Battery Discharger/ Capacity Meter

BENCHTOP POWER SUPPLY
with PC control

8-Channel DMX Demultiplexer

PC Surround Sound Amplifier

Vehicle Adaptor for Notebook PCs

PC Dot Matrix Display

50-W Car Amplifier

VOLTAGE   CURRENT

POWER
ON
OFF

+   −

DIGITAL POWER SUPPLY

0 - 25 V
0 - 2.5 A

9 770268 451098

Digital Benchtop
Power Supply (I)

Part 1:
analogue electronics controlled by microcontroller

Every electronics laboratory needs a powerful regulated bench supply. In the model described here a microcontroller monitors the actual and desired current and voltage settings.

There are many types of laboratory benchtop power supplies available, from the very simple to the highly sophisticated. They range from linear, purely analogue supplies with only voltage regulation to switching supplies with both current and voltage regulation using a microcontroller, also offering programmable signal patterns and various monitoring functions, while also driving an IEEE interface.

Our benchtop power supply lies in the middle of this spectrum. Depending on the rating, it offers a voltage range of 0-25 V at up to 2.5 A or 0-20 V at up to 1 A. The voltage and current settings are adjustable digitally using four buttons each (two for coarse and two for fine control). These provide a resolution of 100 mV in voltage and 10 mA in current. The desired and the actual voltage and current values are shown on a backlit LCD panel. The device can be controlled remotely over its built-in RS232 interface, and the measured current and voltage values are available continuously over this interface. The communication protocol uses only ASCII characters, so that, in the simplest case, HyperTerminal suffices to display and adjust the values. A proper power supply control

program is also available for free download from the author's website at www.pic-basic.de. The source code of this program is also published, so that it can be modified for other applications.

A Microchip PIC16F84 microcontroller controls the power supply, running a program written in PIC-BASIC 1.3. The source code, assembler listing and machine code hex dump for this program are also freely available from the address above.

Classical
analogue regulation

The circuit consists of an analogue part and a digital part, which are assembled on the same circuit board. Only the pass transistors, the LCD module and the mains transformer (along with the mains input and switch) are not fitted to the board. The classical analogue regulator circuit is brought up-to-date using an LT1491. This IC is a quad operational amplifier, which has the same pinout and practically the same (or better) characteristics as the legendary LM324. Also, the LT1491 offers rail-to-rail operation on its inputs and outputs. **Table 1** shows a few of the characteristics of the two ICs. The LT1491 earns its place in this circuit despite its
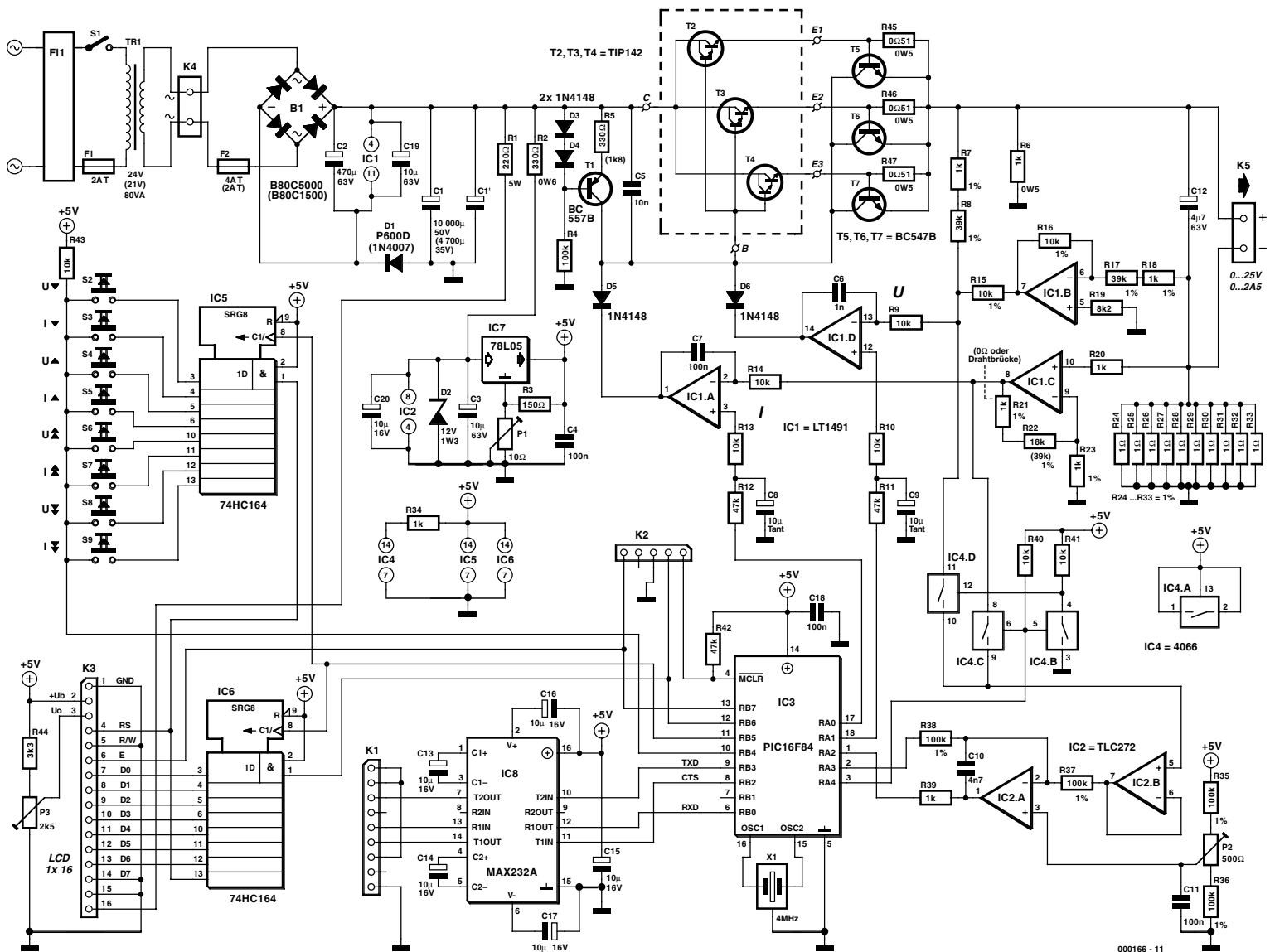
DIGITAL PSU SPECIFICATION IN BRIEF		
	2,5-A version	**1-A version**
Input voltage 230V	−0/+10 % @ 2.5 A / 25 V ±10 % @ 2.5 A / 24 V	±10% @ 1 A / 20 V
Set voltage accuracy	+30 mV typical	+30 mV typical
Set current limit accuracy	+5 mA typical	+5 mA typical
Output voltage ripple	5 mV (voltage regulation) 10 mV (current regulation)	5 mV (voltage regulation) 25 mV (current regulation)

