggering threshold was approximately 30 degrees, while the negative triggering threshold was approximately 54 degrees.

A better solution is to add a Zener diode to compensate for the difference in sensitivity. Naturally, this depends on the specific type of triac used. With a positive mains voltage, the diode acts as a Zener, so a higher voltage is required to cause suffi-

cient current to flow through the gate. When the mains voltage is negative, the Zener diode acts as a normal diode, so a specific trigger threshold is reached more quickly. There are various families of Zener diodes with rated voltages up to 100 V (such as the Vishay ZPY100) or even 200 V (the Vishay BZX85C series). If it is difficult to obtain a 100-V type, it is also possible to connect two 47-V Zeners in series.

The 50-Hz and DC components can be nicely reduced using this approach. However, there is still a possibility of asymmetric triggering. An example of this circuit is shown in **Figure B**. In a prototype, the voltage was decreased by around 12 V using a 75-V Zener and a 33-kΩ resistor. With the tested circuit, the positive triggering threshold was approximately 48 degrees, while the triggering threshold for negative voltages was approximately 54 degrees.

If you want to obtain a voltage that is as symmetric as possible, you can connect two or four Zeners in reverse series. With this approach, triggering depends only on the tolerances of the Zener diodes. The circuit shown in **Figure C** illustrates what is meant. Naturally, this can only be used with an incandescent lamp. A DC component is not healthy for fluorescent lamps, and in the case of low-voltage halogen lamps, any DC current flowing through the DC resistance of the transformer could be rather large and even cause saturation of the transformer, with all of the associated nasty consequences.

Now for a few remarks about interference. Naturally, a switched-voltage circuit can generate interference signals. It may be necessary to use an interference-suppression choke, along with a snubber network to protect the triac against transients.

Building the circuit is of course dead easy. If desired, you can

design a small printed circuit board to fit in an existing lighting fixture or plug. However, the circuit can also be built in a separate (tiny) enclosure fitted 'in line' with the mains cable. Be sure to provide adequate isolation separation. Here we have used a type BT134W-800 V triac, which has an SOT223 SMD package and can handle voltages up to 800 V. In the SOT223 package, the tab is intended to be used for cooling. If it is sol-dered to the printed circuit board, the copper surface of the circuit board acts a heat sink. With this triac, the load must be limited to 100 W. Of course, you are free to experiment with other types of triacs, but remember that when the cable is plugged in, the entire circuit is connected to the mains, and the same applies to any measurement equipment you may be using!

(034046-1)

Add a Sparkle

1

020293 - 11
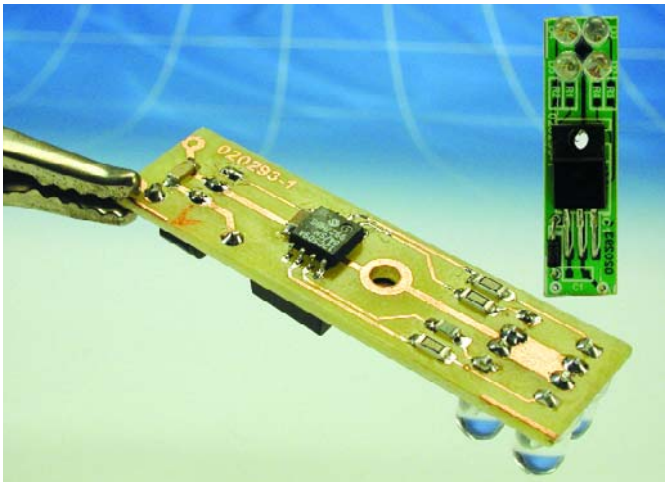
C. Wendt

This circuit was developed to provide novel coloured lighting effects for a crystal glass figurine.

The circuit shown in **Figure 1** consists of an 8-pin (SMD package) PIC microcontroller together with two blue, one red and one green LED. By using two blue LEDs and different valued series resistors it is possible to produce all the basic colours of equal brightness. The microprocessor slowly dims each LED individually in a pseudo-random pattern to produce interesting lighting effects.

Power comes from a standard mains unit supplying 9 V to 15 V while D1 protects the circuit against inadvertent reverse polar-

ity. IC1 provides a regulated 5 V for the circuit.
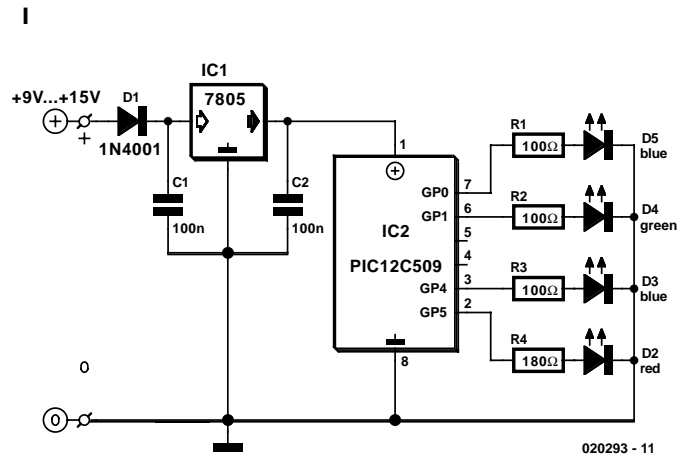
The circuit was fitted into the base of the figurine so it was necessary to keep the PCB (**Figure 2**) as small as possible and use SMD components where possible. The microcontroller is clocked internally and does not require an external crystal.

Mounting the components on the PCB should be straightforward and begins by fitting all the SMD components onto the copper side and then fitting the voltage regulator to the other side, the mounting bolt through the regulator heat sink will be at earth potential and can also be used as a convenient fixing point for the whole PCB.

The source and hex files (along with the PCB layout) can be freely downloaded from the *Elektor Electronics* website. The software can also be ordered as disk **020293-11** (see Readers Services). If your PIC programmer is not fitted with an SMD socket it may be worth ordering the pre-programmed controller (order code **020293-41**), also from our Readers Services.

(020293-1)

COMPONENTS LIST

Resistors:
(SMD size 1206)
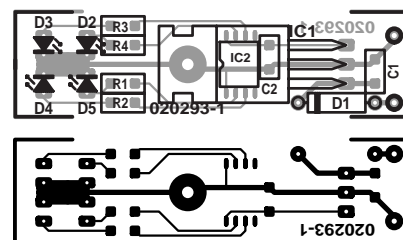R1,R2,R3 = 100Ω
R4 = 180Ω

Capacitors:
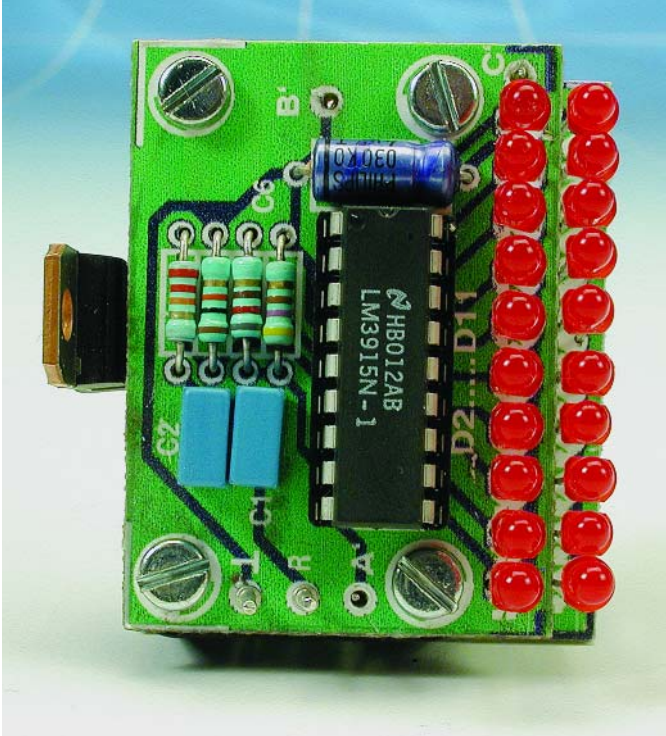C1,C2 = 100nF (SMD size 1206)

Semiconductors:
D1 = 1N4001
D2 = LED, red, (Sharp GL-5HD23)

D3,D5 = LED, blue (Kingbright L53BC)
D4 = LED, green (Sharp GL-5EG23)
(all LEDs superbright, in colourless transparent enclosure)
IC1 = 7805
IC1 = PIC12C509A-04/SM, programmed, order code **020293-41**
Disk, PIC software, order code **020293-11** or Free Download

2

# Car-Stereo LED Power (VU) Meter

041

R. Lalić

This circuit senses AC audio voltage supplied to the car-radio loudspeakers and displays it as power using a LED bar graph, achieving at the same time an attractive visual effect. It is designed to cover common car-radio output power ranges, but can easily be modified to suit different needs. It is supplied from the 12 V car electrical system and is suitable for classical CC (Capacitor-coupled) as well as BTL (Bridge Tied Load) types of amplifier with no changes to the circuitry or connections at all. In fact, only the meaning of the LEDs changes — with BTL, the LED increments equal four times the CC value on the same load.

CC-type amplifiers have the loudspeaker connected via a DC-decoupling capacitor at the output and ground (negative). BTL-type amplifiers, on the other hand, have the loudspeaker DC-coupled and 'stretched' between two equal, parallel, but phase-reversed outputs. The result compared to 'CC' is twice the voltage swing, hence quadrupling the power being fed to the same loudspeaker load.

It is necessary to know to which of the two types this circuit is connected to only in order to correctly assign power levels

(W) to the LEDs. CC-type have no DC voltage to ground at the outputs and return wires. The return wires are actually connected to the common ground (negative). BTL-type have approximately Vcc/2 at outputs and on the return wires too, explaining at the same time why no DC-decoupling capacitors are needed.

The LM3915N integrated circuit used in this circuit has been the subject of numerous publications in this magazine so will not will not be discussed again. In this application, the two LM3915Ns are configured as a LED bar graph drivers (pin 9 connected to pin 3), The ICs share the same power supply section. The audio input signal is fed via network C1/C2, R1, R2 (C3/C4, R5, R6) to pin 5 of IC1 (IC2). Only positive half-waves are processed by the ICs. Internally, the buffered input voltage is compared using comparators to the voltages along a resistor ladder network. The nominal +1.25 V reference source volt-
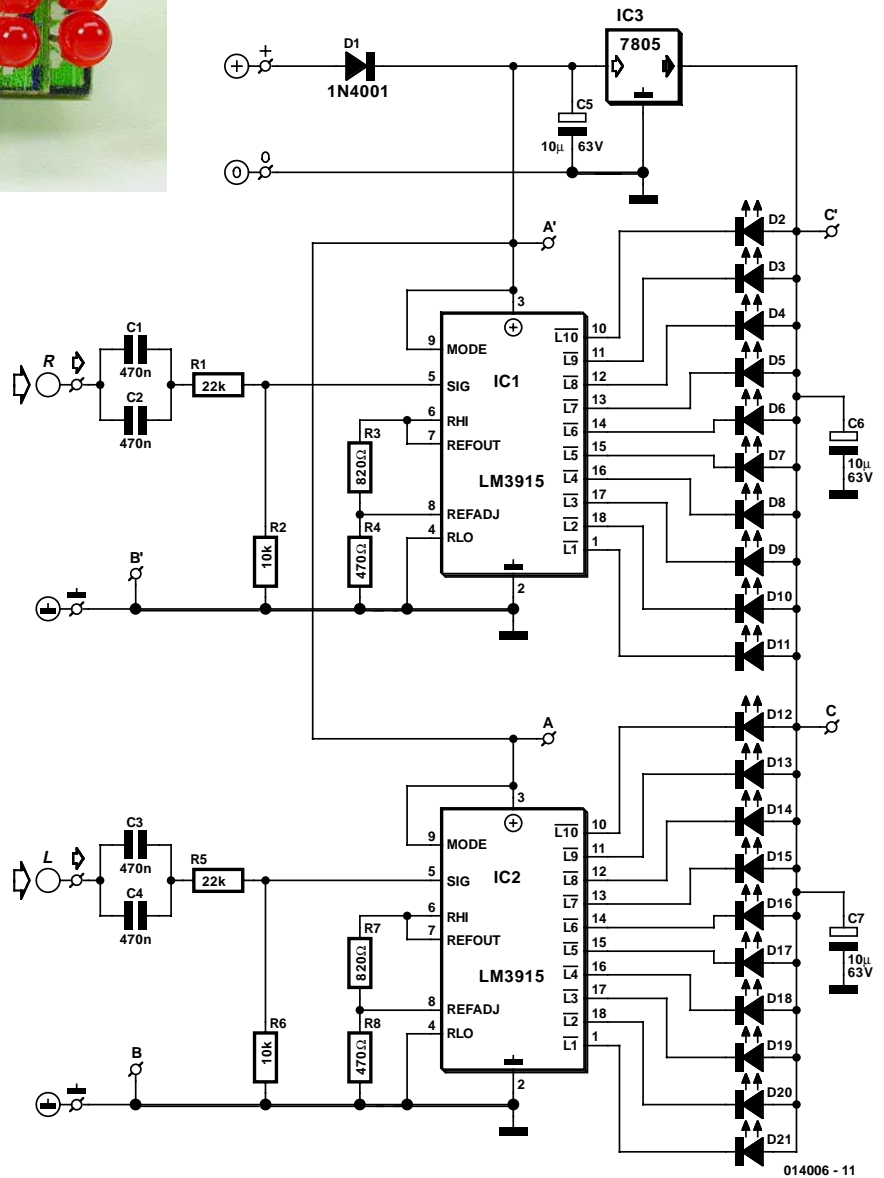
014006 - 11

014006-1
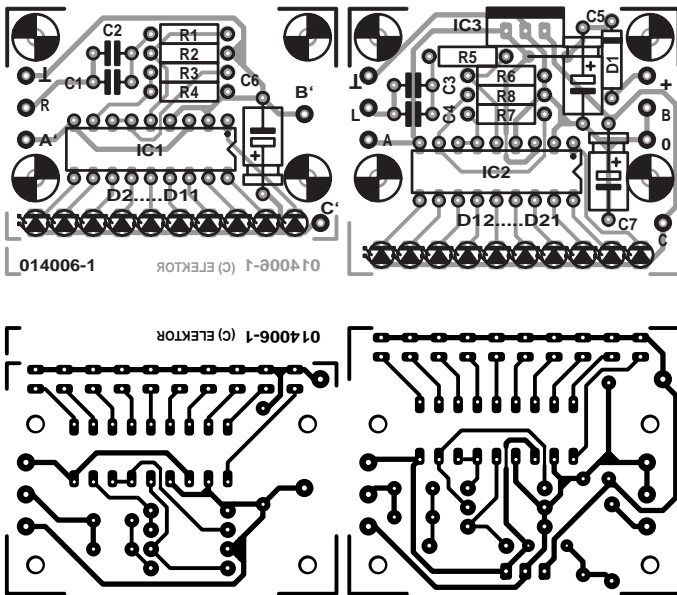
COMPONENTS LIST

Resistors:
R1,R5 = 22kΩ
R2,R6 = 10kΩ
R3,R7 = 820Ω
R4,R8 = 470Ω

Capacitors:
C1-C4 = 470nF, lead pitch 5mm
C5,C6,C7 = 10µF 63V radial

Semiconductors:
D1 = 1N4001
D2-D21 = LED, 3mm dia. or rectangular-face
IC1,IC2 = LM3915N-1 (National Semiconductor)
IC3 = 7805

Miscellaneous:
Heatsink for IC3 (10 K/W)

age (between pins 7 and 8) is applied across R3 (R7) to program the LED current. The programming current flows through R4 (R8) to achieve the desired reference voltage between pin 7 and ground. Here, only 2.0 V is developed, allowing this circuit to be used with low power amplifiers too. This voltage is applied to the 'top' of the on-chip resistor array (pin 6) and so determines the threshold at which the LED connected to the $\overline{L10}$ output comes on. The other (low) side of the array (pin 4) is connected to ground. So, for an input voltage equal to or greater than the voltage at pin 6, all LEDs are on. At input voltages below the threshold set up for the lowest LED (89.3 mV or –27dB below the top LED) all LEDs are off.

In order to limit power dissipation of IC1 and IC2, the LED voltage is stepped down to +5 V using IC3, C6 and C7. Diode D1 protects the circuit against reversed polarity.

If a 'dot' mode graph is preferred pins 9 of IC1 and IC2 should be left open circuit.

Using the listed value for R1 (R5), the indicator range covers audio power levels of 10 W into 4 Ω (CC) or 40 W into 4 Ω (BTL). Each 'lower' LED indicates half the power of the previous 'higher' LED Only R1 (R5) needs to be redimensioned for different power levels. The value can be calculated from

$$R1 = [R2 \sqrt{(P_O Z_L)} / (k * V_{RefOut})] - R2$$

where

P_O = maximum output power to be indicated (LED D2 or D12)
Z_L = loudspeaker impedance
R2 = R6
V_{RefOut} = 2.0 V
k = constant; 2 for BTL, 1 for CC

The condition $\sqrt{(P_O Z_L)} / (k\, V_{RefOut}) \geq 1$ must be met.

A small printed circuit board has been designed to allow a stereo version of the power indicator to be built. The board is cut in two to separate the channels. The boards may be assembled in a sandwich construction with three inter-board connections A-A', B-B' and C-C' made in stiff wire. IC3 should be secured to a small heatsink (10 K/W). Rectangular-face LEDs are recommended for this circuit. If on the other and 3-mm dia. LEDs are used, these may have to be filed down a bit to be able to fit them in a straight row.

The connection to the car radio should not present any problems. The audio signal is taken from the (+) loudspeaker connector for each channel and ground. The power supply leads to the indicator circuit are connected in parallel with car radio power supply.

At a supply voltage of 14.4 V, the maximum and quiescent current consumption of the circuit was measured at 171 and 22 mA respectively.

(014006-1)

Battery Switch with LDO Regulator

G. Kleine

In the form of the LT1579 Linear Technology (www.linear-tech.com) has produced a practical battery switch with an integrated low-dropout regulator. In contrast to previous devices no diodes are required. The circuit is available in a 3.3 V version (LT1579CS8-3.3) and in a 5 V version (LT1579CS8-5), both in SO8 SMD packages. There is also an adjustable version and versions in an SO16 package which offer a greater range of control and drive signals.

The main battery, whose terminal voltage must be at least 0.4 V higher than the desired output voltage, is connected to pin IN1. The backup battery is connected to pin IN2. The regulated output OUT can deliver a current of up to 300 mA.

The LDO regulator part of the IC includes a pass transistor for the main input voltage IN1 and another for the backup battery on IN2. The IC will switch over to the backup battery when it detects that the pass transistor for the main voltage input is in danger of no longer being able to maintain the required output voltage. The device then smoothly switches over to the backup battery. The open-drain status output $\overline{\text{BACKUP}}$ goes low to indicate when this has occurred. When neither battery
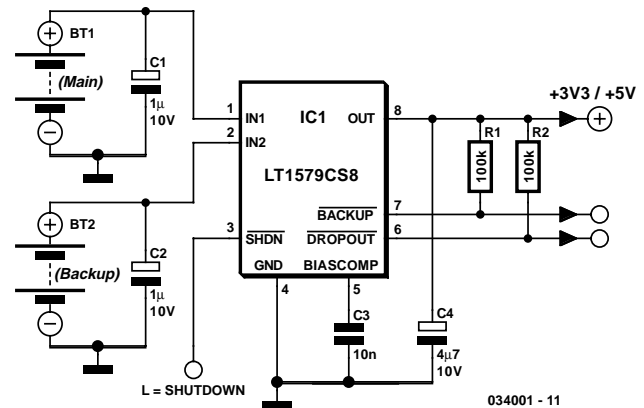
is able to maintain the output voltage at the desired level the open-drain output $\overline{\text{DROPOUT}}$ goes low.

The LT1579 can operate with input voltages of up to +20 V from the batteries. The regulator output OUT is short-circuit proof. The shutdown input switches off the output; if this feature is not required, the input can simply be left open.

(034001-1)

Mini Running Text Display 043
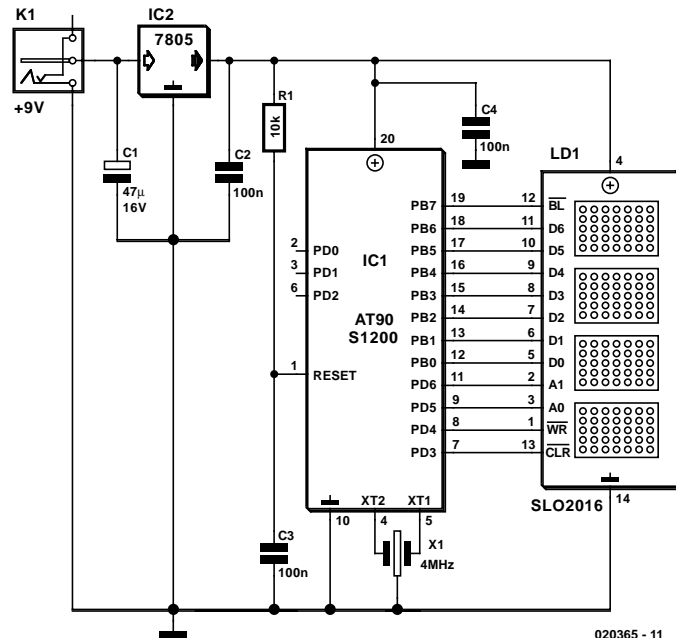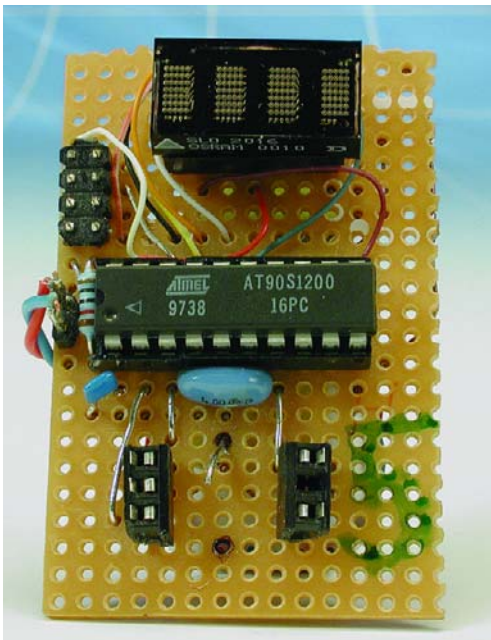
020365 - 11

R. van Arem

This charming little circuit is a genuine four-digit running-text display, complete with a Christmas / New Year's greeting. Naturally, any competent programmer can easily arrange to have a different text scroll across the display. The associated software, including the source code, can be downloaded from the Free Downloads section of our website or obtained from Readers Services on diskette (order number **020365-11**).

As can be seen from the schematic, the hardware consists of little more than an AT90S1200 microcontroller, a 4-digit LED display and a 5-V voltage regulator. The only external circuitry needed by the microcontroller consists of a reset circuit and a 4-MHz crystal, and the remainder of the components are limited to a few decoupling capacitors.

In the prototype model, an Osram SLO2016 display module was used. Although this four-digit module measures only 10×20 mm, it provides an especially clear and bright display. In order to give the 7805 voltage regulator sufficient 'breathing room', the supply voltage should be at least 8 V. A standard 9-V mains adapter should thus be perfectly adequate. The supply voltage does not have to be stabilised, and the adapter does not have to provide an especially large amount of current, since the running-text display draws scarcely more than 50 mA.

(020365-1)

Programing Tool for ATtiny15 044
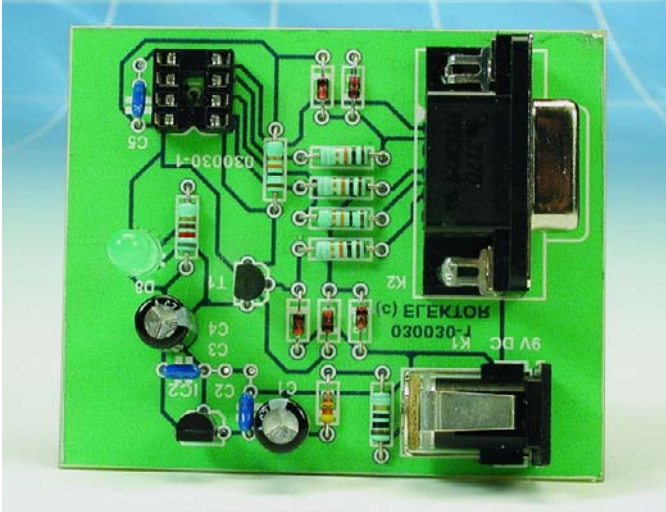
H. Volmer

A small microcontroller like the ATtiny15 is ideal for many simple tasks not requiring too much I/O activity. The ATtiny15 has two I/O connections, offers a 1024-byte Flash memory and a 64-byte EEPROM, all in an 8-pin case.

The programming tool shown here is connected to the RS232 port on your PC. The programming clock signal is generated using a byte sent across the serial interface.

The programmer employs the so-called low-power programming algorithm under Windows ME. The associated software offers four tabs:

```
.equ    lastflash      =0x1ff

Reset:
Ldi     ZL,LOW(lastflash*2)+1
Ldi     ZH,HIGH(lastflash*2);//FLASHEND
Lpm     ;in last memory location of calibration register
Out     OSCCAL,r0
```
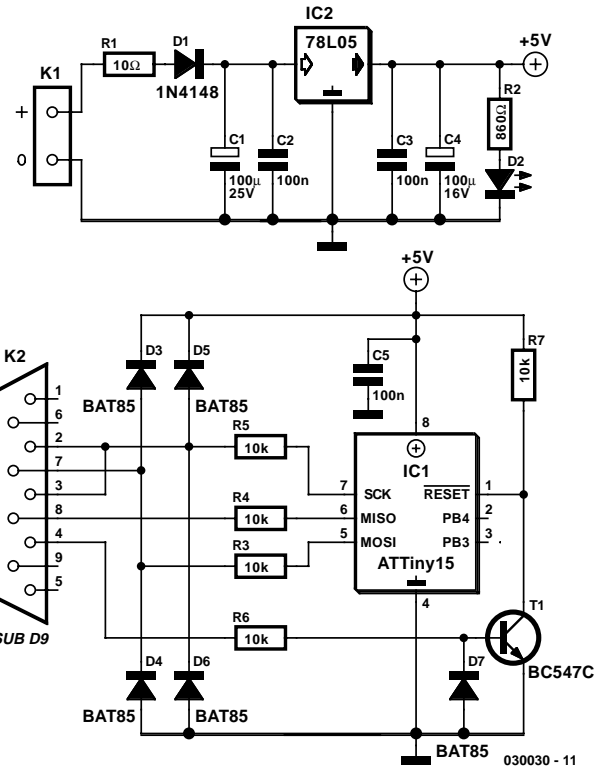

Identify which allows manufacturer data as well as calibration register contents to be read from the ATtiny15 chip.

Flash which expects a file in HEX or binary format for programming into the on-chip Flash memory. When the HEX format is used, the checksum is ignored. Read and write access to the Flash memory is only possible using the HEX format. The calibration byte is read with the aid of PutCallbyte and then written to the indicated buffer address. The internal oscillator is controlled as shown in the listing.
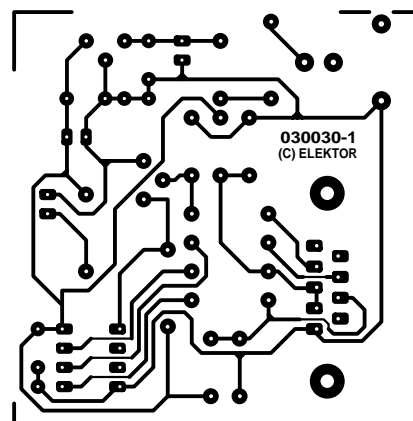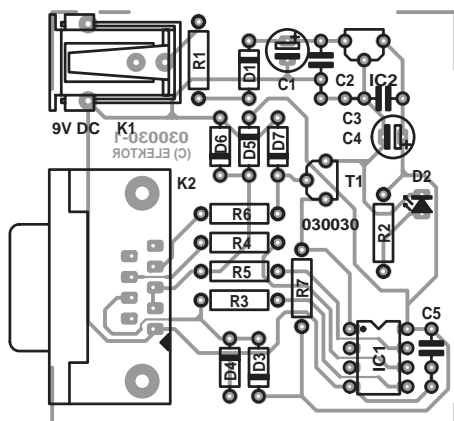
COMPONENTS LIST

Resistors:
R1 = 10Ω
R2 = 820Ω
R3-.R7 = 10kΩ

Capacitors:
C1,C4 = 100µF 25V radial
C2,C3,C5 = 100nF

Semiconductors:
D1 = 1N4148
D2 = LED, green
D3...D7 = BAT85
IC1 = 78L05
T1 = BC547C

Miscellaneous:
IC1 = 8-way DIL
  programming socket
K1 = mains adaptor socket,
  PCB mount
K2 = 9-way sub-D socket
  (female), PCB mount,
  angled pins
PCB, order code **030030-1**
Disk, project software,
  order code **030030-11**

EEPROM does essentially the same as Flash function, only the PutCallbyte is not present.

Fuses allows the chip fuses to be read and programmed. Note, however, that the Fuse and Lockbit programming is not tested because afterwards only the High Voltage mode will work.

A small PCB, order code **030030-1**, was designed for the programmer. The PCB artwork may be obtained from the Free Downloads section of the Publishers' website. The software is also found there. For those without access to the Internet the software is also available on diskette, order code **030030-11**.

(030030-1)

1.2 GHz VCO with Linear Modulation

045

G. Kleine

Since high frequency voltage-controlled oscillators, or VCOs, are not easy to construct, Maxim (www.maxim-ic.com) has produced an integrated 1.2 GHz oscillator, the MAX2754. The centre frequency is set using the TUNE input, and a linear modulation input allows the frequency to be modulated. The IC is available in an 8-pin µMAX package, operates from a supply of between 2.7 V and 5.5 V, and draws a current of less than 20 mA.

Both TUNE and MOD operate over control voltage range of +0.4 V to +2.4 V. TUNE allows the VCO frequency to be adjusted from 1050 MHz to 1270 MHz. In some applications a PLL control voltage will be applied here, allowing the centre frequency to be set exactly to a desired value. For simplicity in the circuit diagram we have shown a potentiometer. The MOD input allows the VCO to be modulated in a digital or analogue fashion, with a transfer slope of –500 kHz/V. In the circuit we have shown an example where MOD is used for frequency shift keying (FSK) modulation. Resistors R1 to R4 shift the level of the data signal so that it has a centre value of +1.4 V and an amplitude corresponding to the desired frequency deviation.

One example set of values, suitable for use with a 5 V power supply, is as follows: R1 = 480 Ω, R2 = 100 Ω, R3 = 220 Ω und R4 = 270 Ω. The input impedance is about 1 kΩ.

The output level of the MAX2754 at OUT is around –5 dBm into 50 Ω. A coupling capacitor is not required here: the IC already contains one.
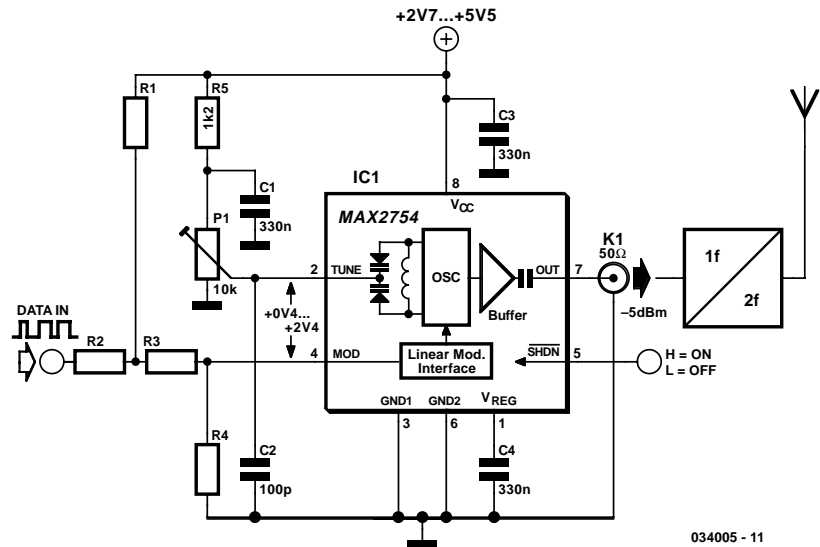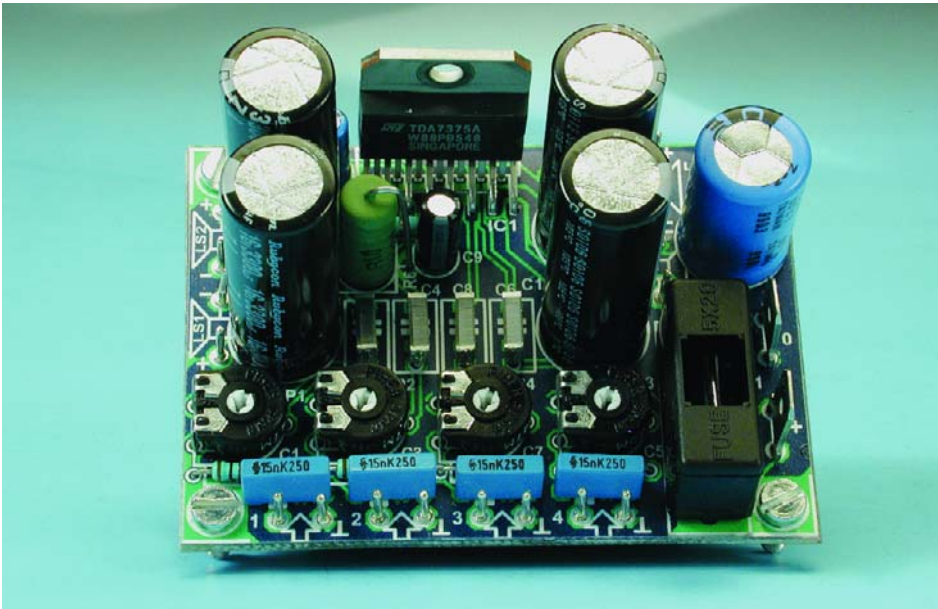

034005 - 11
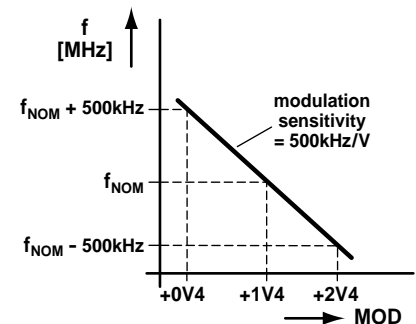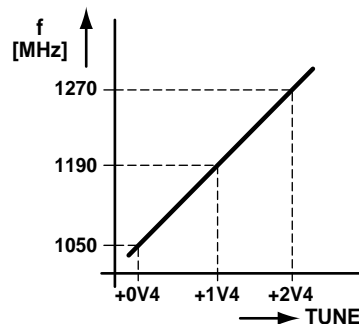
034005 - 12

The MAX2754 is designed for use in transmitters in the 2.4 GHz ISM (industrial, scientific and medical) band. This requires the addition of a frequency doubler, which, along with the 2.4 GHz antenna, is shown symbolically in the circuit diagram.

Quad Car Amp

046

Measurement results

Supply voltage	14.4 V
Quiescent current	100 mA
Pmax. (0.1% THD)	4 x 5.3 W/ 4Ω
Input sensitivity (5.2 W/4 Ω)	0.5 V
THD+N (B = 80 kHz, 1 kHz 1W/4 Ω)	< 0.04 %
Bandwidth	28 Hz to 55 kHz

T. Giesberts

This quad final amplifier is actually intended to be used in a car, but it can naturally also be used for a variety of other medium-power applications. The TDA7375A can be successfully used in all situations in which a reasonable amount of audio power is desired and only a relatively low supply voltage is available. This IC is the successor to the TDA7374B, which forms the heart of the active loudspeaker system described earlier this year. Such a quad IC amplifier is naturally an excellent choice for this application, especially since the individual amplifiers can be connected in pairs in the bridge configuration, which allows them to provide approximately four times as much power. An example of such a bridge configuration is shown elsewhere in this issue.

The new IC can handle a peak voltage of 50 V (10 V more than the TDA7374B), but what is more important is that it is also truly intended to be used for single-ended operation. It includes all imaginable types of protection in order to avoid the premature demise of the four amplifiers, and in fact it is ideally suitable for a 'no-nonsense' mini surround-sound system. For more information about the TDA7375A, we refer you to its data sheet, which can be found at www.st.com.

The circuit shown here has four trimpots for individually setting the output levels of the amplifiers. In addition, all inputs have RC networks (R1/C1, etc.) to block possible RF interference. The function of R6 is to separate the grounds of the input and output stages, in order to avoid possible ground loops that might arise with the use of multiple modules. A 5-W type is used for this resistor, in order to prevent it from going up in smoke if the ground connection of the power supply comes loose.

C10 decouples the internal voltage divider, which biases the internal amplifier stages to half of the supply voltage. RC network R5/C9 provides a delayed, plop-free switch-on. C15 and
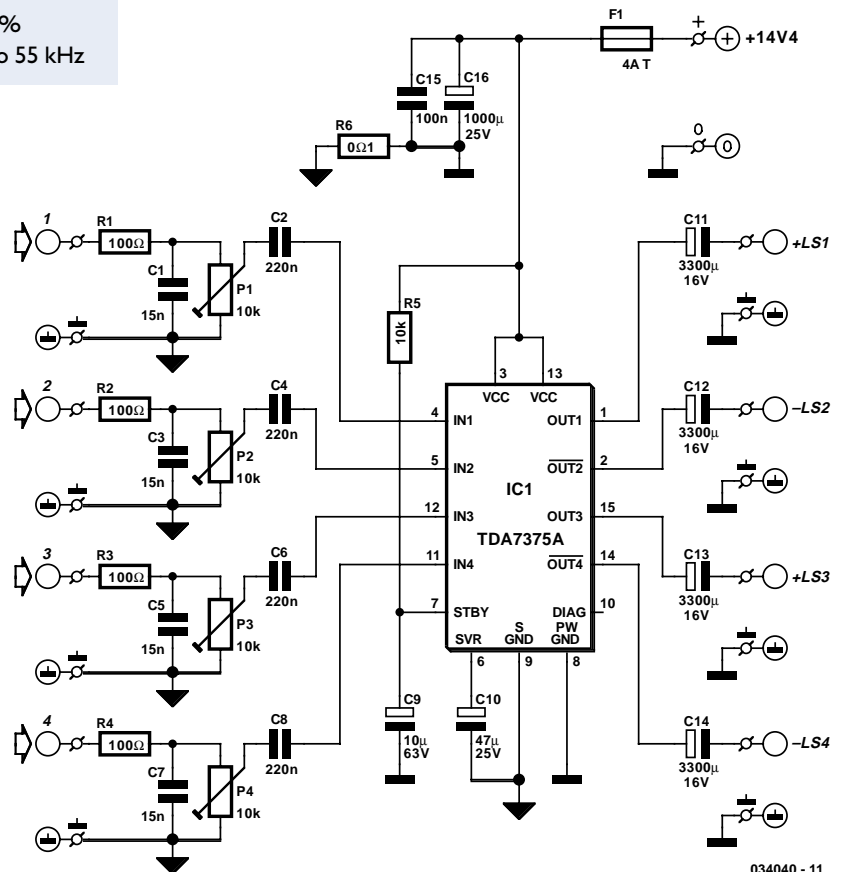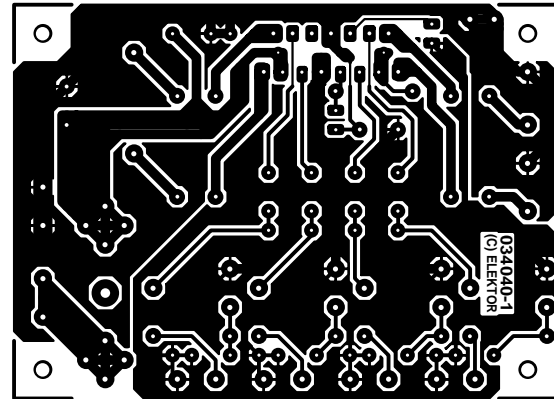

034040 - 11

C16 are local bypass capacitors for the supply voltage.

The power supply ripple rejection of the TDA7375A is approximately 50 dB. If you want to use only a transformer, bridge rectifier and smoothing capacitor for the power supply, the minimum requirement is a transformer rated at 12 V / 30 VA in combination with a 10,000-μF electrolytic capacitor (remember that the maximum allowable supply voltage is 18 V).

One of the few drawbacks of this quad amplifier is that two of the channels are inverted with respect to the other two. For this reason, the polarity of each loudspeaker terminal is marked on the circuit board layout (e.g., +LS1 and –LS4) to indicate which terminal of the loudspeaker should be connected where. Radial electrolytic capacitors rated at 3300 μF / 16 V and having a diameter of only 12 mm are used for the output capacitors, which allows the circuit board to remain relatively compact. Our preferred type of electrolytic capacitor is a member of the Rubycon ZL series, which can handle no less than 3.4 A of ripple current.

The maximum current consumption of the circuit with all four channels driven to the clipping level (with 4-Ω loads) is approximately 2.1 A. The TDA7375A can also be used with 2-Ω loads. However, in this case the internal temperature rises considerably, since the Multiwatt 15V package has a rather large thermal impedance of 1.8 °C/W. In the interest of the service life of the IC, it is thus a good idea to use a somewhat larger heat sink.

A 4 A/T fuse has been selected in consideration of possible

COMPONENTS LIST

Resistors:
R1-R4 = 100Ω
R5 = 10kΩ
R6 = 0Ω1, 5W
P1-P4 = 10 k preset

Capacitors:
C1,C3,C5,C7 = 15nF
C2,C4,C6,C8 = 220nF
C9 = 10µF 63V radial
C10 = 47µF 25V radial
C11-C14 = 3300µF 16V
  radial, max. diameter
  13mm, e.g., Panasonic
(Iripple 2500 mA) or
  Rubycon (Iripple 3400 mA)
C15 = 100nF
C16 = 1000µF 25V radial,
  max. diameter 13mm

Semiconductors:
IC1 = TDA7375A (ST)

Miscellaneous:
F1 = fuse, 4A/T (time lag),
  with PCB mount holder
2 fast-on (spade) terminal,
  male, vertical, solder type
  (2-pin version)

2-Ω operation. If you limit the load to 4 Ω, the fuse value can be reduced to 2 A/T.

The output terminals of the amplifiers can be found on the circuit board next to the associated electrolytic capacitors. The related ground connections for LS1 and LS2 are located next to the LS1 and LS2 terminals, but the ground connections for LS3 and LS4 are located on the left, next to the IC, since this gives the best current paths on the circuit board and the least distortion. Vertical car connectors (spade terminals) are used for the power supply connections.

(034040-1)

Case Modding

047

S. Büching

The aesthetics of 'case modding' (modifying a PC's enclosure) offer plenty of scope for debate and plenty of scope for original circuits. In the April 2003 issue of *Elektor Electronics* we presented a PC temperature indicator; and the circuit shown here falls into the same category.

Low current LED indicators are usually fitted in PC enclosures. Although this certainly saves energy, the LEDs do not light particularly brightly. It is not completely straightforward to replace the low-current types with high-brightness types since the latter draw a current of 20 mA rather than 2 mA. This can — whatever people might tell you to the contrary — in some instances lead to excessive load on the LED drivers on the motherboard.

The problem can be solved using a small external driver stage: two resistors and a transistor mounted on a small piece of perforated board, connected in place of the original LED. The new high-brightness LED is then connected between the output of the current source and a spare motherboard ground connection (for example on the infrared port) or to a grounded screw in the enclosure.

R1 is responsible for the constant current. High-brightness red LEDs are driven at 20 mA (R1 = 150 Ω), whereas high-brightness blue LEDs require 10 mA (R1 = 75 Ω).

In view of the large number of different PC motherboards available, it is not certain that this driver can be used in every PC. It is easy to check whether the circuit will work: use a DC voltmeter to measure the voltage between the positive connection on the LED (generally a red wire or a pin marked with an arrow on the LED connector) and ground (not the other pin of the connector). If this reads +5 V independent of whether the LED is on or not, then the driver can be used.

030071 - 11

(030071-1)
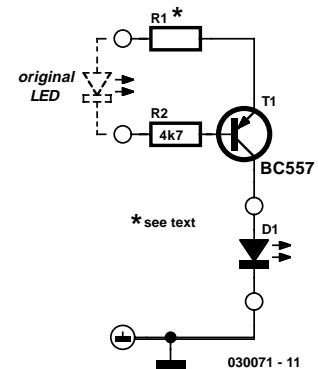
Flight Simulator Extensions 048

The flight simulators from Microsoft have improved much over the years. A great deal of attention has been paid to realistic flight behaviour and the graphical representation of the aircraft and its surroundings. Planning of the flight, flight lessons, weather circumstances and even radio contact are currently part of the simulation.

The only thing that is missing is a cockpit with all the bells and whistles, so that we won't have to use the keyboard, and display the relevant information (height, speed, etc.) on a real instrument panel surrounding us.

There are companies that manufacture these kind of cockpits or parts of cockpits, but do-it-yourself construction is much more fun of course…

It is quite a job to build a beautiful cockpit, but this is not usually the issue that hobbyists have difficulties with. The big problem is the communication between the flight simulator and your own cockpit. The control of the stick (via a joystick) is probably not going to be too much of a problem, but how do you deal with such things as tuning the radio to a different channel or adjusting the landing flaps to 10%? And another big question is how to obtain the relevant information for the instrument panel.

Fortunately, the flight simulator can be expanded with your own functions through DLLs. On the Internet you can find legions of people who enthusiastically occupy themselves with these problems. They often will make their software available to others at no charge or for a very nominal sum. A summary of the available software would never be complete. It is therefore much better if you take a look on the Internet for yourself.

A good place to start is: www.schiratti.com/index.html.

A diverse number of things can be found here, from DLLs to write your own communications programs, to complete programs that perform a particular function. For information, examples and help when building your own cockpit, http://www.simpits.org/ is a good starting point.

(034034-1)

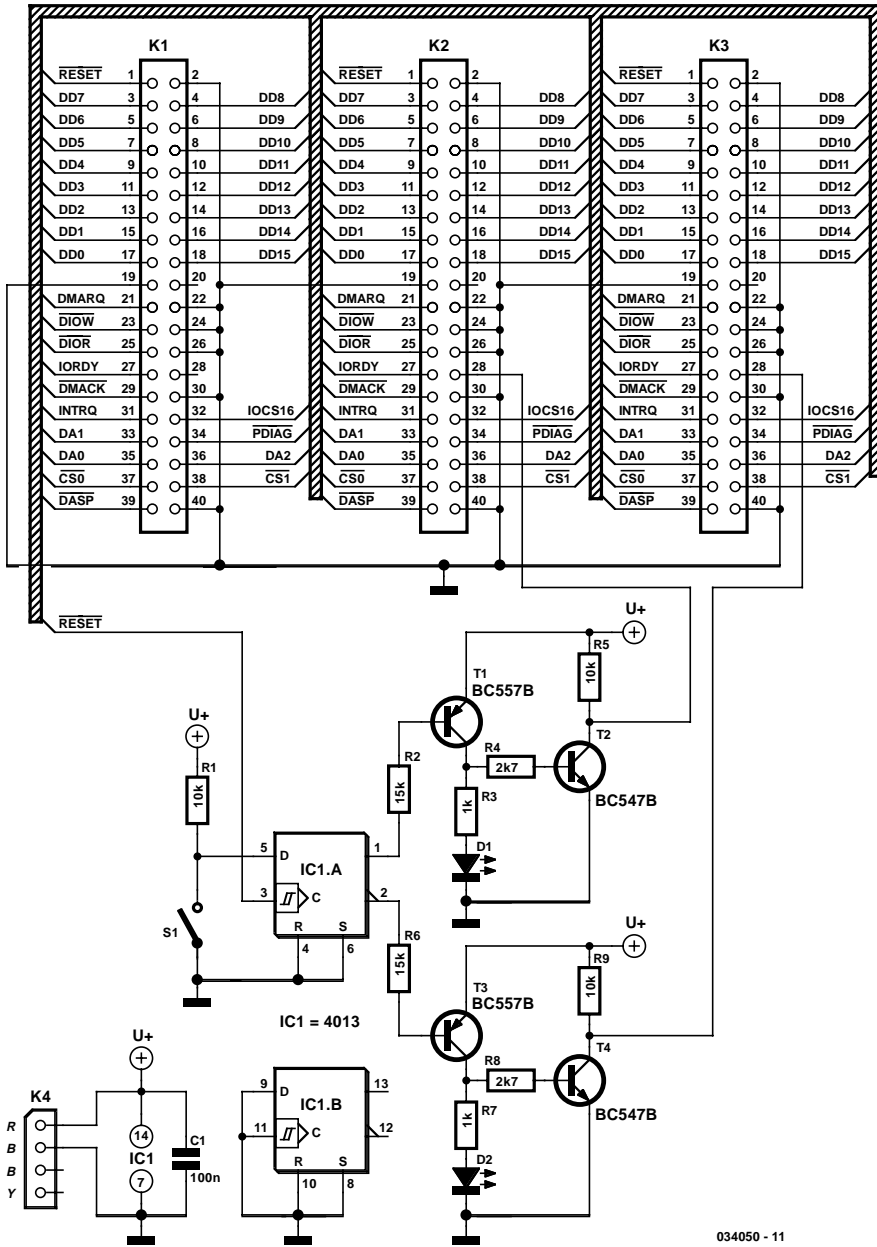# Keypad Extension

049

1

034035 - 11

T. Giesberts

T. Giesberts

Bascom AVR application note no. 105 (www.mcselec.com/an_105.htm) describes a simple circuit for using an AT90S2313 (an 8-bit AVR microcontroller) to transmit RC5 or Sony remote control codes. In this circuit, a small 3×4 matrix is used to connect 12 pushbutton switches to only 7 pins of the microcontroller (see **Figure 1**).

If you need more pushbuttons, the matrix will have to be extended, but quite a bit can be achieved using a simple auxiliary circuit. If the three column bits are used to drive a demultiplexer, up to 32 pushbuttons can be connected. **Figure 2** shows and example of such an approach. Here a 74HC138 has been chosen for the demultiplexer. This IC has inverted outputs. If active-high outputs are more convenient for software reasons, the pin-compatible 74HC238 can be used instead.

Naturally, the software will have to be modified, since it is unlikely that a standard statement or instruction is present in Bascom AVR for this auxiliary circuit. It may be necessary to write a new assembler routine. This is not a particularly difficult task, and moreover, it is a pleasant challenge for would-be users of the extended keypad.

(034035-1)

2

034035 - 12

Hard Disk Selector

050

034050 - 11

P. Goossens

In the last few years, the available range of operating systems for PCs has increased dramatically. Various free (!) operating systems have been added to the list, such as BeOS, OpenBSD and Linux. These systems are also available in different colours and flavours (versions and distributions). Windows is also no longer simply Windows, because there are now several different versions (Windows 95, 98, ME, NT and XP). Computer users thus have a large variety of options with regard to the operating system to be used. One problem is that not all hardware works equally well under the various operating systems, and with regard to software, compatibility is far from being universal. In other words, it's difficult to make a good choice.

Switching from one operating system to another — that's a risky business, isn't it? Although this may be a bit of an exaggeration, the safest approach is still to install two different operating systems on the same PC, so you can always easily use the 'old' operating system if the new one fails to meet your needs (or suit your taste). A software solution is often used for such a 'dual system'. A program called a 'boot manager' can be used to allow the user to choose, during the start-up process, which hard disk will be used for starting up the computer. Unfortunately, this does not always work flawlessly, and in most cases this boot manager is replaced by the standard boot loader of the operating system when a new operating system is installed. In many cases, the only remedy is to reinstall the software.

The solution presented here does not suffer from this problem. It is a hardware solution that causes the primary and secondary hard disk drives to 'swap places' when the computer is started up, if so desired. From the perspective of the computer (and the software running on the computer), it appears as though these two hard disks have actually changed places. This trick is made possible by a feature of the IDE specification called 'CableSelect'. Every IDE hard disk can be configured to use either Master/Slave or CableSelect. In the latter case, a signal on the IDE cable tells the hard disk whether it is to act as the master or slave device. For this reason, in every IDE cable one lead is interrupted between the connectors for the two disk drives, or the relevant pin is omitted from the connector. This causes a low level to be present on the CS pin of one of the drives and a high level to be present on the CS pin of the other one (at the far end of the cable).

The circuit shown here is connected to the IDE bus of the motherboard via connector K1. Most of the signals are fed directly from K1 to the other connectors (K2 and K3). An IDE hard disk is connected to K2, and a second one is connected to K3. When the computer is switched on or reset, a pulse will appear on the $\overline{\text{RESET}}$ line of the IDE interface. This pulse clocks flip-flop IC1a, and depending on the state of switch S1, the Q output will go either high or low. The state on the $\overline{Q}$ out-
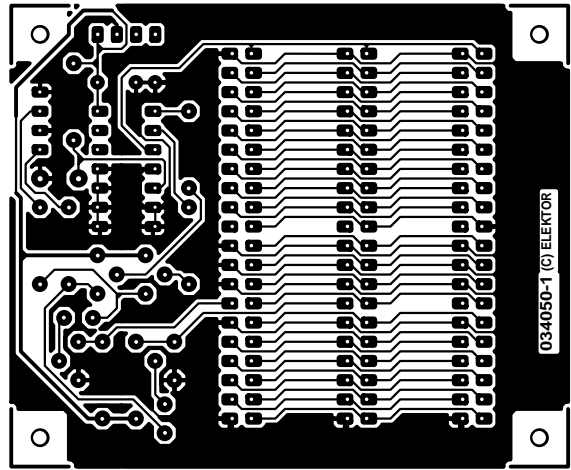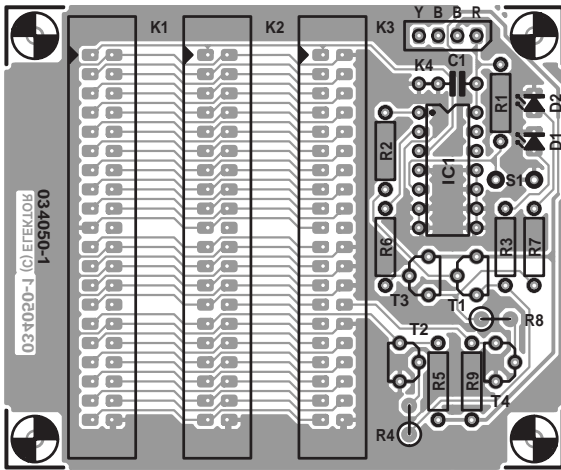
COMPONENTS LIST

Resistors:
R1 = 10kΩ
R2,R6 = 15kΩ
R3,R7 = 1kΩ
R4,R8 = 2kΩ7
R5,R9= 10kΩ

Capacitors:
C1 = 100 n

Semiconductors:
D1 = LED, low-current,

yellow
D2 = LED, low-current,
 green
IC1 = 4013
T1,T3 = BC557B
T2,T4 = BC547B

Miscellaneous:
K1,K2,K3 = 40-way
 boxheader
K4 = 4-way SIL pinheader
S1 = switch, 1 make contact
PCB, order code **034050-1**

put is naturally always the opposite of that on the Q output. If we assume that the switch is closed during start-up, a low level will be present on D input of IC1a, so the Q output will be low following the reset pulse. This low level on the Q output will cause transistor T1 to conduct. The current flowing

through T1 will cause LED D1 to light up and transistor T2 to conduct. The hard disk attached to connector K2 will thus see a low level on its CS pin, which will cause it to act as the master drive and thus appear to the computer as the C: drive.

A high level will appear on the $\overline{Q}$ output following the reset pulse. This will prevent T3 and T4 from conducting, with the consequence that LED D2 will be extinguished and the hard disk attached to connector K3 will see a high level on its CS pin. For this disk, this indicates that it is to act as a slave drive (D: drive). If S1 is open when the reset pulse occurs, the above situation is of course reversed, and the hard disk attached to connector K2 will act as the D: drive, while the hard disk attached to connector K3 will act as the C: drive.

Flip-flop IC1a is included here to prevent the hard disks from swapping roles during use. This could have disastrous consequences for the data on the hard disks, and it would most likely cause the computer to crash. This means that you do not have to worry about affecting the operation of the computer if you change the switch setting while the computer is running. The state of the flip-flop, and thus the configuration of the hard disks, can only be changed during a reset.
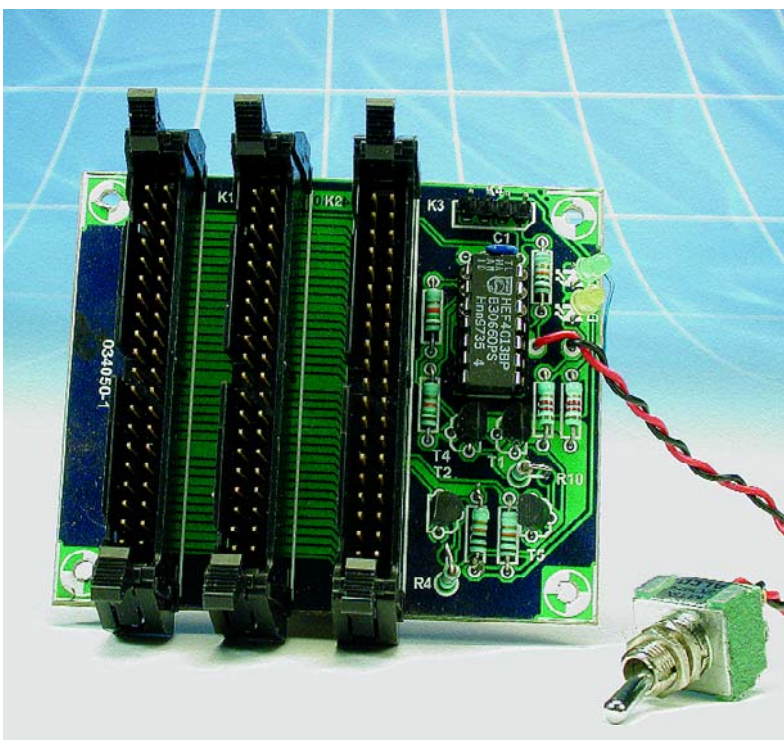
The circuit is powered from a power connector for a 3.5-inch drive. This advantage of using this connector is that it easily fits onto a standard 4-way header. However, you must observe the correct polarity when attaching the connector. The red lead must be connected to pin 1.

Constructing the hard disk selector is easy if the illustrated printed circuit board is used. You will need three IDE cables to connect the circuit. The best idea is to use short cables with only two connectors, with all pins connected 1:1 (no interruption in the CS line). The IDE connector on the motherboard is connected to K1 using one cable. A cable then runs from K2 to first hard disk, and another cable runs from K3 to the second hard disk. This means that it is not possible to connect more than two hard disks to this circuit. You must also ensure that the jumpers of both disk drives are configured for CableSelect. To find out how to do this, refer to the user manual(s) for the drives.

(034050-1)

RC5 Repeater

051

H. Tempelman

The designer of this circuit had fitted two (waterproof) loudspeakers in his bathroom and connected them to the stereo system in the living room via a long cable. Naturally, this promptly led to the desire to be able to use the remote control unit from the bathroom. Commercially available extension sets for this purpose were judged to be unsatisfactory, primarily because they require an additional IR transmitter diode to be fitted in front of the amplifier.

Although the repeater shown here requires a length of coaxial cable, it provides a simpler, and above all more reliable, solution to the problem. The signal transmitted by the remote control unit is received by IR receiver IC2, and the (nearly) open-collector output of T1 is connected to the RC5 bus of the stereo system. This proved to work excellently with Philips equipment, and it will probably also work with equipment from other manufacturers with a few small modifications.

Voltage regulator IC1 is used here to allow the supply voltage to range from 8 V to 30 V, and diode D1 provides protection against a reverse-polarity supply voltage connection.

A nice side benefit arose from the fact that the loudspeakers in question (Conrad models) have transparent cones and protection grilles with rather large openings. This made it possible to fit the tiny circuit, which was built on a piece of prototyping board, to the frame of one of the speakers, behind the cone. The
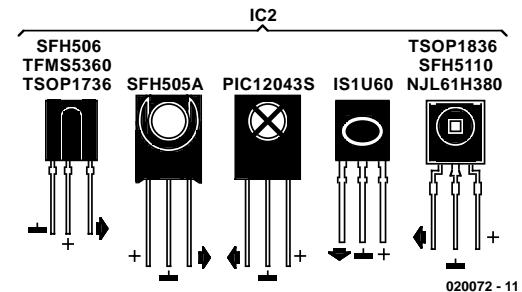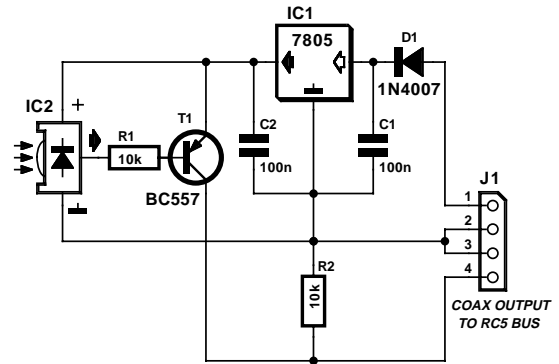
whole arrangement is thus hidden, but the remote control still works perfectly if it is aimed towards the speakers.

(020072-1)

020072 - 11

Adjustable 3-A Regulator 052

G. Baars

By combining a common 78L05 with an integrated audio amplifier of the type TDA2030, an adjustable voltage regulator can be constructed in a very simple manner that works very well. The output voltage is adjustable up to 20 V, with a maximum current of 3 A. Since the TDA2030 comes complete with a good thermal and short-circuit protection circuit, this adjustable regulator is also very robust.

As illustrated by the schematic, the design of this circuit is characterised by simplicity that is hard to beat. In addition to the two ICs, the regulator contains actually only two potentiometers and a few capacitors. The adjustment is done by first turning potentiometer P1 to maximum (wiper to the side of the 78L05) and subsequently turning trimpot P2 until the desired maximum output voltage is reached. P1 is then used to provide a continuously adjustable voltage between this maximum and nearly zero volts.

At relatively small output currents there are no specific
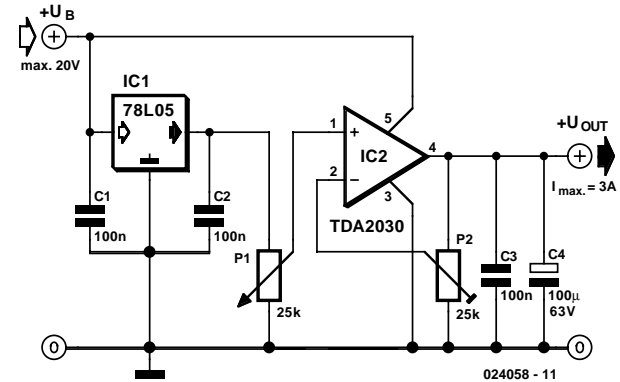
requirements regarding the cooling. However, when the output current exceeds 1 A, or if the input to output voltage difference is quite large, the amplifier IC has to dissipate too much power and a small heatsink is certainly appropriate.

(024058-1)

Floating 9-V Supply for DVM Modules

053

D. Ponting

Most commercial DVM modules with an LCD readout are 9-V powered and based on an ICL7106 or similar A-D converter chip. These modules are typically used in laboratory power supplies and other test and measurement equipment where a drop-in solution needs to be found to realize a voltmeter readout. Particularly in power supply units, the LCD module will need to 'float' relative to the PSU supply rails, and this inevitably requires a separate 9-volt power supply. In some cases, batteries may be used but these have distinct advantages. The alternative, a 9-V converter effectively powered by the PSU and yet floating, is shown here. It is built from the ubiquitous TLC555, LMC555 or 7555) timer IC acting in astable multivibrator configuration producing a 70-kHz square wave fed into a simple rectifier. In essence, capacitors C5 and C6 afford the above mentioned electrical isolation between the PSU supply rails and the LCD module.

The old, bipolar NE555 IC should not be used here because it presents a too heavy loads on the converter's own supply voltage. Depending on the exact type and brand of the CMOS 555 you're using, resistor R6 may need to be redimensioned a bit
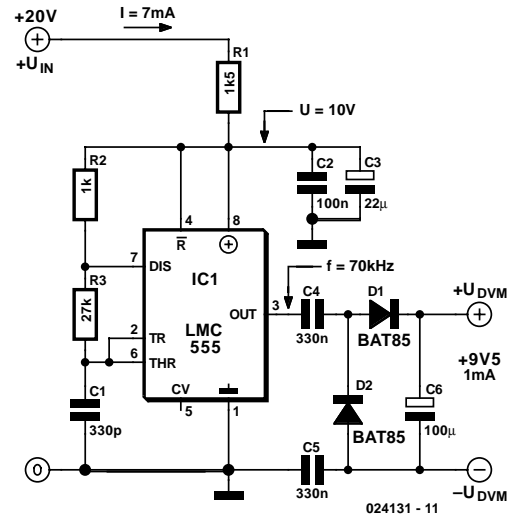
to ensure a supply voltage of about 10 volts at pins 8 and 4 of the chip. At an output voltage of 9.5 V, the maximum output current of the converter s about 1 mA.

DMM Fuse Protector

054

P. Sicherman

Typically the input protection fuse of your DMM will blow in the middle of a demonstration or an exciting phase of your construction work. Spare fuses are always hard to find, and if available take a lot of time to install.

This circuit replaces the fuse by a 500 mA current limiter. When resistor R1 passes about 500 mA, it will drop 0.75 V which is sufficient to switch on T2. With the buzzer acting as a pull-up resistor (and, of course, as a very loud acoustic warning device), the voltage at the gate of power FET T1 will drop to a level at which the drain-source current is limited to a safe value of about 500 mA. Of course, the excess energy caused by the current limiting action is dissipated by the FET. Cooling is required in all cases where the dissipation can be expected to exceed about 1-2 watts. After all, without cooling, the voltage allowed to occur across the FET will be just 4 V (2 W = 0.5 A × 4 V).

Although an IRF740S is indicated in the circuit diagram, almost any power FET may be used. The popular BUZ10, for example, is a good choice when a lot of power has to be dissipated.
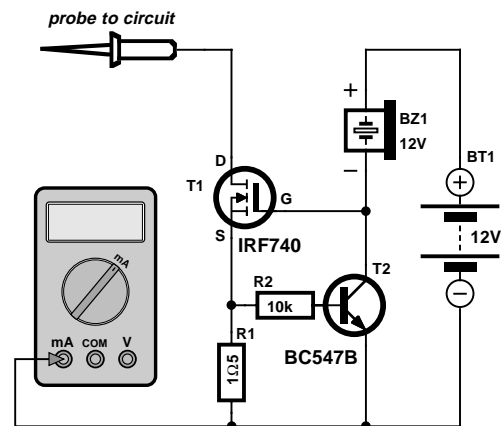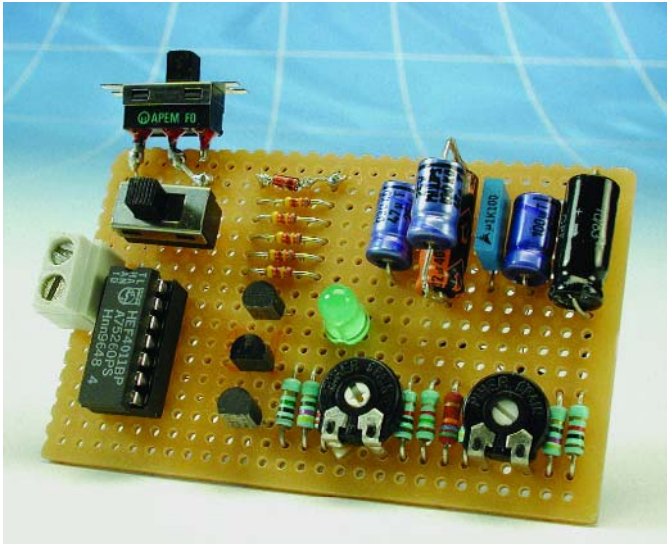

034026 - 11

If a 12-V mini battery is used then the buzzer should also be a 12-V device. However the circuit will also work fine from the more commonly found (and certainly less expensive) 9-V battery and a matching buzzer. If the latter is not required it is simply replaced by a 10-kΩ resistor.

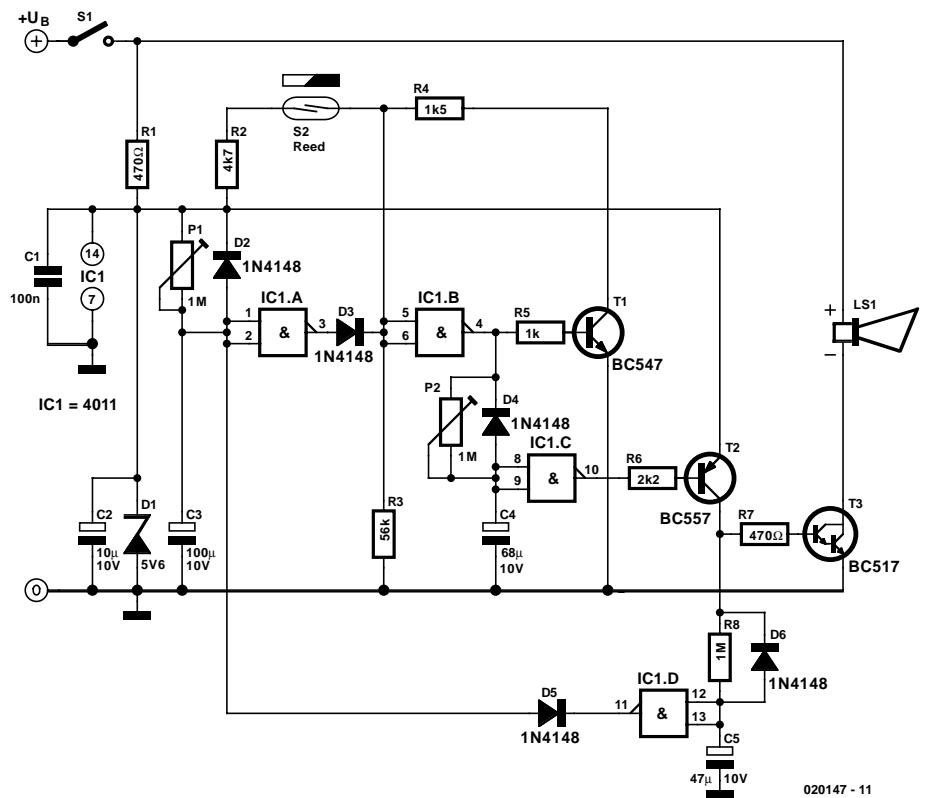(034026-1)

Simple Alarm System

055

L. Libertin

The circuit presented here is a very simple and yet highly effective alarm system for protecting an object. The circuit requires no special devices and can be built using components that you will no doubt be able to find in the junk box. The alarm-triggering element is a simple reed switch. To generate the alarm signal itself any optical or acoustic device that operates on 12 V can be used: for example a revolving light, a siren, or even both.

In the quiescent state the reed switch is closed. As soon as the reed switch opens, the input to IC1.B will go low (previously the potential divider formed by R2 and R3 held the input at 5.17 V, a logic high level). A turn-on delay of between 0 and approximately 90 s can be set using P1, and a turn-off delay of between 0 and approximately 20 s can be set using P2. When the system is turned on (using S1), the turn-on delay is activated, giving the user of the system at most 90 s to leave the object alone before the system goes into the armed state, and the object is then protected.

Once the reed switch opens the turn-off delay of at most 20 s starts: this allows the rightful owner of the object to turn the system off before the alarm is triggered. If some unauthorised person causes the reed switch to open, the alarm will be triggered after the turn-off delay. Also, even if the reed switch is briefly opened and then closed again, the alarm will still be triggered.

Once the alarm is triggered, T3 will conduct for about 45 s (because of R8 and C5). The turning off of the alarm is necessary to avoid the nuisance caused by a permanently sounding alarm system. The system then returns to the armed state, which means that the next time the reed switch is opened the alarm will trigger again. If it is not desired that the duration of the alarm be limited, for example if a visual indication is used, D5 should not be fitted. The system can be extended by fitting multiple reed switches in series. As soon as any one is opened, the alarm is triggered.

When S1 is closed C3 charges via P1. Depending on the potentiometer setting, it takes between 0 and 90 s to reach the input threshold voltage of IC1.A. The output of IC1.A then goes low and D3 stops conducting. Assuming the reed switch is closed, the inputs of IC1.B stay high and the output therefore low. If the reed switch is opened after the turn-on delay expires the output of the gate will change state and turn on T1. This ensures that the output of the gate remains high even after the reed switch is closed again. C4 now starts charging via P2, reaching the input threshold voltage of IC1.C after between 0 and 20 s, again according to the potentiometer setting. The output of IC1.C goes low, and T2 and T3 are turned on — and the siren sounds. Any Darlington transistor can be used for T3. At the same time, C5 charges via R8, reaching the input threshold of IC1.D in about 45 s. When the output of IC1.D swings low, it pulls the inputs of IC1.A low via diode D5: the siren stops and the system returns to the armed state.

020147 - 11

020147 - 12

If the potentiometers P1 and P2 are replaced by fixed resistors it is possible to build the circuit small enough to fit in a matchbox, without the need to resort to SMD components. This is ideal if the circuit is to be used to protect a motorbike. If the alarm system is to be used in a car, an existing door switch contact can be used instead of the reed switch. In this case an RC combination needs to be added to prevent false triggering. Use a 10 µF/25 V electrolytic for C6, a 100 kΩ resistor for R9 and a 1N4001 for D7. It is again possible to wire multiple door switch contacts in parallel: as soon as one contact closes, IC1.B will be triggered.

(020147-1)

Simple Amplifier with Surround System

056

H. Sadeghi

The AN7147 Dual 5.3-watt Audio Power Amplifier from Panasonic is listed as a 'replacement type' so hopefully will be around for some time to come. Together with some extra components, it can represent a simple surround-sound system requiring no opamps or a negative voltage supply.

As shown by the circuit diagram the basic stereo amplifier is changed into a surround-sound system by a trick called 'adding feedback from the opposite channel'. When surround sound is required, the negative feedback signals supplied by C13-R3 and C12-R4 are fed to the inputs of the 'other' amplifier. The resulting phase difference causes the surround effect. If surround sound is not required, the effect can be disabled by pressing pushbutton S1. This causes the bistable built around IC2.A and IC2.B to toggle and drive transistors T1 and T2 such that the above mentioned negative feedback signals are effectively shunted to ground.

A high-efficiency LED and a 3.3-kΩ series resistor (R14) should be used to make sure the maximum output current of the CMOS 4001 device is not exceeded.

The amplifier should not be loaded with impedances smaller than 3 Ω. The AN7147 will typically supply up to 4.3 watts into 4 Ω. The SIL-12 case needs to be cooled wit a small heatsink of about 6 K/W or better. The quiescent current is modest at just 19 mA.
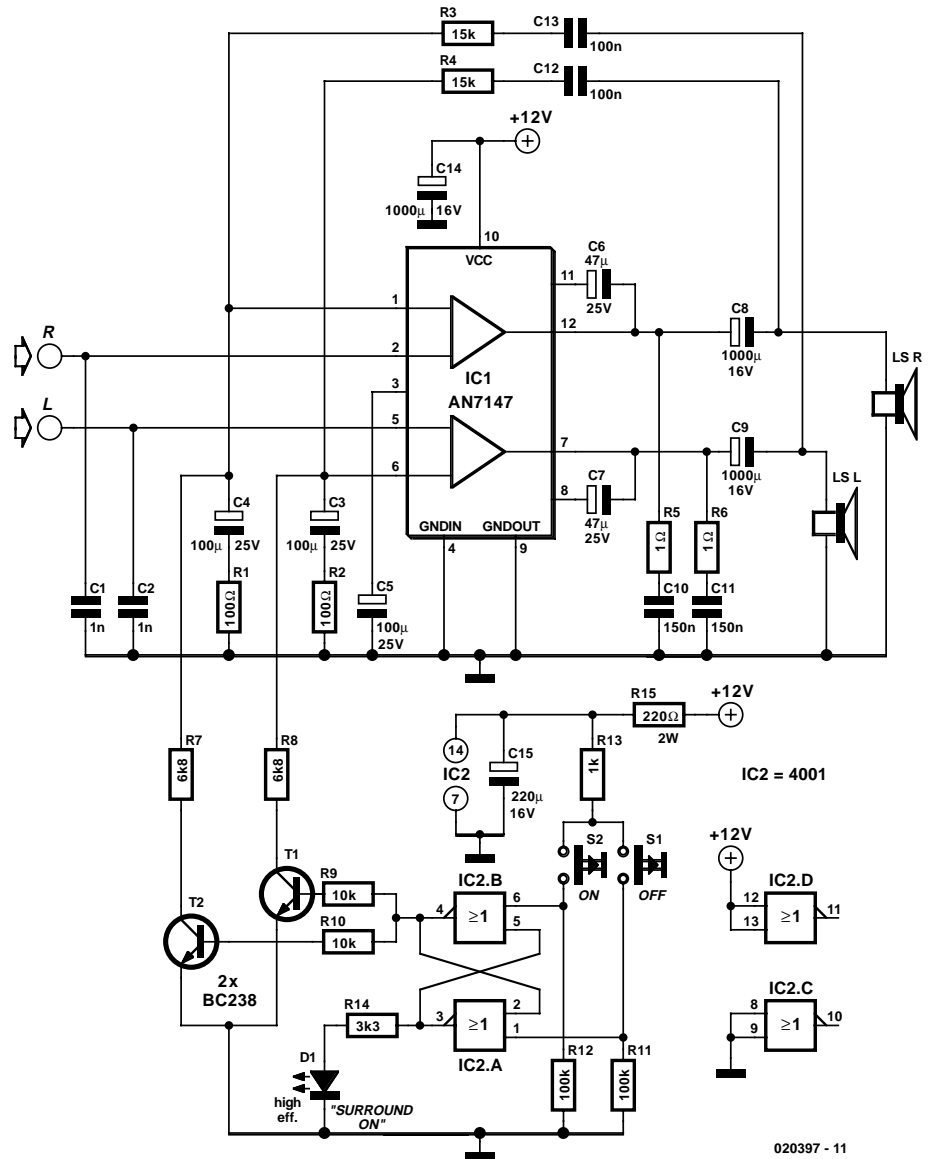
(020397-1)

020397 - 11

In-Vehicle Voltage Regulator 057
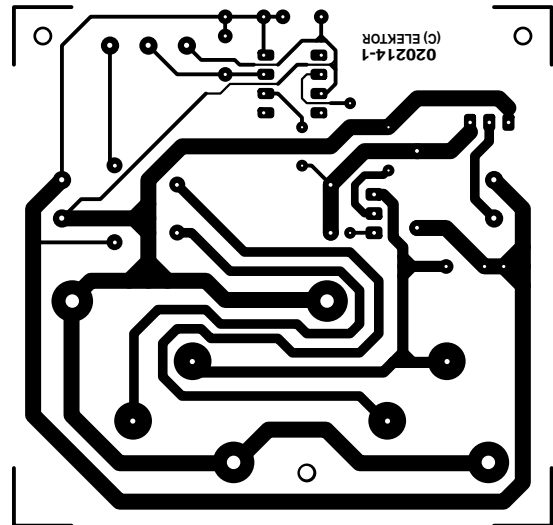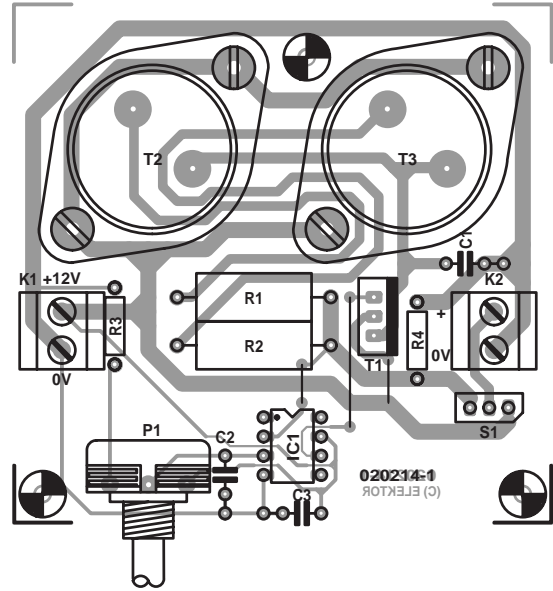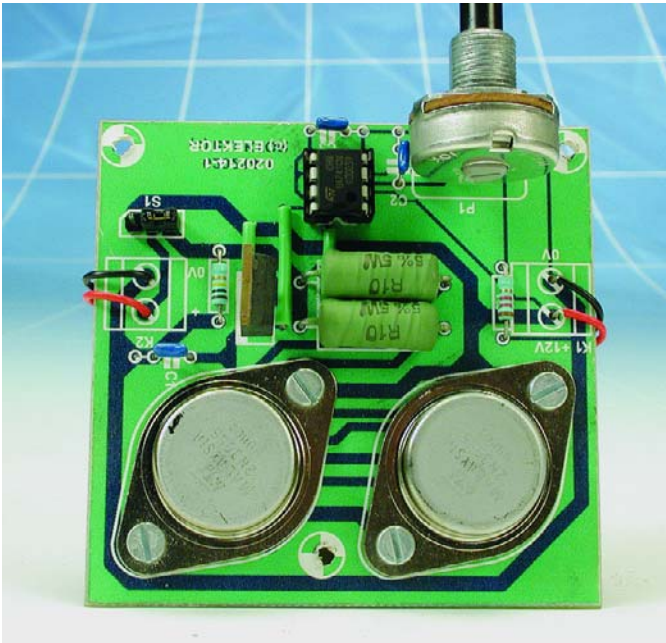
L. Libertin

In vehicles it is often required to have a powerful yet stabilised voltage that's not affected in any way by fluctuations of the battery voltage. The circuit shown here does the job using discrete and inexpensive parts only. While its low cost is a definite advantage over just about any kind of regulator IC, on the downside we have a minimum voltage drop of 2 volts — in fact the output voltage can be set to any value between 1.8 V and about 10 V. Continuous loads up to 100 watts can be handled, while peak values of 140 W should not present problems.

The power stage consists of two parallel-connected 2N3055 transistors in TO-3 cases. Because of their high base current requirement, a driver transistor type BD241B is incorporated.
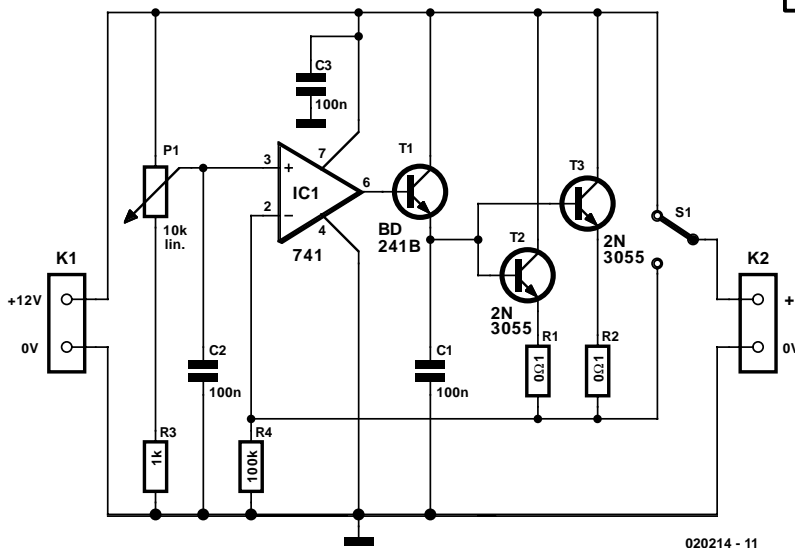
020214 - 11

The feedback voltage arrives at the inverting input of the regulator IC, a type 741 opamp. The level of the reference voltage at the inverting input is adjusted with potentiometer (or preset) P1.

The circuit board, of which the layout is given here, accommodates all parts including the two 2N3055 power transistors. As a matter of course, they should be properly cooled. Remember, the case of a 2N3055 is connected to the collector which is at battery-positive potential.

If necessary the voltage regulator may be bypassed by an external switch connecting the battery + terminal with the output terminal. The switch, if used, should be capable of passing considerable currents — at relatively low output

COMPONENTS LIST

Resistors:
R1,R2 = 0Ω1, 5W
R3 = 1kΩ
R4 = 100kΩ
P1 = 10kΩ linear potentiometer

Capacitors:
C1,C2,C3 = 100nF

Semiconductors:
IC1 = 741CN
T1 = BD241B
T2,T3 = 2N3055 (TO-3 case)

Miscellaneous:
K1,K2 = 2-way PCB terminal block, lead
  pitch 5mm
S1 = switch, heavy-duty, 1 change-over
  contact (see text)

voltages (up to about 6 V) currents of up to 15 A (continuous) or 20 A (peak) may be expected. Although the output current is reduced to 10 A when the 10-V level is approached, it is better to be safe than sorry.
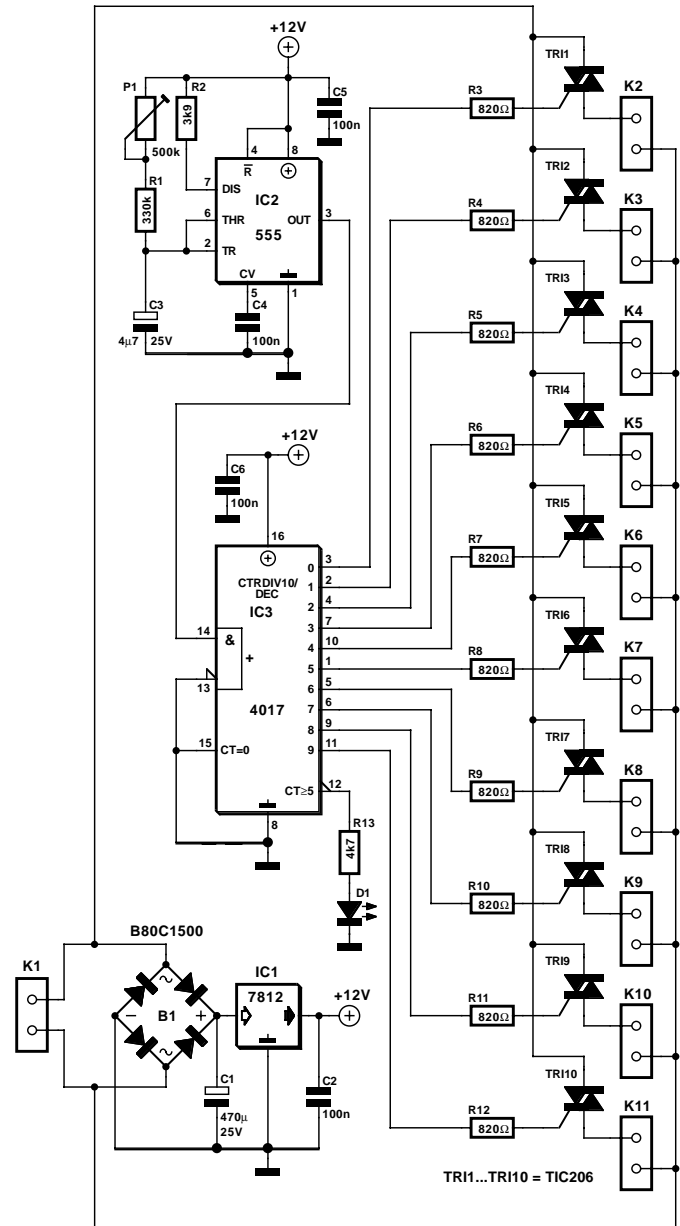
(020214-1)

Railway Points Sequencer 058

F. Pascher

Dedicated model rail enthusiasts using sophisticated train and points controllers often have the problem that as their layouts get bigger and more complex, the transformer supplying power to the points does not have enough current to switch several points at the same time. The actuators in the points are designed for ac operation so it doesn't help by rectifying the supply and adding reservoir capacitors, the coils can overheat and burn out if they get jammed during their travel (ac operation actually helps to overcome friction in the mechanism).

The circuit shown here solves this problem by using a sequencer to ensure than only one points actuator can be active at any point in time. During operation the controller will switch all the points on one line at the same time as usual, but the other connection to each coil is connected to the sequencer unit. This circuit will only allow current to flow through one coil at a time. The sequencer circuit consists of a 555 timer configured as an astable multivibrator clocking a 4017 Johnson counter where the ten outputs are used to switch ten triacs in sequence, enough for ten sets of points. P1 alters the oscillator frequency of the 555 timer and can be adjusted so that each time interval of the sequencer is long enough to allow the points to switch. The switching time varies depending on the type of points but is typically between 1 s and 1.5 s. Any points that jam during switching give out a characteristic humming noise in time to the switching frequency so it makes them easier to find.

The eleventh output of the 4017 can be connected to an LED (together with a series resistor). This will flash to give a visual indication of the sequencers operation. Power for the circuit is provided by 15 V ac from the points transformer. The B80C1500 bridge rectifier (80 Vpiv, 1.5 A) and regulator IC1 produce a stabilised 12 V for the circuit. Current consumption is only a few milliamps.

(020300-1)

020300 - 11

Quad Bridge Car Amp

059

Measurement results

Supply voltage	+14.4 V
Quiescent current	200 mA
Pmax (THD+N = 0.1 %)	4 x 17.9 W
	(1 kHz, 4 x 4 Ω)
Sensitivity (P= 17.9 W)	0.46 V
THD+N	
(B = 80 kHz, 1 kHz, 1 W/4 Ω)	<0.03 %
Bandwidth	24 Hz to 55 kHz

T. Giesberts

If you want to obtain more power at a given supply voltage (such as the battery voltage of a car) and you do not want to resort to a switched-mode power supply or class-H amplifier, your only choice is a traditional bridge amplifier. Various types of integrated versions have been available for years already. New types also appear regularly, such as the ST TDA7375A, which has the advantage that it requires very few external components. This IC is a pin-compatible successor to the TDA7374A, which can also be used in the circuit shown here.

Since many people nowadays are already used to surround-sound amplifiers, and it is common for more than two loudspeakers to be fitted in cars, four channels per module is just about the minimum. This is why we have fitted two ICs on a single circuit board for this design. The two ICs share common input and

power grounds. These two grounds are connected by a 0.1-Ω resistor (R7), in order to limit the undesirable effects of ground loops when two ore more modules are used together.

The inputs have RC networks to suppress RF interference. The four channels can be aligned to each other using the four trimpots. The values of C2, C4, C8, and C10 are twice as great as in a single-ended configuration (see the 'Quad Car Amp' article elsewhere in this issue).

034039 - 11

R3/C5 and R6/C11 ensure plop-free switch-on and switch-off. C6 and C12 decouple the internal voltage dividers, which bias the output stages at half the supply voltage. Both ICs are also well decoupled using separate electrolytic capacitors (C4 and C15). RF decoupling capacitor C13 is shared by the two ICs and located between them.
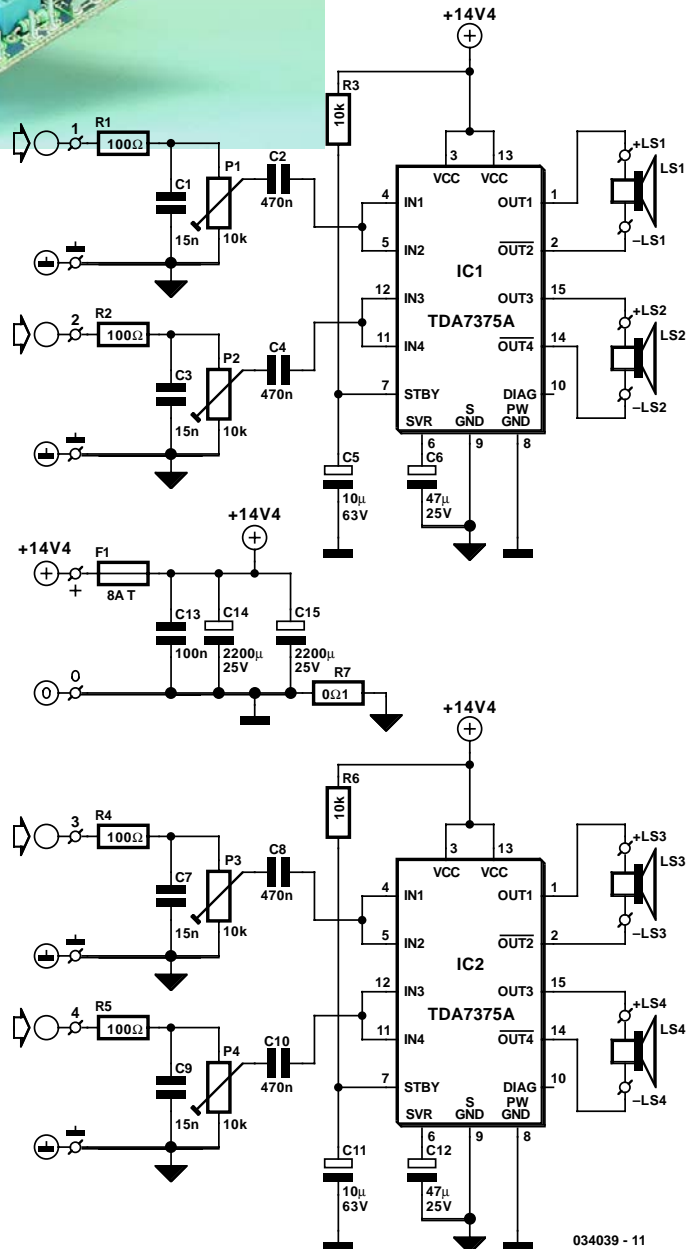
The printed circuit board has been designed to be as compact as possible, with the result that some of the connections are a bit cramped. The loudspeaker connections are located on both sides of the ICs. When connecting the loudspeakers, it is a good idea to cut the cables to the proper length and solder them directly to the circuit board. The power supply connections (which use car connectors) are located at the ends of the fuse holder ('0' and '+'). Don't forget the three wire links, and use insulated wire for the two links underneath the ICs to avoid shorts. The third wire link is right next to R7.

If the amplifier is driven to its maximum output level using four sine-wave signals, it draws 7.7 A! This is why an 8-A fuse is used to protect the circuit. In addition, a heat sink with a maximum thermal resistance of 1 K/W is recommended to provide adequate cooling. When fitting the circuit board, be careful

COMPONENTS LIST

Resistors:
R1,R2,R4,R5 = 100Ω
R3,R6 = 10kΩ
R7 = 0Ω1, 5W
P1-P4 = 10kΩ preset

Capacitors:
C1,C3,C7,C9 = 15nF
C2,C4,C8,C10 = 470nF
C5,C11 = 10µF 63V radial
C6,C12 = 47µF 25V radial
C13 = 100nF

C14,C15 = 2200µF 25V radial, max. diameter 16mm.

Semiconductors:
IC1,IC2 = TDA7375A (ST)

Miscellaneous:
F1 = fuse, 8A/T (time delay) with PCB mount holder
2 fast-on (spade) terminal, male, vertical, solder type (2-pin version)
PCB, order code **034039-1**

with the corner holes next to he ICs. The copper extends to the holes here, in order to keep the circuit board as small as possible, so you must use plastic standoffs to fasten the board. Use insulating washers and rings to attach the ICs to the heat sink, in order to electrically isolate them from the heat sink.

(034039-1)

DirectX for Delphi (DelphiX) 060

P. Goossens

It is hard to believe that it's only been a few short years since the game 'Wolfenstein' made its debut and caused a revolution in the PC game world. This was because the game gave a realistic, for the time, impression of the 3D-world, something that used to be the realm of very expensive CAD software only. Many other games have subsequently been released that also present a 3D-world through which the player can move freely about (only obstructed by various monsters, soldiers, aliens, etc. who are all out to get you). With the rise of Windows, Microsoft has recognised the importance of migrating these kinds of games to the Windows platform. It was time for a new API, so that the operating system became responsible for the display of the 3D-world, because it was not desirable that programs accessed the hardware directly under Windows. This new API has been called DirectX, a complicated piece of interface technology. Later on, the API was further expanded with other functions for the PC game industry. These days there are DirectX interfaces for the joystick (including force-feedback), keyboard and other input devices as well a network interface optimised for game play, sound card interface and much more.

Although this API is primarily intended for games, it is also useful for 'normal' programs. It is possible, for example, to use the network interface for other purposes. Plus, it looks very profes-sional if one or more 3D-objects enhance the appearance of your program. But above all: it is fun and educational to use DirectX. The Japanese programmer Hiroyuki Hori has apparently made an extensive study of the DirectX-material, with the result a package of Delphi-components that make programming of DirectX-applications easier. The installation of these components is done with a setup-program. After installation, an additional tab with the name 'DelphiX' has been added to the components (**Figure 1**).

It is a good idea to study the many examples that are included to see what can be done with all these new components. The examples vary from simple applications (that make it easier to examine the various functions of DelphiX) to very beautiful graphical effects. To illustrate these, **Figure 2** shows the screen dumps of two of the examples: Samples/d3drm/AlphaBlending and Samples/d3dim/Texture.

The file can be downloaded from www.yks.ne.jp/~hori/DelphiX-e.html.

We suggest that you download the three tools on this page as well. These are very handy when converting graphics images or audio to a file format that is suitable for DirectX.

(034031-1)
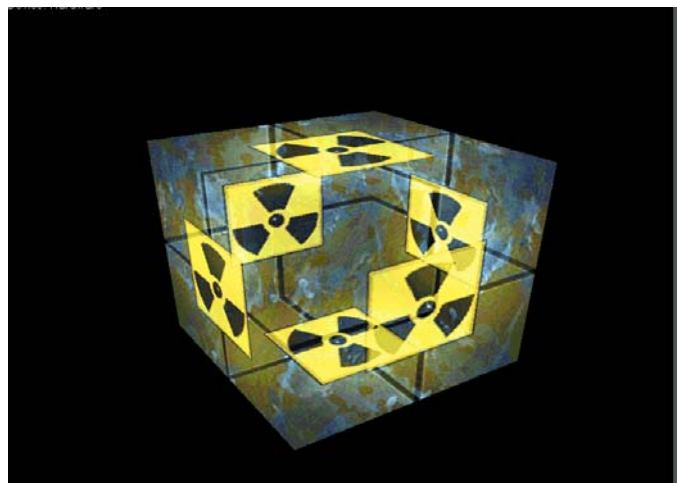
Lights On!

061

R. 't Hooft

This circuit ensures that you will never again forget to switch on the lights of your car. As soon as the engine is running, the dipped beams and the sidelights are automatically switched on. The circuit also causes the dipped beams to be extinguished as soon as the main beams are switched on.

As you can see from the schematic diagram, no special components are needed. When the engine is running, the alternator will generate a voltage of more than 14 V. Diode D1 reduces this voltage by 5.6 V and passes it to the base of T1 via R1. Due to the resulting current, T1 conducts. The amplified current flows via R3, the base of T3 and D3 to ground. This causes T3 to also conduct and energise relay Re1.

If the driver now switches on the main beams, a current flows through D2 and R2 into the base of T2, causing this transistor to conduct. As a result, the voltage on the base of T3 drops, causing T3 to cut off and the relay to drop out. When the main beams are switched off, the previous situation is restored, and the relay again engages.

The dipped beams and the sidelights are switched by the contacts of relay Re1. Diodes D5 and D6 ensure that the sidelights are illuminated if either the dimmed beams or the main beams
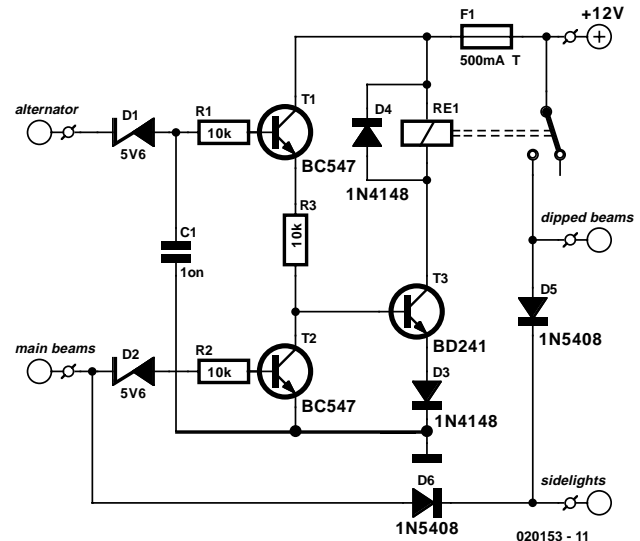
are switched on. In practice, this means that the sidelights will be on whenever the engine is running, regardless of whether the main beams are switched on.

(020153-1)

Processor Fan Control

062

B. v. Gijzen

Fans in PCs can be objectionably loud. In many cases, the amount of noise produced by the fan can be considerably reduced by lowering its speed. Although this will decrease the amount of cooling, this need not be a problem as long as you don't go overboard with slowing down the fan. Particularly with older-model processors, which consume quite a bit less power than the latest models, this trick can be used without any problems.

This circuit is anyhow intended to be used with relatively old PCs, since more recent models generally have a fan control circuit already integrated into the motherboard. These controllers ensure that the amount of cooling is increased if the processor becomes too warm and decreased if the processor temperature is relatively low.

The circuit described here consists of only a handful of components, which you will probably already have in a drawer somewhere. Transistors T1 and T2 are driven into conduction by the base current flowing to the fan via P1 and D1. There will always be a current flowing through R1, and it will be approximately 120 times as large as the current through R2. R3 has been added to prevent the base current of T2 from becoming too large when
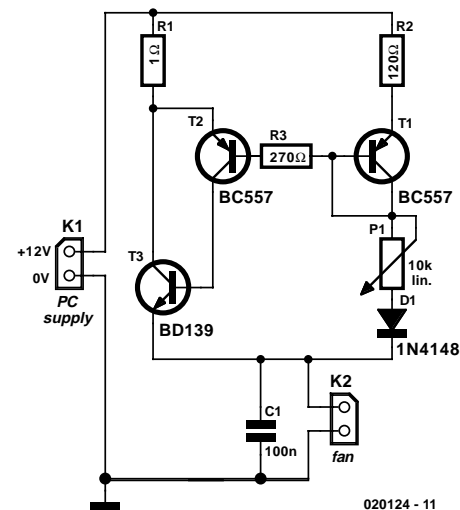
020124 - 11

P2 is set to its minimum resistance. D1 ensures that even at this extreme setting, the voltage on the base-emitter junction of T3 will still be large enough to allow it to conduct.

(020124-1)

Longwire Match for SW Receivers 063

S. Delleman

Most shortwave receivers for use 'in the shack' have a 50-_ coaxial input (usually a SO239 socket) which is not directly suitable for the high impedance of a typical longwire antenna. The problem is usually overcome by inserting a balun (balanced to unbalanced) transformer whose primary purpose is to step down the antenna impedance from 'high' to to 50 Ω and not, as would be expected, to effect a change from balanced to unbalanced (note that a longwire is an unbalanced antenna). Unfortunately, such a balun may be difficult to obtain, make yourself, or both.

The circuit shown here is a transistorised (i.e., inductor-free) equivalent of the wire balun. The grounded-collector configuration is used because a relatively high input impedance (the longwire antenna) has to be stepped down to 50 Ω (the receiver input impedance). Voltage amplification is not required here.

The two anti-parallel diodes at the antenna input prevent damage to the circuit as a result of static discharges or extremely strong signals.

Like an active antenna, the circuit receives its supply voltage (in this case, 9 V) via the download coax cable. Current con-

sumption will be of the order of 20 mA. The coax cable should be earthed at the receiver side.
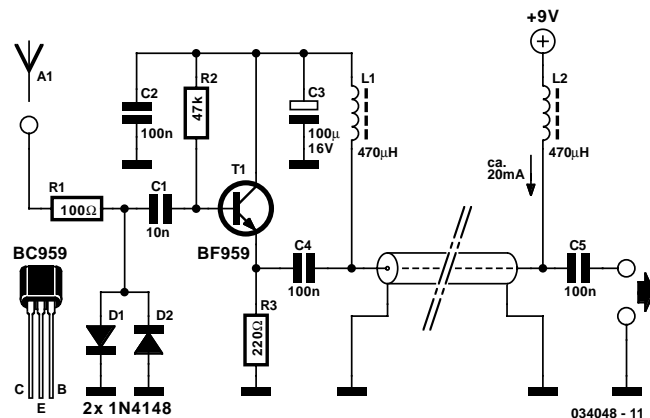
The length of the antenna wire will depend on local conditions and what you hope to be able to receive. For most SW broadcast service and amateur radio listening, a wire of about 3 m will be sufficient but bear in mind that the longwire antenna is prone to pick up electrical interference.

(034048-1)

Mini Test Chart Generator

A video test chart for less than a tenner

Design by F. Simonnot

Recognise this? You have to adjust a television or monitor but do not have access to the required tools… This small test chart generator for less than a tenner is then just the bee's knees.

The circuit described here is actually just a standard video signal generator that can be used to synchronise a television or monitor, provided that the equipment being tested is fitted with a composite video signal (CVBS) input. All the timing and corresponding signal levels are generated by a PIC12C508 microcontroller.

This circuit also has a second function. Many video recorders can record stereo sound. It is interesting to exploit this property to make a good quality recording from a radio broadcast, potentially using the recorder's built-in timer. Unfortunately, modern video recorders switch to a background colour when they do not sense a proper video signal at their input. This prevents noise from being recorded, but at the same time the audio signal is also ignored!

Only a small amount of electronics is required to generate a signal that fools a video recorder into thinking that a nice and stable video signal is present at its input.

Finally, we can use the circuit as a simple and reliable stand-alone tester when tracking down video problems.

The schematic

Is it really that easy to generate a video signal with a PIC12C508? As shown by **Figure 1**, a video raster line lasts 64 µs. The start of the line is formed by a sync pulse of about 5 µs duration, followed by a horizontal level of also 5 µs, then follows the actual video signal and finally finishes with a constant level
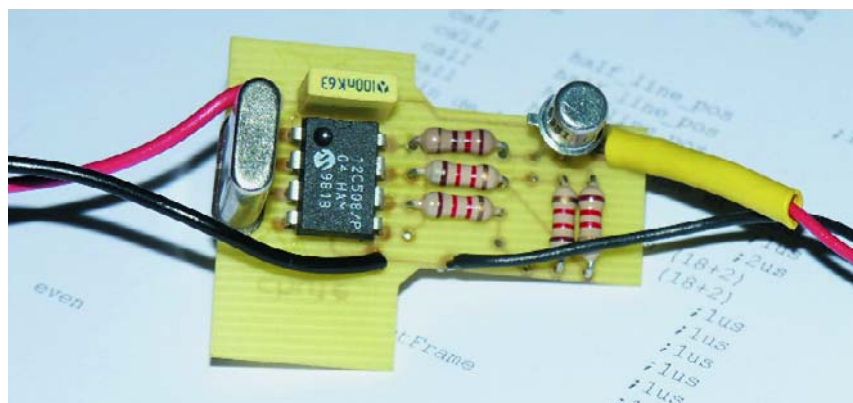
of about 2 µs (this circuit does not generate a sync burst). A small calculation shows us that the length of the 'visible' line is:

$$64 - 5 - 5 - 2 = 52\ \mu s$$

Although the PIC12C508 can't be accused of being a speed devil, its capabilities (1 instruction per µs at a clock of 4 MHz) are more than sufficient to do what is expected of it. In addition, because if its RISC-architecture (Reduced Instruction Set Computer) it is eminently suitable for synchronous applications.

The number of necessary signal levels is 3: the level for the sync pulse, the level for black and the level for white. The relative amplitudes between black and black/white are 33 and 66% at 1 V

and 75 Ω.

Since the PIC12C508 does not have an on-board D/A converter, we will have to make a kind of DAC ourselves with the aid of a few resistors. By connecting resistors with a value of 1k2 to two outputs of the PIC12C508, we get an output voltage V_{out} of 1/3 V_{CC} (2MSB+LSB), where the MSB is GP0 and the LSB is GP1. When using a 4.5-V battery this generates the following signals: 0 V for the sync pulse, 1.5 V for black, 3 V for grey and 4.5 V for white — values that correspond exactly to the PAL TV standard, which defines the sync pulse as 1/3 of the total amplitude of the signal, and 66% for white.

Transistor T1, connected as an emitter follower, lowers the impedance of the video signal at the output

Figure 1. The constituent parts of one raster line of a video signal.

Figure 2. The electronics for the circuit does not amount to much.

Figure 3. Layout and component overlay for the printed circuit board for the mini test chart generator.

COMPONENTS LIST

Resistors:
R1-R4= 1kΩ2
R5= 120Ω
R6= 75Ω

Capacitors:
C1= 100nF

Semiconductors:
T1 = 2N2222
IC1 = PIC12C508C (Microchip)

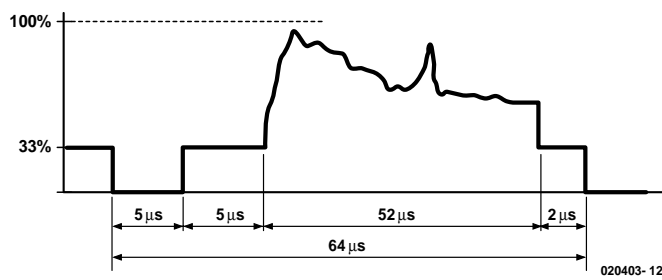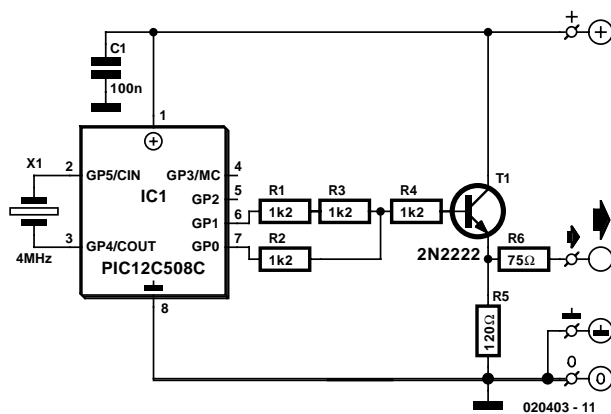**Miscellaneous:**
X1 = 4MHz quartz crystal
Disk, PIC program, order code
020403-11 or Free Download

to almost 75 Ω. Nothing else is required to generate a good quality black and white video signal.

The PCB

A quick glance at the PCB in **Figure 3** shows that there are quite a few differences between our design and the author's design (refer photo at the beginning of this article). The missing bottom resistor is explained by the fact that it is incorporated in the wiring for the output (it is hidden in the small piece of shrink sleeving).

The PCB is not available via Readers Services, but can be ordered from The PCBShop via the *Elektor Electronics* website. Alternatively you can etch a board yourself, based on the printed layout (also available from www.elektor-electronics.co.uk). But the number of parts is so small that it is also very easy to mount them on a small piece of prototyping board and connect them according to the schematic.

The program in the PIC

As already noted, the program in the PIC has to be synchronous, because the core of the PIC12C508 cannot service interrupts (INT). And even if it were capable of doing that, it would not be fast enough: at 4 MHz a PIC carries out one instruction per μs. What performance can we expect from this microcontroller? A video line lasts 52 μs, which corresponds to the time it takes to execute 52 instructions. Because of the structure of the DAC, it is not possible to use the BCF and BSF instructions. We therefore have to use movlw xx followed by movwf GPIO, so that it takes 2 μs to change from one level to another. The resulting minimum dimension of the 'pixel' to be displayed is therefore 625×(4/3)×2/52 = 32 columns. How did we arrive at this number? The display aspect ratio of 4:3 results in 625 video lines in 830 columns. 830 columns in 52 μs corresponds with 16 columns per μs and therefore 32 columns per 2 μs. The duration of the main loop is exactly the same as the period of the raster frequency, 20 ms.

The author decided to select a checkerboard pattern of alternating black and white fields. This is particularly useful when fault-finding two frequently occurring situations: checking the convergence of a doubtful picture tube and checking the electron guns.

The program consists of several calibrated waiting loops (to make economical use of the available ROM space) and two routines to generate the video lines. One is called 'chess' and the other is called 'inv_chess'. The alternating black and white squares displayed on the screen are generated using macro commands.

Figure 4 shows the flow diagram of the program inside the PIC, the source code of which is available from our website or may be ordered on floppy disk (order code **020403-11**).

Some notes

This circuit takes some liberties compared to the proper video standard. The standard makes a distinction between the even and odd raster lines and the composition of the retrace lines. Here, the same raster lines are being generated all the time, but that should

Figure 4. Flowchart for the program inside the PIC.

Table I. Elements of a picture line

Time (µs)	level	instruction	comment
–1	black	macro TOPLVL	end of previous line
0	sync.		start of sync pulse
1	sync.	return	duration 7 µs
2	sync.		
3	sync.	decsfz line_count	
4	sync.	goto $-2	
5	sync.		
6	sync.	macro BLCKLVL	end of sync pulse
7	black		start of back porch
8	black	call inv_chess	duration 5 µs
9	black		
10	black	nop	
11	black	macro WHITELVL	end of back porch
12	white		start of visible content
13	white	macro BLCKLVL	duration 52 µs
14	black		
15	….		
62	white	macro BLCKLVL	
63	black		front porch
64	black	macro TOPLVL	duration 2 µs
65	sync.		

quence of the structure of the PIC.

For clarity, **Table 1** shows the elements of a picture line.

The construction

There is not much to say about the mounting of the components. The circuit can be realised whichever way you see fit. Once everything is finished, and the PIC has been programmed, the circuit can be tested. After a 4.5-V battery has been connected to the points next to the crystal (observe the correct polarity) the only other thing remaining is to attach a short length of coaxial cable to the output pins. The other end of the cable is fitted with a cinch connector. Modern televisions and video recorders often have cinch connectors, but if you prefer to use a SCART connector instead, then the video signal is connected to pin 20 and ground to pin 17. If, after you connect the circuit to a TV, the pattern of **Figure 5** appears, then everything is functioning correctly (both the electronics and the program).

Getting acquainted with the PIC12C508

The PIC12C508 from Microchip, which has only 8 pins, is one of the smallest microcontrollers currently

on the market. The PIC12C5xx family contains, in addition to the '508, the '509 and '518. The '508 has an EPROM size of 512 words of 12-bit width and a RAM of 25 bytes. The instruction set for this family comprises only 33 instructions. The '509 has a 1024-word EPROM and 41 bytes of RAM. The 'CE518 and 'CE519 are versions with a data-EEPROM of 16 bytes. The members of this semiconductor family carry out every instruction in one processor cycle (that is 1 µs with a crystal frequency of 4 MHz).

A more recent version is the PIC12C508A, and also the 12C509A.

For extensive information about this subject we recommend that you visit the Microchip website: www.microchip.com/1000/pline/ picmicro/category/digitctrl/8kbytes/ devices/12c508/

(020403-1)

not cause any problems in practice. Another liberty compared to the standard is the assembly of the line itself: a sync pulse actually lasts 7 µs (instead of 5 µs), a conse-
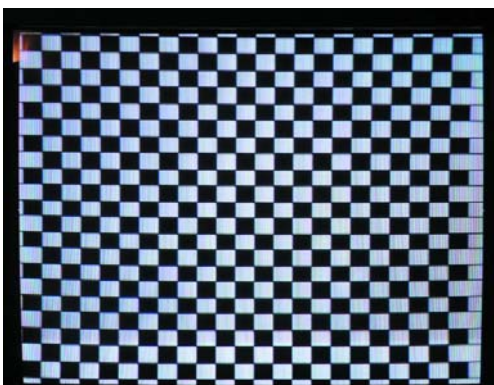

Figure 5. This picture will appear on your TV after connecting the circuit.

Building RF Circuits

Try the Manhattan method

By G. Baars

It's not essential to use a printed circuit board when building RF circuitry. There is an alternative method, in which a piece of unetched circuit board material is used as a foundation for constructing the circuit. In certain situations, this method is even preferable to using a regular PCB, particularly when high frequencies are involved.

However, RF signals sometimes behave in their own particular manner, and this must be taken into account. A number of rules are thus indispensable in order to avoid undesired effects. This article describes how the Dead-Bug construction method can be optimised for RF design and points out a number of essential details. The result is a component mounting technique called 'Manhattan' for reasons which are quite obvious!

Preparation

To start with, you have to saw a suitably sized piece of PCB material. It should not be too large, but it should certainly not be too small. Next, the board must be thoroughly cleaned. This can be done using a scrubbing sponge with lukewarm water and a scouring agent, such as Cif or Vim, but a bit of steel wool or a piece of fine sand paper can also work wonders (see **Figure 1**). Some companies sell a 'Poliblock' for this purpose, and it also gives excellent results.

Once the board has been thoroughly cleaned, it can be silver plated if desired. You can buy liquid silver-plating preparations that only have to be lightly rubbed on using a

With what radio amateurs like to call the 'Dead Bug' construction method (which is also called 'Ugly Construction'), the components making up the circuit are simply soldered to each other 'suspended' in the air, with the copper surface of a printed circuit board serving as a ground plane. Solder islands can be created at strategic locations by milling away the surrounding copper foil, or by cutting small pieces of PCB material and attaching them to the ground plane

with crazy glue or double-sided adhesive tape. This avoids the need to design a printed circuit board, which means that you can work faster and still achieve amazingly good results. This type of construction is particularly handy for prototypes, since it's easy to make changes to the circuit and components when the Dead-Bug method is used.

Figure 1. The printed circuit board material must always be scrubbed to obtain a clean surface.
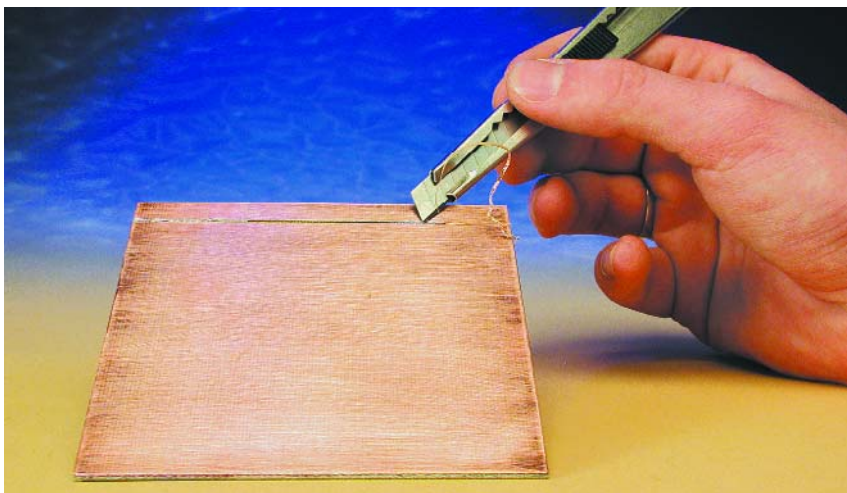
Figure 2. A small portion of the board can be isolated from the rest using a hobby knife or a router, so that it can be used as a supply rail or for some other purpose.
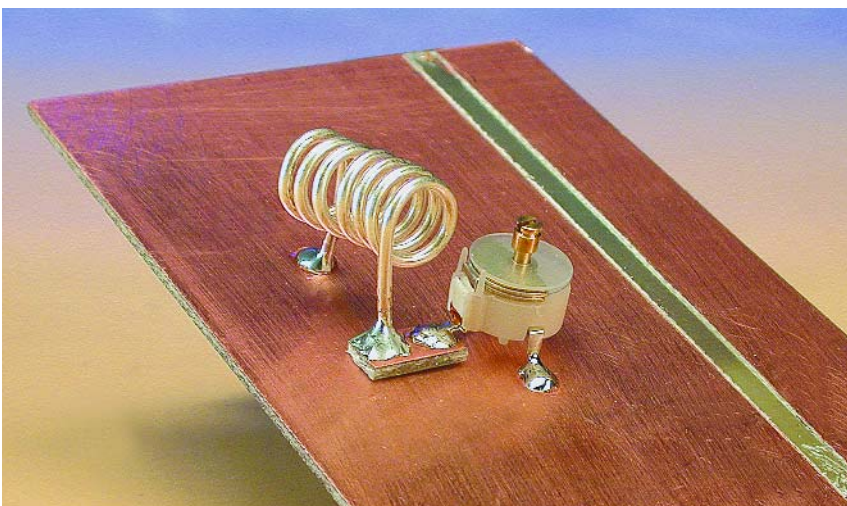
Figure 3. Coils must always be elevated a few millimetres above the board. The 'hot' end can be attached to an island.

cotton bud. This produces a thin silver coating on the surface of the circuit board, which can later be used for soldering in the usual manner. However, silver plating is by no means essential, especially if very high frequencies are not involved.

On the other hand, it is a good idea to coat the circuit board with a layer of PCB lacquer. This keeps the board nice and shiny, so that it can still be soldered even years later.

It's sometimes handy to isolate an edge of the board from the rest. The isolated portion can then be used as a supply rail. An edge can be readily isolated by making two parallel cuts in the copper foil with a knife and then prising out the copper between the cuts (see **Figure 2**). An easier method is to use a minidrill with a small routing bit.

The real work

Now you can start building. If you have a schematic diagram, it's best to start with the input portion, which is usually located at the left-hand side of the drawing. If the first stage is an RF input amplifier, for instance, with its input and output tuned using trimmers and air-core coils, it is advisable to fit the coils at right angles to each other. This minimises the coupling between the coils, thus reducing the tendency of the stage to oscillate.

In such cases, a small screen is often fitted above the amplifier between the input and output circuitry, in order to eliminate feedback. It can be made from a piece of PCB material around 2 to 3 cm high, which is soldered directly to the ground plane.

Self-supporting coils are best made from silver-plated copper wire with a diameter of approximately 1 mm. If the 'cold' end of the coil is connected to ground, it can be soldered directly to the ground plane, which provides adequate mechanical strength. If one end of the coil must be connected to the supply rail or something other than ground, an island can be created using a small piece of PCB material or some other method, in order to adequately support the coil. A trimmer or other component can then be soldered to this island as well (see **Figure 3**). Naturally, if you have a minidrill and a small router bit, you can simply rout out an island where you need it.

While we're on the subject of trimmers, whenever you use a foil (PTFE) trimmer, you should always rebend the middle lead at a right angle so it can be used a solder point for another component, such as the 'hot' end of a coil. The other two leads can then be soldered to the ground plane (for example). If these two leads are not connected to ground, a small island can again be used to support the trimmer.

Short connections

When working with RF circuits, it's always a good idea to keep signal-carrying connections as short as possible. Good decoupling is also necessary, and it is important to solder the decoupling capacitors as close as possible to the transistors or ICs carrying the signal. Small ceramic capacitors are preferable, since they allow the connections to ground to be kept short.

You should bear in mind that a length of wire has an intrinsic self-inductance of around 10 nH per centimetre. At relatively high frequencies, this inductance can easily become significant if adequate decoupling is not present. Decoupling also prevents feedback via the supply rail, which can cause oscillations and other side effects. At very high frequencies, it is advisable to use SMD capacitors for decoupling. They have better characteristics than other types of capacitors, such as multilayer (film) capacitors.

With the dead-bug method, it is also highly advisable to keep the circuitry fairly low and close to the surface of the PCB material, which serves as a ground plane. This shorts out possible interference fields, thus reducing the likelihood of radiation and feedback. However, coils must always be fitted a few millimetres above the surface of the board, since otherwise their fields will be short-circuited (which reduces their self-inductance and increases damping). This applies to DIY coils as well as ready-made E12 miniature chokes.

Rigid construction

Another factor that plays a role in certain circuits is mechanical strength. For instance, a VFO (variable frequency oscillator) circuit must be built in a mechanically rigid manner in order to avoid detrimental effects on its frequency stability. There must be no noticeable effect from a shock or blow. For this reason, special attention is often given to the resonant circuit of a VFO. For instance, the coil is often wound on a ceramic form, and if the coil is small, heavily silver-plated copper wire is preferred. VFOs are also commonly fully screened using sheet-metal enclosures, with the advantage that the amount of electromagnetic radiation is reduced and the circuit is screened from air movements. This is important, since moving air may cause undesired temperature changes that can produce frequency fluctuations.

Fitting semiconductor devices

Various methods can be used to fit ICs. Some builders prefer to mount them flat on

Figure 4. With a few homemade islands, a complete circuit can be built quite quickly using the Manhattan method, which may be described as an RF-optimised variant of Ugly Construction.

their backs with their leads in the air, and then solder all the other components to the leads. The disadvantage of this method is that the arrangement of the IC leads is a mirror image of the usual arrangement, which can be somewhat inconvenient in practice.

Another method is to rebend all of the leads of the IC (except the leads connected to ground) at right angles to the package and then clip off the narrow ends of the leads. This produces convenient solder islands, as can be seen in the title illustration for this article. The easiest way to bend the leads is grasp them ten at a time using flat-jawed pliers. All of the wide portions of the leads must end up being perpendicular to the package once they have been rebent.

Working with SMD devices is somewhat more difficult, but certainly not impossible. It is often possible to directly solder to the leads of an IC with eight pins at a 50-mil pitch, for example, but if more pins are involved or a finer pitch is used, it is recommended to make an adapter board. Such an adapter board can convert the SMD lead pitch to a standard DIP pitch with 100-mil spacing, which is easy to solder to.

As a rule, transistors can be best placed flat against the circuit board, as illustrated in **Figure 4**. The outer

leads are bent at right angles to the left and the right, so that they act as 'solder pillars' for the following components. Voltage regulators in the common TO220 package can also be quite readily fitted flat against the surface of the board, which provides the extra benefit of improved cooling.

In the case of RF power amplifiers, the transistors that are used often have rather wide leads. They can be supported using (you guessed it!) small islands sawn from PCB material and attached to the circuit board, which can also serve as solder points for other components. It is also possible to cut or rout islands in the copper foil of the base circuit board, as previously described. This is a difficult job with a hobby knife, but with a minidrill and a small routing bit it's a piece of cake.

Conclusion

If there are connections that carry heavy currents, such as a supply connection or a loudspeaker connection, it is preferable to use a 'star' grounding point. The advantage of using star points is that the connections in question are individually routed to the central grounding point. This prevents the generation of undesired ground currents that could have detrimental effects on the circuit.

(030032-1)

Real-Time Clock

For the 89S8252 Flash Micro Board

Design by M. de Martelaer

This article was an entry to the Flash Competition of Elektor Electronics, and describes how a real-time clock (RTC) can be implemented in software, without using any dedicated RTC peripheral ICs. Since we also have to take account of drift, summertime and wintertime, an automatic synchronisation has been included with the DCF time signal transmitted from Frankfurt, Germany (range 1,000 miles).

All of the operations of this 'circuit' happen at the interrupt level. In this way it can be added easily to a larger application where it provides the correct time without disturbing the main program. Since a DCF receiver is used to obtain the time, there is no need for any buttons to set the time when the microprocessor system is started.

An application has been included as an example. Every second it:

- – updates the LCD display with the correct time,
- – transmits the time through the serial port.

To polish this project off, a Windows program was written (in Visual Basic), which displays this time on the PC screen and sets the PC clock.

The microcontroller software is written in Basic, which is converted into machine code by the BASCOM compiler. The following description should make it possible for anybody to convert the routines into another language of their choice.

Resources

The program requires just a single 16-bit timer for the clock and one I/O pin (digital input) to read the output of the DCF receiver.

The DCF seconds signal is provided by a ready-made receiver module from Conrad Electronics (www.int.conradcom.de), this
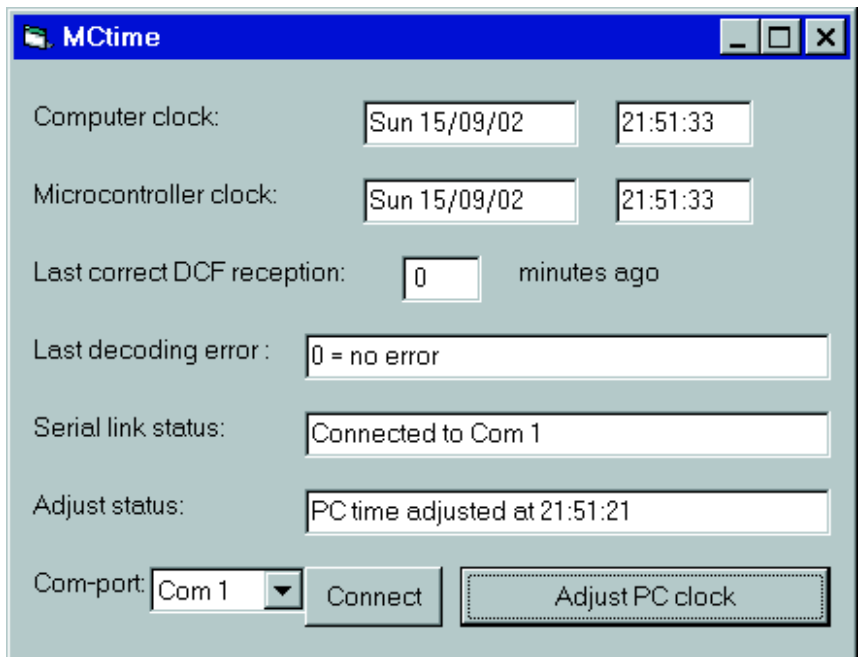
Figure 1. The PC clock can be synchronised using the 'Adjust PC Clock' button.

is cheaper (approx. £6.50) and easier to obtain than the individual parts and also prevents many problems.

The example program also makes use of several other I/O pins: an LED that flashes every second, an LED that shows the DCF pulses and finally the serial port to the PC.

Operation of the RTC

We've used an internal timer in interval mode. In this mode the timer/counter is incremented by 1 for every processor cycle, which is every 12 crystal pulses.

As we're using an 11.0592 MHz crystal this happens 11,059,200 / 12

= 921,600 times per second.

Since we're working with 16 bits, there will be an overflow after the timer reaches a value of 65,535. At that moment it will be reset to zero (or another predefined value) and an interrupt occurs. This interrupt should therefore occur 921,600 / 65,535 = 14.06 times per second.

This, however, is not a good value to use for a clock tick. The nearest, higher, round value is 20 times per second, which gives a period of 50 milliseconds. This can be realised by configuring the timer such that it resets earlier: 921,600 / 20 = 46,080.

If we can set up the timer such that it resets after 46,080 cycles, we obtain a clock that ticks every 50 milliseconds. There will still be some drift due to the inaccuracy of the crystal and the software overhead.

The value at which the timer resets is not adjustable: this is always 65,535. It is however possible to vary the starting value. This will therefore no longer be zero, but: 65,535 − 46,080 = 19,455.

For a very precise clock, the starting value of the timer should be adjusted slightly to overcome its deficiencies. (See later). Increasing the starting value makes the timer reset earlier, causing the RTC to tick faster and vice versa. On top of this is the DCF synchronisation, which provides the correct time every minute when there is a good reception.

In the interrupt routine that is called every 50 milliseconds, it is a simple task to count the clock pulses to make seconds, the seconds to make minutes, and the minutes to make hours. Updating the date is much more difficult. For this reason the date is always set to what was sent by the DCF transmitter. If the DCF signal drops out, the date will remain the same. For most applications this is acceptable, but if a date routine is required you will have to add this yourself.

The DCF signal

The DCF77 transmitter near Frankfurt in Germany transmits an AM modulated signal at 77.5 kHz in the VLF band. The signal can be received at least a few times every day in most of continental Europe,

Scandinavia and the south-east of England. Every second a new bit is transmitted by reducing the amplitude of the carrier to 25 percent. The length of this amplitude reduction determines the value of the transmitted bit: 100 milliseconds is a '0' and 200 milliseconds is a '1'.

The DCF receiver converts the amplitude changes into pulses on its open collector outputs. There is a non-inverting output (high during the pulsing of the DCF transmitter) and an inverting output (drops to 0 Volt during the pulsing).

A description of the bits transmitted in the DCF77 signal can be found in the 'DCF-controlled LED clock' article, published in *Elektor Electronics* May 1998.

Decoding the DCF signal

The non-inverting output of the DCF receiver is connected to a digital input (in this case P3.3). We have already mentioned in the main description of the RTC that an interrupt is called every 50 ms. This routine is also used to poll the level at the input pin.

A '0' bit is recognised when the input is high for one or two clock ticks (100 ms pulse), and a '1' bit when it is high for three to five clock ticks. If we can't detect a high state for a period of 30 ticks (= 1.5 s), we know that the time message is at an end and that the next pulse signifies a change in minutes.

Of course only those bits that are required to extract the time and date are decoded from the 59 bits.

Implementation of the RTC

This takes place in the very first and last sections of the 'Clocktimeroverflow' routine. First the timer register has to be set. After an overflow this should be set to the calculated value. Since other interrupts may occur in the application which our clock is part of, it is best to add the reset value on to the value found in the timer register. The jump to our timer routine could have been delayed if another interrupt was already in progress (at the same or a higher priority). In the meantime the counter will have passed zero. An accurate

clock will take this into account: we read the value of the timer register, add on the reset value and write back the total.

The constant 'Reset_value' should in theory be set to 19,455 as was determined earlier. This is however increased by an offset value. In our example this is 150 and its function is to absorb the software overhead. After all, a number of instruction cycles pass between the reading and writing of the timer register, during which the timer doesn't run. The extreme case when the timer interrupt is serviced too late is checked for as well. The error variable 'Dcferror' then contains 15. In this case the RTC is not compatible with the main program: the interrupt routines of the main application are then taking more than 50 milliseconds to complete.

Since an 8052 processor has at least two interrupt priority levels, it is best to set the Timer0 interrupt to the highest priority. The other interrupts are set to the lower (default) priority. In this way a long interrupt in the main program won't affect the operation of the RTC. Instead, they are momentarily interrupted by the Clocktimeroverflow interrupt routine.

Operation of the DCF decoder

Many errors can occur during the minute-long coded message. These are made known through the error variable Dcferror; it is defined at the beginning of the BASIC file.

The BCD coded values are converted into decimal, pulse by pulse, in the 'Increment_dcf' routine. This is found right at the end.

You should also take care with the use of the Return statement in the interrupt routine: this may only occur once. The first Return statement is converted by BASCOM into the RETI assembler instruction. Any others following won't be, causing the program to fail, even though it compiles. If we want to exit the Clocktimeroverflow routine early we have to use a Goto instruction to jump to the label 'Clocktimeroverflow_return', which is where the only Return instruction is.

Reading the time

The time variables should be copied all at once to your own variables if you want to obtain a consistently reliable time. During this copying the timer interrupt should usually be disabled. In the example program (LCD and serial port) this isn't necessary because we only make use of the time directly after a change in seconds.

You should also make sure that the variable 'Dcfsince' is smaller than 255, otherwise
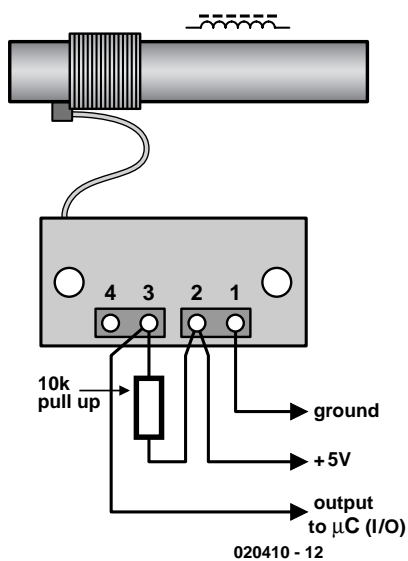
Figure 2. The DCF correction is provided by a ready-made receiver module.

the time is no longer valid.

The LCD and serial port

For diagnostic purposes the values of the RTC are shown on the LCD display. This LCD is connected for use with BASCOM (unfortunately, at the time of writing the author did not have the latest version of BASCOM which can configure the LCD pins on the Elektor board).

The first line of the display shows the time and the number of minutes since the last correction (S = since). The second line contains the date and the last error code (E = error):

    14h1m10s S:0
    Fr 18/10/2 E: 0
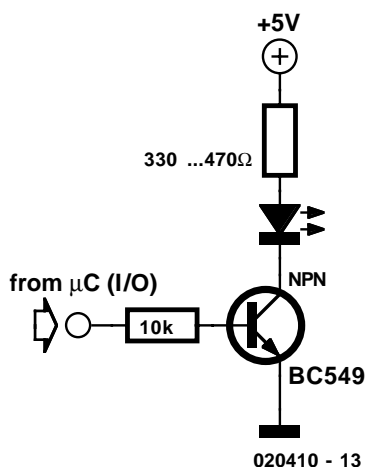
Figure 3. The LEDs are driven in the simplest way possible.

This is where we find a limitation of BASCOM: the length of the lines varies depending on the values of the time and date. The Print and LCD statements can't be used to display values in leading zero or leading space formats. The 'Print Using...' instruction found in Qbasic is not available in BASCOM either.

Every minute the date and time are transmitted from the serial port in the following format (ASCII):

Byte no.
1-3: Header Text: 'DCF'
4: Day of Week.
  1 = Monday, etc.
5-6: Day (1-31)
7-8: Month (1-12)
9-10: Year (0-99)
11-12: Hours (0-24)
13-14: Minutes (0-60)
15-16: Seconds (0-60)
17-18: Error code from DCF reception
19-21: Number of minutes since the last correctly decoded message
22-23: Checksum (0-98)
24-25: Terminator string:
  Carriage-Return /LineFeed

The checksum has been added because a parity bit cannot be implemented easily on the 8051. This value is calculated as follows: we first calculate the sum of all values sent (Day of Week + Day + Month + Year, etc.). We then take the remainder of this sum after dividing it by 99. This results in a number having two digits.

The 'Print Using...' statement can't be used here either. Any leading zeros are added manually because the message length has to be constant.

The PC program

The instructions for using the PC program are very simple: first choose a COM port and then press the 'Connect' button. If the last correctly received DCF message occurred less than 255 minutes ago, the PC clock can be synchronised using the 'Adjust PC clock' button (see **Figure 1**).

It is also possible for the connection and the synchronisation of the PC clock to happen automatically.

For this, you'll have to add the following parameters when starting the program from a DOS window, batch file or shortcut:

/comx: Automatic connection to the specified COM port, without the need to press the 'Connect' button. For example: /com1.

/boot: Automatic setting of the PC clock, without the need to press the 'Adjust PC clock' button; the program then exits. This option can only be used in conjunction with the COM port option. It is used to set the PC clock to the DCF clock every time Windows starts.

/min: The program starts 'minimized' and the window is not visible. This keeps the program in the background when used with the /boot option.

The baud rate of the COM port is automatically set to 19,200 bps, 8 bits, no parity, 1 stop bit.

Hardware connections

DCF input: P3.3 (req.)
Seconds LED: P3.4 (opt.)
DCF control LED: P3.5 (opt.)
A 16*2 LCD display connected for use with BASCOM (optional).

Figures 2 and 3 show the connections to the DCF receiver and the LEDs respectively.

Practical matters

Keep in mind that the PC, and especially the monitor, can cause interference in the DCF receiver. They should preferably be placed apart by at least one metre. At unfavourable locations the reception can leave something to be desired. In these cases it is recommended to place the DCF receiver as high as possible (e.g. in the attic). And finally, don't forget to connect the pull-up resistor to the receiver, shown in figure 3.

(020410-1)

Note:

The software for this project is free and may be obtained via our website at www.elektor-electronics.co.uk, file number 020410-11. Select Free Downloads, then month of publication.

I²C General Purpose Driver Interface

with a practical application

By W. Huiskamp

The I²C interface has become a popular way to hook up external devices to microprocessors. However popular the I²C bus may be, there are still many peripherals that use a parallel interface. This article presents a low-cost I²C port expander that can be used to control peripherals without an I²C interface. Our example shows how to connect the General Purpose Driver Interface to an alphanumeric LED display.
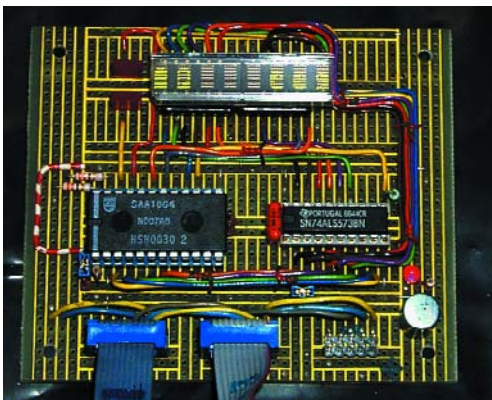
Note: The circuit and software described in this article have not been tested in the Elektor Electronics design laboratory.

I²C slave devices range from simple input/output ports to complex parts like EEP-ROMs. Devices without an I²C interface can be connected to the I²C bus by means of a Slave microprocessor with I²C hardware. This solution makes the slave 'smarter' and takes some load off the main processor but the dis-advantages are that a Slave microprocessor adds cost to the system while software needs to be developed for both the Master and Slave processor. I²C port expanders are a good alternative to interface peripherals to the I²C bus.

Hardware Concept

I²C port expanders translate I²C messages into 8 bits of parallel data. The best known I²C port expander is the PCF8574. This device can control slaves like character LCD's using the '4 bit' mode of the HD44780 [1]. However, many slave devices need a wider interface: 8 bit databus, some address bits and several control lines. Two or more PCF8574's could do the trick, but it quickly results in costly hardware and unwieldy software. Our design employs the SAA1064 device, which has two 8 bit ports capable of driving LEDs directly (see **Figure 1**).

The SAA1064 is normally used in multiplex mode, allowing direct drive of 32 LEDs (see [2]). The device can also operate in a non-multiplexed (static) mode resulting in 16 available output pins. The 'I²C General Purpose Driver Interface' employs the static mode to provide an 8-bit 'address/databus' and an 8-bit 'control bus'. In a way, the design emulates the multiplexed Address / Data bus and Control bus of an 8051 processor. There is one restriction: the SAA1064 only supports 'out-puts'. The Data bus can not be used to read back from the Slave device. In many cases, this limitation is acceptable for simple slaves.

Hardware Design

Figure 2 shows the schematic diagram of the Driver Interface implemented for a Hewlett-Packard (now Agilent [3]) 'Smart Alphanumeric Display'. A brief description of the design is given below.

The I²C bus connector provides SDA, SCL, GND and regulated 5 V power. Two I²C connectors are used to allow daisy chaining. SDA and SCL lines are connected through a

Figure 1. SAA1064 block diagram.

J1	J2	J3	Slave Address
–	–	x	0111000R/$\overline{W}$
–	–	–	0111001R/$\overline{W}$
–	x	–	0111010R/$\overline{W}$
x	–	–	0111011R/$\overline{W}$

Where 'x' denotes the presence of a jumper. R/$\overline{W}$ indicates the lowest address bit.

So, for example:
01110000 = 70H = write
01110001 = 71H = read

Note that only one jumper is allowed. Fitting both J1 and J3 will short out the power supply !

series resistor (R13, R14) to afford protection against too high voltages. The I^{2}C pull-up resistors for SDA and SCL must be provided externally, e.g., on the I^{2}C Master circuit board.

The SAA1064 device (U1) receives and decodes I^{2}C traffic and provides the address/data on Port 1 (P1-P8) and control signals on Port 2 (P9-P16). The SAA1064 can be assigned to one of four possible I^{2}C slave addresses. The voltage on pin 1 of U1, as set by jumpers J1-J3, selects the active address :

Port 1 of U1 emulates the multiplexed Address/Databus. The pins are connected to the Databus of the slave device and to the SN74ALS573 latch (U2). The latch freezes the Address bits on the falling edge of the pulse at the ALE (Address Latch Enable) pin. The latch output is the Address bus for the slave device.

Port 2 of U1 emulates the 'Control bus' for the slave device. It provides the following signals:

Figure 2. Circuit diagram of the I^{2}C driver with HDSP2533 display.

– ALE – *Address Latch Enable*
This pin receives a pulse that latches the Address bits on the falling edge.

– $\overline{Reset}$
The active low Reset signal may be used to reset slave devices.

– C/$\overline{D}$ – Command / Data (Not)
This control signal may be used to select Command or Data registers on a slave device. LCDs based on HD44780 driver chip would refer to this signal as RS (Register Select).

– $\overline{WR}$ – *Write*
The active low $\overline{WR}$ signal activates the write operation on the slave device. Some devices, like the HD44780, may require an active high 'enable' signal instead.

– $\overline{CE0}$ … $\overline{CE3}$ – *Chip Enable*
Four general-purpose control bits are available. They may be used to select a specific peripheral device when more that one is connected, in this case only one of these $\overline{CE}$ signals should be active at any time.

Note that there no $\overline{RD}$ signal is provided since the SAA1064 does not support reading back data from a slave. Please make sure that any $\overline{RD}$ control signals on slave devices are **disabled** (i.e., pulled high) to prevent shorting the slave databus outputs with the SAA1064 Port 1 Address/Databus!

All Port outputs need a 10-kΩ pull-up (R3-R10 and R15-R22) because the outputs are 'open-collector' current sources. The resistors provide defined logic levels for the slave devices.

HDSP253x Example

The Hewlett-Packard (now known as 'Agilent') HDSP253x device is an 8-digit 'Smart Alphanumeric Display' available in several colours (green, orange, red and yellow). The on-board decoder accepts 128 different ASCII symbols. Character codes are stored in internal RAM and shown on the display without external refresh action. The device can show flashing characters, has seven brightness levels, several blanking functions and supports 16 user defined characters (UDCs) to generate special symbols — See **Figure 3**.

Similar displays are available from Siemens (e.g. PD2435), some having only four characters per device (e.g. SLR2016). See also [4] and [5]. These displays differ from the HDSP in size, number of characters and other details. The example software and hardware will therefore need some modification when replacing the HDSP with the Siemens
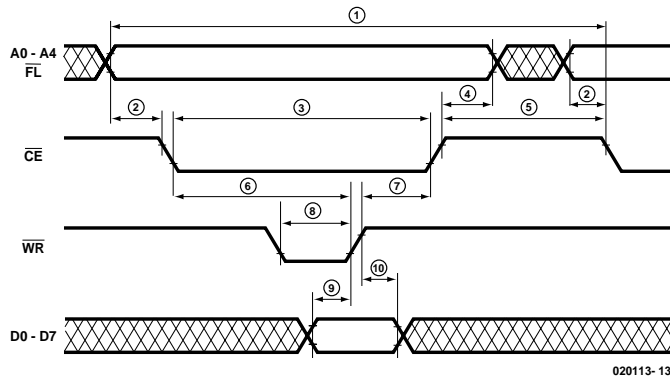

Figure 3. Timing diagram for HDSP253x.

devices, but the basic operation is identical.

The timing diagram of the HDSP data-, address- and control-lines is shown in **Figure 4**. The Address bus selects the digit position, the Data-bus provides the ASCII character code and $\overline{WR}$ will activate the data transfer to the display. Please note that the $\overline{CE}$ pin of the device may not be tied low permanently but must be toggled between each Read or Write operation.

Hooking up the HDSP253x to the General Purpose Driver Interface is straightforward: the Data bus of the HDSP connects to AD0-AD7 of SAA1064 Port 1, Address lines A0-A4 are connected to the corresponding Address lines on latch U2. For simplicity, the $\overline{FL}$ control line is connected to A5 of the latch. The $\overline{FL}$ line allows access to the 'flashing character' RAM of the HDSP. The remaining control lines ($\overline{RST}$, $\overline{WR}$ and $\overline{CE0}$) are connected to Port 2 of the SAA1064. Two control pins on the HDSP are pulled 'high': the $\overline{RD}$ line (to avoid bus collision) and the CLS pin (to select the internal clock of the display).

In this application example, the spare $\overline{CE2}$ and $\overline{CE3}$ drive two LEDs (D1, D2) that provide additional signalling. Both LEDs can be connected to the SAA1064 without additional series resistors because the outputs of the SAA1064 are in fact current sources.

Software

The software for the Interface may be downloaded from this month's Free Downloads items at www.elek-

tor-electronics.co.uk. The program was developed in 8051 assembler (Metalink). The original Intel 8051 does not have I²C hardware and the necessary routines were implemented through 'bit banging' of two port pins representing SDA and SCL. Supporting routines for I²C and serial port communication, utility subroutines and specific control software for the slave device are all located in separate modules. This allows easier software maintenance and reuse. All modules have the same general structure and consist of two parts:
– Mod_cnst.inc, contains constant definitions and variable declarations;
– Mod_sub.asm, contains the subroutines and program memory constants (e.g. tables).

The software modules will be briefly described below. Details can be found in the source code that is provided with comments and explanations.

SCL and SDA may be assigned to any of the available processor port pins by setting an 'EQU' in the source code of 'I2C_cnst.inc'. Separate macro's are used for I²C bit Setup and bit Hold times to allow easier porting of the software to faster 8051 types (e.g. Atmel versions running at 24 MHz or higher). The default settings are adequate for an 8051/80C535 running at 11.0592 MHz. No particular delays are required in that case because the software is now slower than the maximum allowed I²C bus speed.

The lowest level I²C software generates the I²C 'Start' and 'Stop'

sequences. The I2C bus is initialised to the appropriate levels after a 'power-on' by calling 'I2C_init'. The second level of the I2C code provides Byte Send and Receive functionality. The highest level of I2C code sends or receives an I2C message. This involves generating I2C Start and Stop conditions and sending a Slave Address and an optional I2C sub address. Flags are used to set or receive the I2C Acknowledge bit.

The general software for the SAA1064 interface provides subroutines to set values on the 'Address/Databus' and on the 'Control bus'. There is also a routine that allows writing an Address to the Address latch, which consists of first writing data to the Address/Databus and then toggling ALE. Separate macros are provided to allow setting or resetting a specific Control bus bit. The SAA1064 hardware inverts all actual signal levels: setting a port bit 'high' will result in a 'low' level on the port (due to the current source output circuit). The inverting effect is compensated in the low-level routines just before I2C data is transmitted to the SAA1064.

Based on the general SAA1064 routines, a set of specific software modules is available to control the Hewlett-Packard display (files: 'hpd_cnst.inc' and 'hpd_sub.asm'). The Low level 'I2C_HPDInit' routine initialise the display device. This routine first selects the correct mode for the SAA1064 (e.g. no multiplexing) then initialises levels for all control bits (e.g. ALE is low), generates a Reset sequence for the HDSP and finally programs the control registers of the display and clears the display memory. Higher level routines are

available that write characters (I2C_HPDPutChar) and strings (I2C_HPDPutStrCnst and I2C_HPDPutStrBuf). The display cursor will automatically wrap around. The cursor may be set by the 'I2C_HPDGoTo' routine. Additional support functions allow uploading of a user-defined pattern (5?7 bits) to display special symbols or logo's (I2C_HPDUDC).

The serial port software (contained in 'ser_cnst.inc' and 'ser_sub.asm') provides initialisation of the 8051/80535 serial port hardware. Assembler directives are available to select 4800/9600 baud and select the CPU clock frequency (11.0592 or 12 MHz). Basic routines allow character transmit and receive and string transmission to a terminal program (e.g., Hyperterminal).

The UTL module ('utl_cnst.inc' and 'utl_sub.asm') provides general support functions e.g. ASCII to Hex, translation to upper case etc. This module also has special character/symbol definitions that may be uploaded into the HDSP device. Examples are a battery full/empty symbol and some 'pac-man' icons.

The main software module is 'Test51.asm' and it contains the actual application, it uses the #include assembler directive to incorporate all the necessary support modules.

Default settings for the 'Test51' software are: 80C535 processor at 12 MHz, 9600 baud serial port, SDA at P3.4, SCL at P1.0, HDSP device at I2C slave address 76h (jumper SW1 placed). Selection of a specific processor type (8051 or 80C535) and other modes/options (e.g. bau-

drate) are possible by activating assembler directives in 'Test51' or one of its #included modules.

The 'Test51' software initialises the 8051/80C535 (serial port, stack, etc.), the I2C hardware (SDA and SCL pins, flags, etc.) and the I2C general purpose interface (i.e., the SAA1064). Finally the slave display device connected to the interface is initialised (e.g., clear the display, reset the cursor, etc.). After completing the initialisation process the 'Test51' software enters an infinite loop that activates the HDSP display at specific times to show different strings. The operation of the software may be observed by connecting a terminal program (e.g., hyper terminal) to the serial port. A text string is displayed after initialisation and a '#' character is transmitted for each iteration of the main loop.

Experiments

Readers can modify the example hardware and code to meet their own needs. The structured software is easy to understand and for most devices software adaptation should be straightforward. Some hints :

– Remember that the I2C 'bit-banging' software is relatively slow and any required delays (e.g. data setup times before activating $\overline{WR}$) are normally satisfied without additional delays.

– Applications that really need read-back of data (e.g. graphics display where a single bit in the display RAM is modified) can sometimes still be supported by keeping a 'copy' of the appropriate data in the processor's RAM, modify the particular value of the copy and write back the entire result to the slave.

(020113-1)

The software for this project may be downloaded as file number **020113-11.zip** from the Free Downloads section at www.elektor-electronics.co.uk, under month of publication.
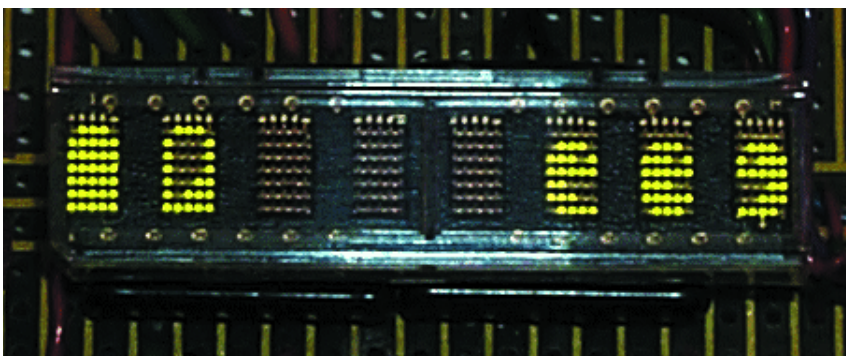

Figure 4. Examples of User Defined Characters.

References:

[1] I2C Alphanumerical Display, Elektor Electronics September 1993.

[2] I2C LED Display, Elektor Electronics June 1992.

[3] www.agilent.com

[4] PC Dot Matrix Display, Elektor Electronics November 2001.

[5] Distance Measurement using Infrared, Elektor Electronics July/August 2002.

All about the Decibel (dB)

By Marc Basquin

Having read a good many letters and emails from various correspondents we concluded that although the decibel (dB) is one of the most frequently used units in audio, RF electronics and acoustics, it is unfortunately one of the least understood. High time, we thought, to clear up the misunderstandings and publish Mr. Basquin's article on the subject.

Basically, the dB is a relative unit, expressing the ratio of two values using the same unit:
– the value being measured
– a clearly defined and indicated reference value.

A logarithmic scale is used to make it easier to handle otherwise unwieldy numbers. For example, the ratio of 0.0000316 V to 1 V is expressed as: –90 dB.

Difference between dB for voltage and dB for power

dB (voltage) $= 20 \log_{10} (U / U_0)$

In this formula, U_0 represents the reference voltage. Consequently, a value of +6 dB means a doubling of the voltage, since $20 \log_{10} (2) = 6$.

dB (power) $= 10 \log_{10} (P / P_0)$
In this case, P_0 is the reference power level. Doubling the power equals a +3 dB increase.

Oddball dB's?

dBV expresses the ratio of two voltages using 1 V_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no relation to impedance (remember, the 'V' in 'dBV' stands for volts).

dBV $= 20 \log_{10} (U / 1 \, V_{rms})$
0 dBV $= 1 \, V_{rms}$

–10 dBV $= 0.316 \, V_{rms}$

This is the standard unit in hi-fi audio design and specification, as well as with some manufacturers like Tascam.

dBV $=$ dBu + 2.2 dB

Table 1 shows the corresponding voltage values at different levels, expressed in dBV.

dBv = dBu
Because the unit dBv could easily be confused with dBV, it is often replaced by the less ambiguous 'dBu'.

The units dBv and dBV are not equivalent or equal.

dBv $= 20 \log_{10} (U / 0.775 \, V_{rms})$
0 dBv $= 0.775 \, V_{rms}$

dBu expresses the ratio of voltages, using 0.775 V_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no relation to impedance (u = unloaded or unterminated).

dBu $= 20 \log_{10} (U / 0.775 \, V_{rms})$
0 dBu $= 0.775 \, V_{rms}$
+4 dBu $= 1.23 \, V$

This is a frequently used level in pro-

fessional audio equipment.

dBu $=$ dBV – 2.2 dB

Table 2 shows the relation between dBu values and voltage.

dBj expresses the ratio of voltages using 1 mV_{rms} as the reference level. Because the signal source is assumed not loaded, the unit has no

Table 1.
dBV/voltage conversion

dBV	Voltage (V)	dBV	Voltage (V)
+1	1.112	–1	0.891
+2	1.259	–2	0.794
+3	1.413	–3	0.708
+4	1.585	–4	0.631
+5	1.778	–5	0.562
+6	1.995	–6	0.501
+7	2.239	–7	0.446
+8	2.512	–8	0.398
+9	2.818	–9	0.354
+10	3.162	–10	0.316
+20	10.00	–20	0.100
+30	31.62	–30	0.031
+40	100.0	–40	0.010
+50	316.2	–50	0.003
+60	1000	–60	0.001

relation to impedance.

$dBj = 20 \log_{10} (U / 1 \text{ mV}_{rms})$
$0 \text{ dBj} = 1 \text{ mV}_{rms}$

dBr allows the reference voltage to be specified ('r' for reference).

$dBr = 20 \log_{10} (U / U_0)$
For example, $0 \text{ dBr} = \text{'dBre } +4\text{'} = 1.23 \text{ V}_{rms} = +4 \text{ dBu}$

dBVU expresses the ratio of voltages with the reference level freely chosen and clearly specified. This unit helps to pinpoint a discrete level or a certain range on a measuring instrument. For example, a low-pass filter may be used with the measurement. Remember, VU = volume unit. The unit is typically used
- with radio, to indicate 100% modulation level;
- with analogue tape recorders, to indicate the ideal operating area depending on the magnetic tape being used. It then corresponds to a certain magnetic flux level expressed in Wb/m — This is not the highest permissible signal level;
- with digital tape recorders, to indicate the level above which distortion occurs.

$dBVU = 20 \log_{10} (U / U_0)$

0 dBVU is a reference level at which

Table 2.
dBu/voltage conversion

dBu	Voltage (V)	dBu	Voltage (V)
+1	0.869	−1	0.690
+2	0.975	−2	0.615
+3	1.095	−3	0.548
+4	1.228	−4	0.489
+5	1.377	−5	0.435
+6	1.546	−6	0.388
+7	1.735	−7	0.346
+8	1.946	−8	0.308
+9	2.183	−9	0.274
+10	2.450	−10	0.245
+20	7.750	−20	0.0775
+30	24.50	−30	0.0245
+40	77.50	−40	0.0075
+50	245.0	−50	0.00245
+60	775.0	−60	0.000775

Table 3.
Subjective perception of sound pressure levels

Surroundings	dB SPL	Perception
Rocket launch	180	
30 m from a military jet plane at takeoff; rifle shot at 100 m	140	
Pain threshold, pneumatic press; large siren op 1 m distance	130	Unbearable
At 60 m from a plane taking off; machine room of an ocean liner	120	
Old subway, sewing shop	110	
Maximum level in a discotheque	105	Very loud
Book/magazine press, train on steel bridge; small fireworks	100	
Building site, average level of a hifi set	90	
Very busy road; alarm clock at 1 m	80	
Loud radio, busy street	70	Noisy
Conversation in a restaurant; large shop	60	
Office; normal conversation at 1 m	50	Quiet
Bedroom; buzz from conversation at 2 m	40	
Normal conversation at 3 m, buzz at 5 m	30	
Recording studio; rustling leaves	20	Very quiet
Desert	10	
Absolute hearing threshold	0	

the needle of a VU meter indicates 0. **Table 3** shows some reference values.

dBm expresses a ratio of powers using 1 mW as the reference level ('m' is from 'mW).

In audio engineering, 0 dBm equals 1 mW into an impedance of 600 Ω.

$dBm = 10 \log_{10} (P / 0.001 \text{ W})$

The corresponding voltages are easily extracted using

$U_0 = \sqrt{(P_0 Z_0)}$

Normally, 0 dBm = 1 mW into 600 Ω = 0.775 V_{rms}, this is proved by

$U_0 = \sqrt{(0.001 \text{ W} \times 600 \text{ Ω})} = \sqrt{0.06} = 0.775 \text{ V}$

In RF engineering, 50 Ω is the more commonly used impedance (because of the typical impedance of coax cables and connectors), so 0 dBm = 1 mW into 50 Ω.

dBW expresses a power ratio using 1 watt as the reference level. This allows easy comparison of output levels produced by power amplifiers ('w' from 'watt').

$dBW = 10 \log_{10} (P / 1 \text{ W})$
$0 \text{ dBW} = 1 \text{ W}$

Therefore, a 100-watt amplifier can be said to deliver +20 dBW, since $10 \log_{10} (100/1) = 20$. Similarly, a 1-kW amplifier delivers +30 dBW to the loudspeakers, and a combination of a transmitter and an antenna system may produce +40 dBW = 10 kW effective radiated power (ERP).

dBk is a power ratio using 1 kW (1,000 watts) as the reference level. This unit, too, is used to compare amplifier performance ('k' from 'kilowatt')

$dBk = 10 \log_{10} (P / 1 \text{ kW})$
$0 \text{ dBk} = 1 \text{ kW}$

dBi in RF engineering expresses gain over an isotropic (hypothetical, sphere-shaped) reference antenna.

dBd in RF engineering expresses gain over a dipole antenna.
$0 \text{ dBd} \approx +2,15 \text{ dBi}$

dBPWL indicates the ratio of acoustic powers, allowing for the reverberation time in a closed space ('PWL' from 'PoWer Level').
$dBPWL = 10 \log_{10} (P / P_0)$

where P = effective power level (in watts) and $P_0 = 10^{-12} \text{ W} = 1 \text{ pW}$.
However, you'll find that the unit dBSWL is more commonly used.

$dBSWL = dBPWL$
('SWL' from 'Sound PoWer Level')

dBSPL indicates a ratio of an acoustic sound

Table 4.
A- (acoustic-) weighted filter coefficients

f in Hz	dBA	f in Hz	dBA	f in kHz	dBA	f in kHz	dBA
10	−70.4	100	−19.1	1	0	10	−2.5
12.5	−63.4	125	−16.1	1.25	+0.6	12.5	−4.3
16	−56.7	160	−13.4	1.6	+1	16	−6.6
20	−50.5	200	−10.9	2	+1.2	20	−9.3
25	−44.7	250	−8.6	2.5	+1.3		
31.5	−39.4	315	−6.6	3.15	+1.2		
40	−34.6	400	−4.8	4	+1		
50	−30.2	500	−3.2	5	+0.5		
63	−26.2	630	−1.9	6.3	−0.1		
80	−22.5	800	−0.8	8	−1.1		

pressure level and a reference pressure ('SPL' from 'Sound Pressure Level')

0 dBSPL = 0.0002 dynes/cm^2
    = 0.00002 N/m^2
    = 0.0002 μbar = 20 μPa

$$dBSPL = 20 \log_{10} (SPL / SPL_0)$$

where SPL = the effective pressure in Pa and SPL$_0$ = 20 μPa (in air).

From this we could be lead to believe that a 6-dB increase in sound pressure means 'twice as loud'. This is not the case, however, because psychoacoustics has shown human hearing response to be frequency as well as pressure dependent (physiological curve, *loudness*). For reference purposes, **Table 3** lists the sound levels of a few typical sound-related phenomena.
dBA expresses the ratio of acoustic pressure and a reference level (SPL = Sound Pressure Level) using an A-weighted filter.

In **Table 4** you find the frequency-dependent attenuation of an A-weighted network relative to the 1-kHz reference frequency.

dBFS represents the maximum permissible voltage level before clipping (or limiting) occurs ('FS' from 'full scale').

The full-scale value depends on the A/D and D/A converters applied. It is established by applying a 997-Hz digital signal and measuring the resultant analogue voltage, observing that (THD+N) < −40 dB (THD+N = Total Harmonic Distortion plus Noise).

Some typical dynamic ranges:

16-bit converter: −96 dBFS
20-bit converter: −120 dBFS
24-bit converter: −144 dBFS

0 dBFS is the maximum level with digital audio equipment — all applied signals need to stay well below this level.

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

High-Q Notch Filter

Without close-tolerance components

Design by K.-J. Thiesler

A notch for a narrow frequency band of a few per cent or even less normally requires close-tolerance components. At least, that's what we thought until we came across a special opamp IC from Maxim.

In filters with steep slopes, the component tolerances will interact in the complex frequency response. This effect rules out the use of standard tolerance components if any useful result is to be achieved. The circuit shown here relocates the issue of the value-sensitive resistors that determine the filter response from 'visible' resistors to ready available integrated circuits which also make the PCB layout for the filter much simpler.

The operational amplifiers we've in mind contain laser-trimmed resistors that maintain their nominal value within 1 ‰ or less. For the same accuracy, the effort that goes into matching individual precision resistors would be far more costly and time consuming.

The desired notch (rejection) frequency is easily calculated for both R-C sections shown in **Figure 1**.

Dividing the workload

The circuit separates the amplitude and frequency domains using two frequency-determining R-C networks and two level-determining feedback networks of summing amplifier IC2, which suppresses the frequency component to be eliminated from the input signal by simple phase shifting.

IC1 contains two operational amplifiers complete with a feedback network. The MAX4075 is available in no fewer than 54 different gain specifications ranging from 0.25 V/V to 100 V/V, or +1.25 V/V to 101 V/V when non-inverting. The suffix AD indicates that we are employing the inverting version

here (G = –1). These ICs operate as all-pass filters producing a phase shift of exactly 180 degrees at the roll-off frequency f_0. The integrated amplifier resistors can be trusted to introduce a gain variation of less

than 0.1 %. They are responsible for the signal level (at the notch frequency) which is added to the input signal by IC2 by a summing operation. However, they do not affect the notch frequency proper — that is the
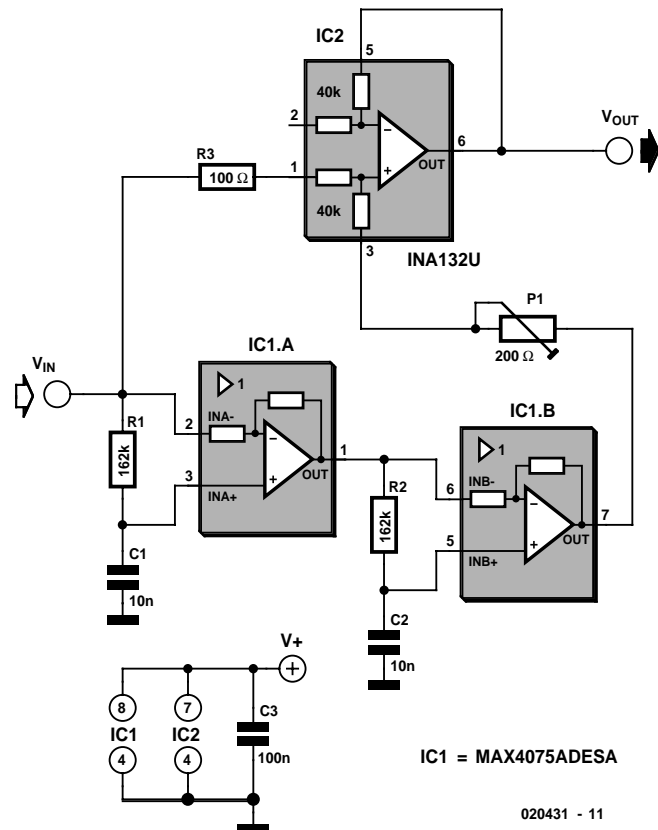

Figure 1. Special opamps incorporating laser-trimmed resistors.

domain of the two external R-C sections which, in turn, do not affect the degree of signal suppression.

In general, SMDs (surface mount devices) have smaller production tolerance than their leaded counterparts. Because the two ICs in this circuit are only available in an 8-pin SOIC enclosure anyway, it seems logical to employ SMDs in the rest of the circuit as well. Preset P1 allows the filter to be adjusted for maximum rejection of the unwanted frequency component.

R-C notch filter

Using standard-tolerance resistors for R1 and R2 (i.e., 1%, 0806 style) and 10%-toleance capacitors for C1 and C2 (X7R ceramic) an amount of rejection better than that shown in **Figure 2** may be achieved. The notch frequency proper may be defined more accurately by the use of selected R-C sections.

Pin 3 of IC2 receives a signal that's been 90-degrees phase shifted twice at the notch frequency, while pin 1 is fed with the input signal. These two signals are added by way of the two on-chip resistors.

IC2 is a differential precision operational amplifier containing precision resistor networks trimmed to an error not exceeding ± 0.2 ‰. Here, it is configured as a modified summing amplifier with its inverting input, pin 2, left open.

For frequencies considerably lower than the resonance frequency

$$f_0 = 1 / (2 \pi R C)$$

the capacitors present a high impedance, preventing the inverting voltage followers from phase-shifting the signal. At higher frequencies than f_0, each inverting voltage follower shifts its input signal by 180 degrees, producing a total shift of 360 degrees which (electrically) equals 0 degrees. The phases of each all-pass filter behave like a sim-
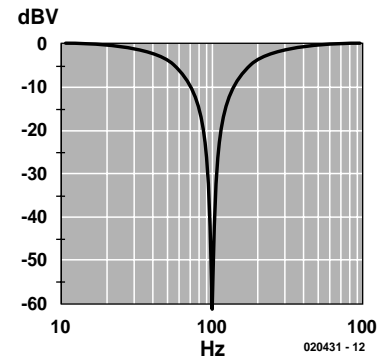
Figure 2. This deep notch is within reach using just 5%-tolerance resistors and 20%-tolerance capacitors.

ple R-C pole, hence shift the signal at the resonance frequency by 90 degrees each.

The three precision amplifier ICs can handle signals up to 100 kHz at remarkably low distortion. The supply voltage may be anything between 2.7 V and 5.5 V. Current consumption will be of the order of 250 μA.

(020431-1)

Table 1. Selection of standard SMD parts.				
Desired notch frequency, f_O, in Hz R1 / R2	Nearest value (E12, ± 5%) in kΩ	C1 / C2 Selected value (± 20 %) in nF	Actual notch frequency f_0 (using ± 0.1 % R + C)	Theoretical maximum tolerance on f_0 in Hz (using ± 5 % R and ± 20 % C)
50	300	10	53	42 - 70
60	270	10	59	47 - 77
100	150	10	106	85 - 140
120	56	22	128	100 - 170
400	18	22	401	320 - 530

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

IMT902 Microstep Driver for Two Motors

$\frac{1}{16}$th step, with constant-current drive

Source: Nanotec GmbH

The IMT902 from Nanotec is a PWM chopper type sinusoidal microstep bipolar stepper motor driver. Two stepper motors can be controlled by a single low loss and highly integrated driver IC, which is supplied in a space saving 36-pin SMD enclosure.

Besides four DMOS H bridges with an $R_{DS(on)}$ of just 0.5 Ω, the constant-current driver type IMT902 also contains two 4-bit D/A converters that enable microstep switching from 1/1 (full step) to 1/16th stepping (microstep). Sinusoidal output voltages are supplied to ensure resonance and noise free operation of the motor(s). The drivers supply the motors with voltages of up to 40 V at currents of up to 1.5 A per phase.

Further advantages of the IMT902, whose internal architecture and pinout are given in **Figure 1**, include an integrated charge pump employing two external capacitors, and the programmable 'mixed decay mode' that enables a speed-independent current drive to be realised in combination with significant reductions in power dissipation. In order to keep the number of pins on the device to a minimum, all settings are conveyed to the device via two 16-bit shift registers with latches, at a data speed of up to 25 MHz. The chopper frequency is determined by external resistors and capacitors and may extend beyond 100 kHz.

Calculations

Figure 2 shows a typical application circuit for the IMT902. Only one device half is shown (A/B). The unit C/D for the second motor is configured identically. Clearly, the stepper motor driver requires just a handful of external parts to operate. The two motor windings are connected to the respective outputs A/$\overline{A}$ and B/$\overline{B}$. The instantaneous current level through the windings is adjusted by means of the two resistors at the R_s inputs. The following equation applies:

$$I_{out} = (V_{REF} \, HC) / (5 \, R_s)$$

where HC represents the hold current programmed by the respective dataword (more about this further on). The equation also allows you to calculate the power dissipation of the resistor.

Components R1 and C3 fix the oscillator frequency (and with it, the chopper rate). The oscillator frequency equals

$$f_{osc} = 1 / [C3 \, (0.523 \, R1 + 313.8)] \text{ hertz}$$

and the chopper frequency is 1/8th of the oscillator frequency.
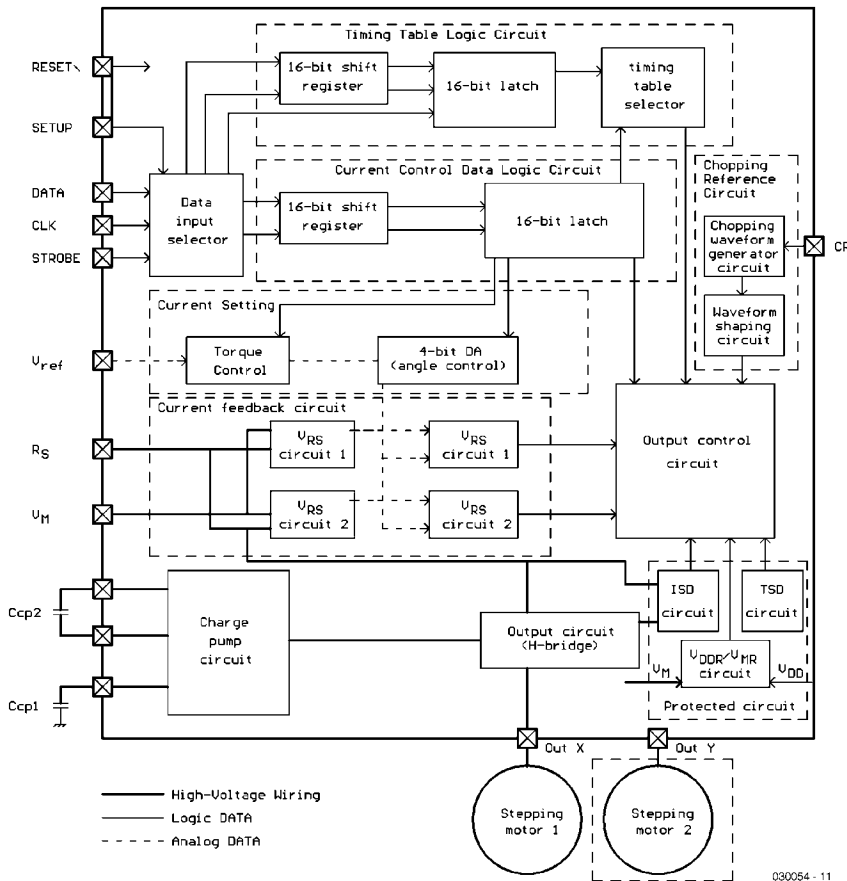
The IMT902 chip is controlled

Figure 1. Internal diagram and pinout of the IMT902.

I	$V_{M\,B}$	Power supply for output B block
2	OUT B	Output B pin
3	$R_{S\,B}$	Channel B current pin
4	PGND	Power GND pin
5	$\overline{\text{OUT B}}$	Output $\overline{\text{B}}$ pin
6	LGND	Logic GND pin
7	Ccp A	Capacitor pin for charge pump (Ccp1) (capacitor C2)
8	CR	External C/R (osc) pin (sets chopping frequency)
9	$V_{REF\,AB}$	V_{REF} input pin AB
F_{IN}	V_{SS}	Logic GND pin
10	$V_{REF\,CD}$	V_{REF} input pin CD
II	nc	not connected
12	Ccp B	Capacitor pin for charge pump (Ccp2) (capacitor C1)
13	Ccp A	Capacitor pin for charge pump (Ccp3) (capacitor C1)
14	$\overline{\text{OUT D}}$	Output $\overline{\text{D}}$ pin
15	PGND	Power GND pin
16	$R_{S\,D}$	Channel D current pin
17	OUT D	Output D pin
18	$V_{M\,D}$	Power supply for output D block
19	$V_{M\,C}$	Power supply for output C block
20	$\overline{\text{OUT C}}$	Output $\overline{\text{C}}$ pin
21	$R_{S\,C}$	Channel C current pin
22	PGND	Power GND pin
23	OUT C	Output C pin
24	STROBE CD	CD Strobe (latch) Signal input pin
25	CLK CD	CD clock input pin
26	DATA CD	CD serial data signal input pin
27	V_{DD}	Power pin for logic block
F_{IN}	V_{SS}	Logic GND pin
28	$\overline{\text{RESET}}$	Output reset signal input pin
29	DATA AB	AB serial data signal input pin
30	CLK AB	AB clock input pin
31	STROBE AB	AB Strobe (latch) Signal input pin
32	OUT A	Output A pin
33	PGND	Power GND pin
34	$R_{S\,A}$	Channel A current pin
35	$\overline{\text{OUT A}}$	Output $\overline{\text{A}}$ pin
36	$V_{M\,A}$	Channel A current pin
	All GND pins and F_{IN} must be grounded.	
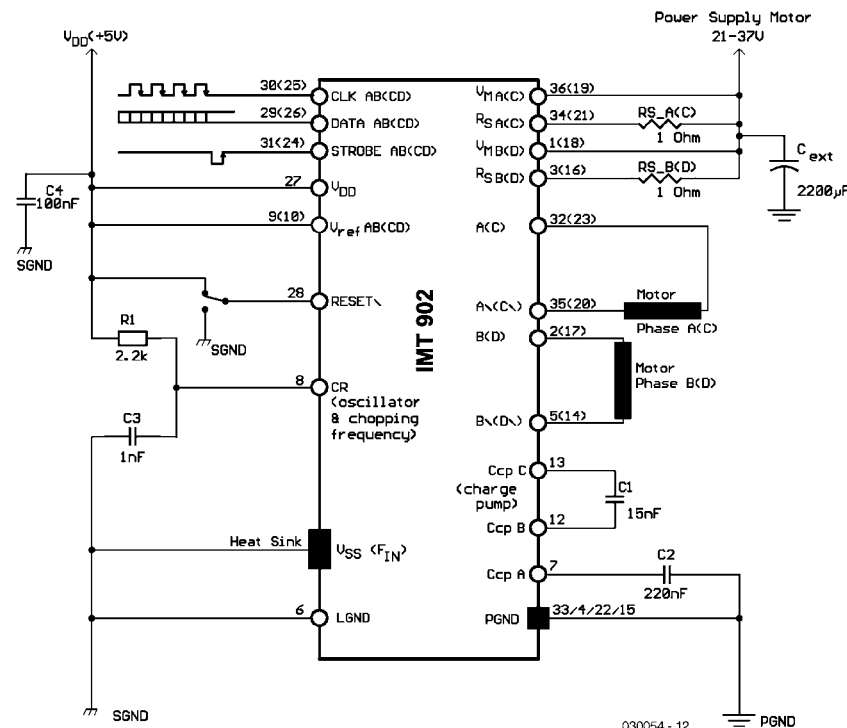
Figure 2. Standard application circuit.

using its DATA, CLK and STROBE inputs. Besides, there's a reset switch which not only clears the outputs but also all registers/latches.

Control

To control the IMT902 three signals are needed: clock serial data and a strobe pulse (see **Figure 3**). The dataword has a total width of 16 bits. Each bit in the sequence DATA0 (LSB) through DATA15 (MSB) is applied at the rising edge of the clock signal, and shifted into the shift register on the falling edge. Once all 16 bits have been copied in, the rising edge of the strobe pulse causes the data to be copied into the internal latch. During the data reception phase, the strobe signal may be Low or High.

The first two bits program the hold current, the next two, the decay mode. Next arrive the 4 bits that set the current in motor phase B using the internal D/A converter, followed by a bit for the phase information — in other words, the current direction. Bits 9 through 15 repeat this information for phase A (**Table 1**). Obviously, the other motor is controlled with its very own dataword.

The device datasheet at

http://nanotec.com/
page_steuerungen_imt902_en.html

provides tables for each mode of operation (from full step to 1/16th step) that list all relevant datawords. **Figure 4** shows an extract from such a table, as well as the associated current curve. With full-step mode a pure rectangular signal is used (the internal DACs always supply both currents at 100% intensity), while only the current direction is reversed. By contrast, Figure 4 illustrates the almost sinusoidal current that flows in 1/16th step (microstep) mode.

Details

The internal functions referred to as TSD and ISD provide an effective protection against overheating (thermal shutdown) and current overload (overcurrent protection) respectively. The TSD guard is activated at a device temperature of 130 degrees Celcius typ. (up to 170 degrees C) and shuts down the outputs to both motors. At the same time, the charge pumps are cut off and the registers cleared. The IMT902 may be released from this state by means of a reset pulse, but only if the device temperature has dropped below 35 degrees Celcius.
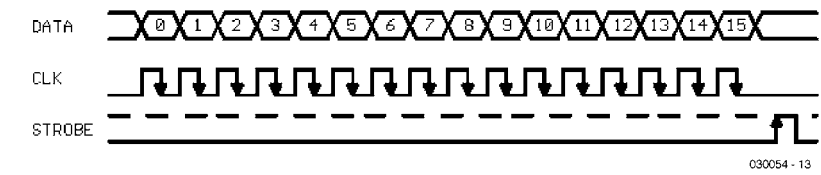
A similar scheme applies to the overcurrent protection circuit. As soon as the ISD guard registers excessive output current, both motor windings and the charge pumps are switched off. Also, all functional data is cleared. The overcurrent protection remains active until a reset action. Despite these protective measures a fuse should be included in the power supply line.

(030054-1)

Figure 3. Serial input data.

Table 1. Dataword structure		
DATA	**Name**	**Function**
0 (LSB)	Hold Current 0	HH = 100 %, LH = 85 %,
1	Hold Current 1	HL = 70 %, LL = 50 %
2	Decay Mode B_0	HH = fast decay, LH = mixed decay 37.5 %,
3	Decay Mode B_1	HL = mixed decay 75 %, LL = slow decay
4	Current B_0	
5	Current B_1	Current for phase B (LLLL = all outputs off)
6	Current B_2	max. 16 steps possible
7	Current B_3	
8	Phase B	H: OUT B = High, $\overline{\text{OUT B}}$ = Low, L = OUT B = Low, $\overline{\text{OUT B}}$ = High
9	Decay Mode A_0	HH = fast decay, LH = mixed decay 37.5 %,
10	Decay Mode A_1	HL = mixed decay 75 %, LL = slow decay
11	Current A_0	
12	Current A_1	Current for phase A (LLLL = all outputs off)
13	Current A_2	max. 16 steps possible
14	Current A_3	
15 (MSB)	Phase A	H: OUT A = High, $\overline{\text{OUT A}}$ = Low, L = OUT A = Low, $\overline{\text{OUT A}}$ = High

	Hold Current 0	Hold Current 1	Decay B_0	Decay B_1	B_0	B_1	B_2	B_3	Phase B	Decay A_0	Decay A_1	A_0	A_1	A_2	A_3	Phase A
Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	1
2	1	1	1	0	1	1	1	1	1	1	0	1	0	0	0	1
3	1	1	1	0	0	1	1	1	1	1	0	0	1	0	0	1
4	1	1	1	0	1	0	1	1	1	1	0	1	1	0	0	1
5	1	1	1	0	0	0	1	1	1	1	0	0	0	1	0	1
6	1	1	1	0	1	0	0	1	1	1	0	1	0	1	0	1
7	1	1	1	0	0	1	0	1	1	1	0	0	1	1	0	1
8	1	1	1	0	1	0	0	1	1	1	0	1	1	1	0	1
9	1	1	1	0	0	0	0	1	1	1	0	0	0	0	1	1
10	1	1	1	0	1	1	1	0	1	1	0	1	0	0	1	1
11	1	1	1	0	0	1	1	0	1	1	0	0	1	0	1	1
12	1	1	1	0	1	0	1	0	1	1	0	1	1	0	1	1
13	1	1	1	0	0	0	1	0	1	1	0	0	0	1	1	1
14	1	1	1	0	1	1	0	0	1	1	0	1	0	1	1	1
15	1	1	1	0	0	1	0	0	1	1	0	0	1	1	1	1
16	1	1	1	0	1	0	0	0	1	1	0	1	1	1	1	1

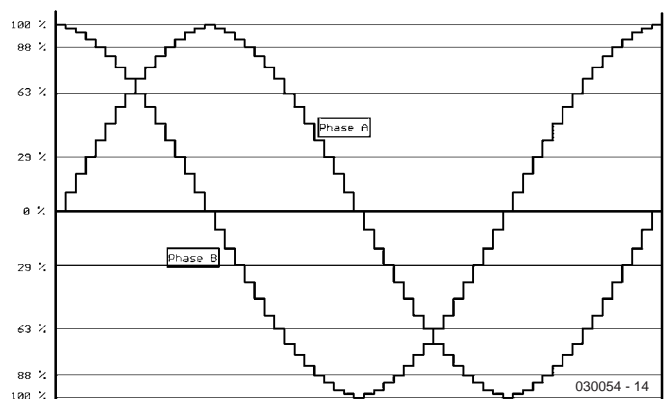Output current waveform of pseudo sine wave:

030054 - 14

Figure 4. Sample of current shape for 1/16th step mode with associated control words.

Step-Down Switching Regulator

for Negative Voltages

By G. Kleine

Special switching regulator ICs for negative voltages are conspicuously absent in the catalogues of semiconductor manufacturers. However, you can make do with a positive-voltage regulator IC and a few circuit tricks.

Switching regulator ICs are used for voltage conversion with minimal losses. If you want build a high-efficiency circuit to convert a positive voltage to a higher or lower voltage, you can choose from a large number of switching regulator ICs from several manufacturers. However, if you want to convert a negative voltage, the situation is rather different. There are practically no special ICs available for this purpose, and typical application circuits showing how this problem can be solved are equally scarce.

This article shows how a step-down regulator for negative voltages can be built using readily available positive-voltage switching regulator ICs.

Basic circuits

There are many different types of switching regulator ICs that can be used to convert positive voltages into other positive voltages, and they employ several different working principles. Some ICs use chokes for energy storage, while others use capacitors, but the latter type is of no interest for our purposes.

Switching regulator ICs that use storage chokes can be divided into step-down and step-up types. In **Figure 1,** the operating principle of each type is shown at the top and the usual complete circuit is shown at the bottom. Depending on the type of IC used, additional components may be needed for compensation, and various shutdown or sync inputs may also be present.

A step-down regulator converts a voltage into a lower voltage by applying a switched voltage to the storage choke. The combination of the choke and the following storage capacitor acts as a low-pass filter, which removes the switching frequency from the output voltage. The voltage divider at the feedback (FB) pin determines the value of the output voltage, since the IC will adjust the switching rate or duty cycle such that the voltage at the FB pin matches the internal reference voltage (usually +1.25 V or +1.5 V).

The second basic circuit is the step-up regulator (**Figure 1b**), which generates an output voltage that is higher than the input voltage. In such a regulator, one terminal of the choke is connected directly to the input voltage, while the other terminal is temporarily connected to ground by the switch in the IC. This causes the choke to build up stored energy in the form of a magnetic field in its ferrite core. When the switch is opened, a voltage with the opposite polarity is induced by the collapsing magnetic field and appears at the terminals of the choke. This voltage adds to the input voltage to produce a higher voltage, which is passed to the output capacitor via the diode. The diode also prevents the output capacitor from discharging through the switch. The physical effect can be understood as follows: when the switch is opened, the current in the choke wants to continue flowing. The only way it can do so is to flow through the diode into the capacitor and the load.

A step-up regulator also has a voltage divider connected to the feedback (FB) sense input. The IC regulates the duty cycle or pulse rate such that the output voltage has the desired value.

Using a step-up switching regulator as a step-down regulator for negative voltages

Although there aren't any ICs for negative-voltage step-down switching regulators, we can make do with ICs that are actually intended to be used for positive voltages. If you look at the basic circuit for a negative-voltage step-down switching regulator in **Figure 2**, which is a modified version of the circuit shown in Figure 1a, you can clearly see that a positive-voltage step-up regulator IC can be used to chop the negative input voltage and then smooth the
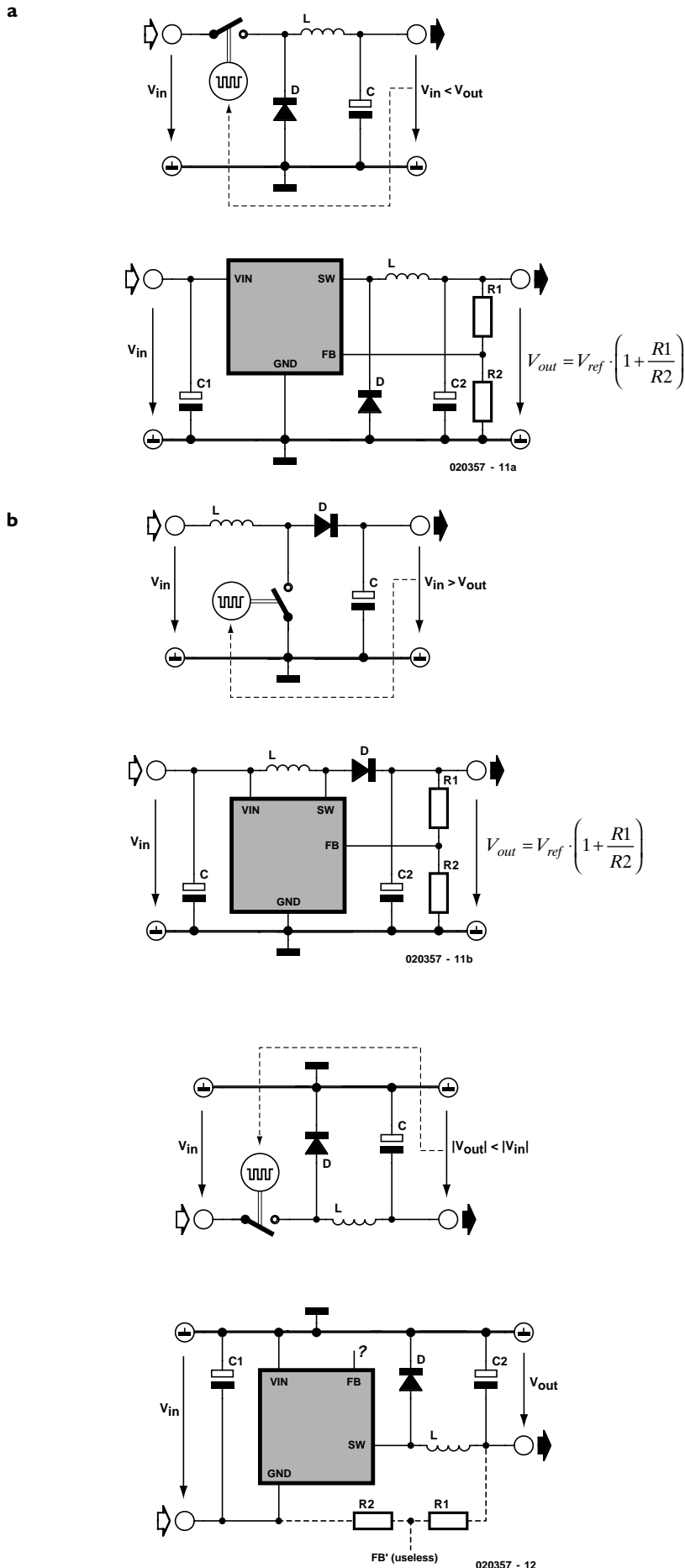
Figure 1. Switching regulators:
a) step-down, b) step-up

result using the LC low-pass filter, yielding an output voltage having a smaller magnitude and a negative sign.

Of course, here you must bear in mind that the positive supply voltage pin of the IC has to be connected to ground, while the GND pin of the IC has to be connected to the negative input voltage. All external components, such as compensation capacitors, must be connected to the negative input voltage instead of ground.

Generating the feedback signal

The only problem with this circuit is the direction of regulation of the feedback signal and its reference potential. The lower end of the feedback voltage divider is normally connected to the GND pin of the IC, which is now connected to the potentially variable input voltage. It is thus obvious that this simple voltage divider cannot be used as is. Instead, we must generate a voltage between the FB and GND pins of the IC that is directly dependent on the negative output voltage but referenced to the negative input voltage. Several potential solutions are shown in **Figure 3**.

Figure 3a shows a circuit using an operational amplifier with its non-inverting input connected to a potential partway between V_{out} and V_{FB}, which is labelled 'V_{shift}'. Resistors R1 and R2 at the inverting input of the opamp have equal values, so the voltage at the FB pin of the switching regulator IC is lower than V_{shift} by exactly the amount that V_{out} is higher than V_{shift}. The two voltage differences can be visualised as two level arms whose common pivot point is V_{shift}. These arms have equal lengths because the resistors have equal values. The formulas for calculating the value of V_{shift} are shown in the figure.

The drawback of this circuit is that the output voltage also depends on the level of the input voltage (via V_{shift}). If the input voltage varies, the output voltage will vary accordingly. One way to improve this circuit in this regard would be to use a Zener diode to stabilise the voltage divider (R3 and R4) However, the resulting circuit would be quite a bit more complicated than the other alternatives, which we can now examine.

Figure 2. Basic circuit for a negative step-down switching regulator

a

V_{out} −3.0V

R2 68k R1 68k 100p

FB V_{FB}

R3 5k6 V_{shift} R4 10k

GND

V_{in} −5.2V

$$R1 = R2$$

$$V_{Shift} = V_{in} \cdot \frac{R4}{R3+R4}$$

$$= \frac{V_{out} - V_{FB}}{2}$$

$$V_{FB} = V_{in} + V_{Ref}$$

$$\Rightarrow V_{out} = \frac{R4-R3}{R4+R3} \cdot V_{in} - V_{Ref}$$

b

V_{out} −5.0V

R4 33k R1 82k

FB I_2 I_1

2x BC857S

R3 15k R2 15k

GND

V_{in} −8V ... −16V

$$\left| V_{out} \right| = \frac{R1+R2}{R4} \cdot V_{Ref} + V_{BE}$$

$$R4 = \frac{V_{Ref}}{\left| V_{out} \right| - V_{BE}} \cdot (R1+R2)$$

$$V_{BE} = 0.6V$$

c

V_{out} −7.2V

R1 68k 10k

I_1 BC856B

FB

I_2

R2 15k

GND

V_{in} −9V ... −15V

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$$\left| V_{out} \right| = \frac{R1}{R2} \cdot V_{Ref} + V_{BE}$$

$$R1 = \frac{\left| V_{out} \right| - V_{BE}}{V_{Ref}} \cdot R2$$
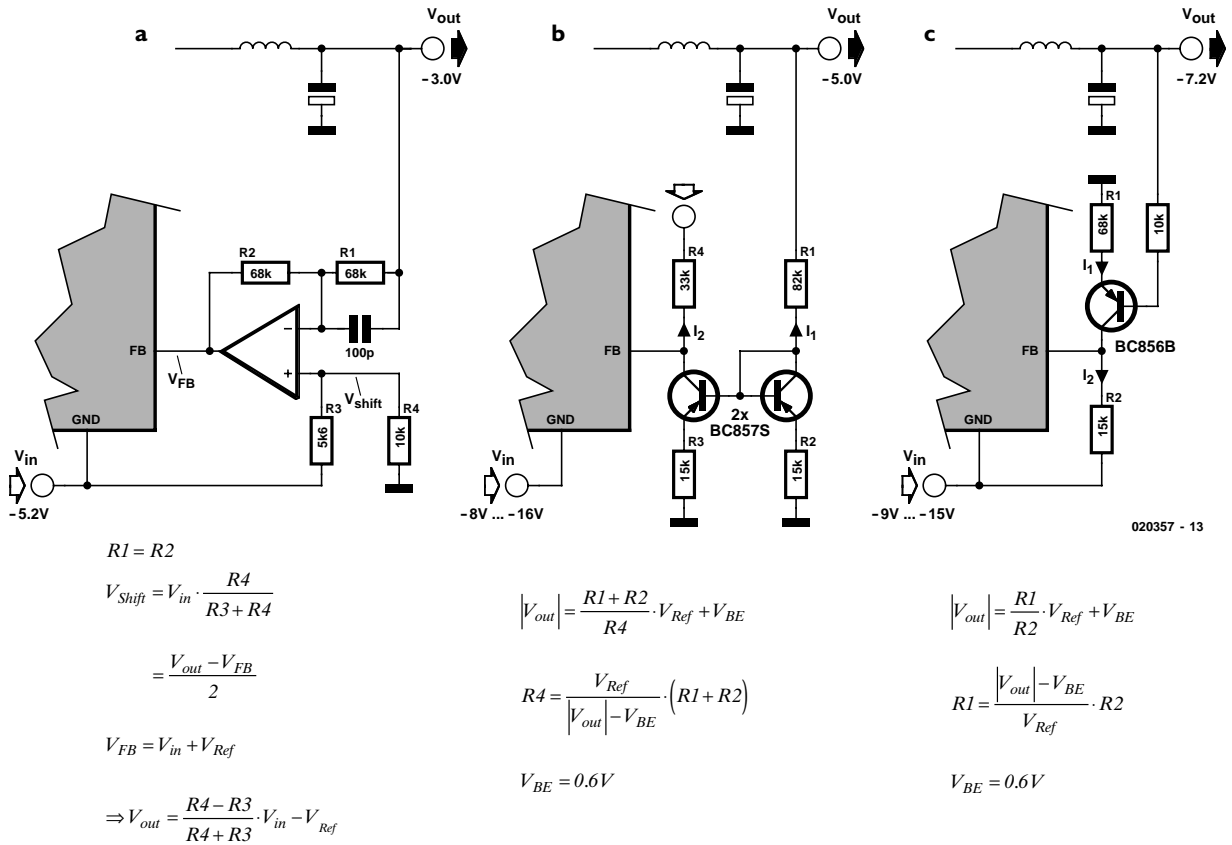
$$V_{BE} = 0.6V$$

Figure 3. Various options for generating the feedback signal: a) using an opamp as an inverter, b) using a current mirror, c) using a transistor

As shown in **Figure 3b**, the feedback voltage can also be reversed using a current mirror. Here a current flows through resistors R1 and R2 and the right-hand transistor, which is wired as a diode. As indicated in the figure, this current is determined by the value of the output voltage (less a diode voltage drop of approximately 0.6 V) and the values of the resistors. Since R2 and R3 have equal values, a current of the same magnitude must flow through R3, particularly as the base-emitter junction of the left-hand transistor is wired exactly the same as that of the right-hand transistor. The collector current of the left-hand transistor is thus equal to the current in R3, assuming that the base current can be neglected. This current flows into the negative supply line via R4, producing a feedback voltage with the proper polarity for the feedback (FB) pin of the switching regulator IC. This circuit is fully independent of the value of the input voltage, since the two equal currents in the current mirror depend only on the value of the output voltage.

The simplest circuit for generating the FB signal requires little more than an ordinary PNP transistor, as shown in **Figure 3c**. The base of the transistor is connected to the neg-

C1 100μ 16V

ES1B D1

C2 100μ 16V

−7.2V 500mA

2 8 1
LBI ⊕ LBO

MAXIM LX 7

L1 33μH

IC1 MAX761

4 SHDN FB 3

REF

R3 10k R1 68k

5 6
C3 100n

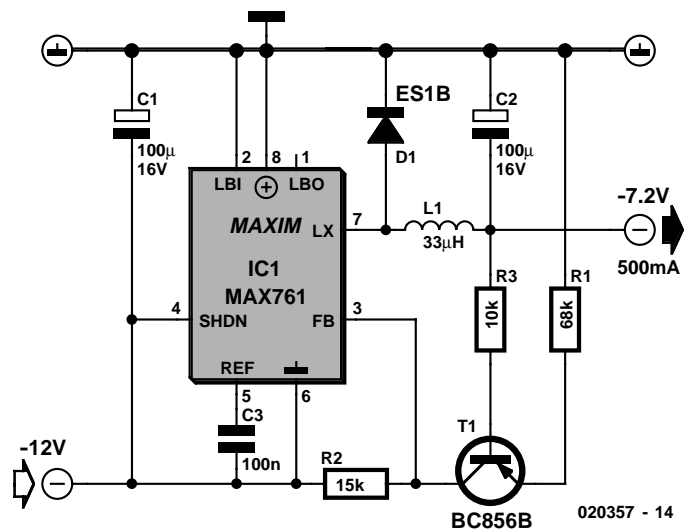−12V

R2 15k

T1 BC856B

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Figure 4. Negative-voltage step-down switching regulator using a MAX761

ative output voltage by a series resistor, whose exact value is not critical. The negative output voltage, reduced by the forward voltage of the base-emitter junction (approximately 0.6V), also appears at the upper end of the emitter resistor. The resulting current also flows from the collector of the transistor through R2 to the negative input voltage. If the transistor has sufficiently high current gain (β > 100), the base current
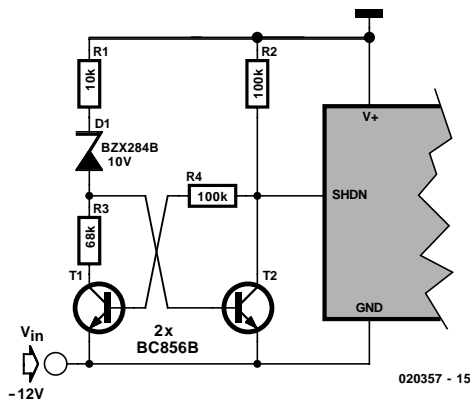
Elektor Electronics

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Figure 5. Auxiliary shutdown circuit

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Linear Technology: www.linear.com

can safely be neglected. The voltage drop thus generated across R2, which depends on the value of the output voltage, provides the necessary input for the FB pin of the switching regulator IC. It can also be seen that the output voltage appears across R1 and the base-emitter junction of the transistor, while V_{FB} (the reference voltage the switching regulator IC, usually 1.25 V or 1.5 V) appears across R2. Consequently, the magnitude of the input voltage must be greater than the magnitude of the output voltage by at least V_{FB}.

−7.2 V at 0.5 A from −12 V

Now it's time to try out our theory with an actual circuit, which is shown in **Figure 4**. Here we use a Maxim MAX761 step-up switching regulator IC, which can supply a current of up to 0.5 A in this type of circuit. Diode D2 is an ultrafast Schottky diode (General Semiconductor type ES1B). If somewhat higher losses are acceptable, other types of Schottky diodes can also be used. A 33-μH SMD coil from the TDK SFL series (type SLF12575T-330M3R2) has been selected for the storage choke. The electrolytic capacitors must have low effective series resistance (ESR). Suitable types are available from several manufacturers. The lower their ESR, the better the capacitors can filter out the residual components of the switching frequency.

The circuit shown in Figure 4 can be constructed in a very compact form. Its efficiency, which is ratio of the output power (2.88 W in this case) to the input power (3.36 W), is approximately 86 percent at an output current of 400 mA. The output voltage is determined by the values of resistors R1 and R2, which can be calculated using the formulas given in Figure 3c.

Delayed switch-on

As we have seen in Figure 3c, the feedback mechanism using a transistor as a voltage converter only works properly above a certain magnitude of input voltage, to wit the magnitude of the output voltage plus V_{FB} (which is usually 1.25 V or 1.5 V). Consequently, we can add a small circuit connected to the shutdown pin of the switching regulator IC to disable it until the input voltage has reached the required level (see **Figure 5**).

This circuit works as follows: if the magnitude of the input voltage increases from 0 V towards −12 V, at first T1 conducts, since it receives base current via the two 100-Ω resistors R2 and R4. It thus holds the base of transistor T2 at ground potential, cutting it off. This situation only changes when Zener diode Z1 starts to conduct, which occurs when the input voltage is sufficiently great (−11 V in this case). When Z1 conducts, T2 switches on, which causes the circuit to toggle due to the feedback provided by resistor R4. As the collector–emitter current of T1 drops, the base current of T2 increases, further driving T1 towards cut-off.

The Zener voltage of diode Z1 roughly determines the voltage at which the SHDN input is released. It must be chosen according to the input voltage range. Also, this circuit only works with step-up regulator ICs that are enabled when the SHDN input is at ground potential. For many types of switching regulator ICs, this input is labelled '$\overline{\text{ON}}$', but its function is the same.