Figure 1. Circuit diagram of the 2.5 A power supply. Values in brackets refer to the 1 A version.

higher price. With the aid of a few close-tolerance metal film resistors the op-amps work sufficiently accurately that only a few calibration points are required.

In a power supply with classical analogue regulation such as the circuit in **Figure 1**, the output voltage and current are measured and continuously compared against the desired values by comparators. For this, the output voltage is taken directly from the output connectors (thereby avoiding errors due to the resistance of the tracks and contacts) and brought into the input voltage range of the comparator using a simple voltage divider.

Current measurement is somewhat more complicated, since in general a shunt resistor is required in the current feedback loop. The resistance of the shunt must be as low as possible in order not to reduce the output voltage range too severely and to keep the power losses low, but on the other hand must be high enough and accurate enough to ensure that the voltage drop (which is proportional to the current) is practically measurable by the comparator and not lost in the offset voltage or noise of the electronics.

The shunt resistance consists of ten 1 Ω resistors (R24-R33) wired in parallel. This is rather cheaper than a 0.1 Ω resistor with a tolerance of 1 %, and the expected deviation from the true value is rather lower. The layout is organised so that only a little track resistance affects the measurement.

With an output current, or load, of 2.5 A, 0.25 V is dropped across the shunt resistance. Op-amp IC1.C multiplies this voltage by a factor of 20, in the 2.5 A version, and 40, in the 1 A model. This amplified voltage is measured and taken to the comparator via R14.

However, the current also has an effect on the voltage measurement. Op-amp IC1.B divides the voltage drop across the shunt by four and inverts it, giving –0.0625 V. If the voltage across the output terminals (i.e., across the load) is 25 V, then 25.25 V relative to the circuit's ground appears at the positive output terminal. Voltage divider R7/R8 and R15 have a total value of 50 kΩ. Across the voltage divider we have 25.25 V+0.0625 V=25.3125 V. Of this, 4/5th is dropped across R7 and R8, and 1/5th is dropped across R15. Across R15 we therefore have a drop of 5.0625 V. At the voltage divider output (at the junction of R8 and R15) we therefore have exactly 5 V relative to the circuit's ground. The voltage at the output of the voltage divider (relative to ground) therefore reflects exactly the output voltage, independent of the current flowing in the shunt resistor. Without this compensation for the voltage error the voltage across the shunt resistor (up to 0.25 V)

Table 1. LM324 vs LT1491		
	LT1491 (typical values)	**LM324** (typical values)
Offset voltage	200...350 μV	2 mV
Offset voltage drift	2 μV / °C	7 μV / °C
Input current	4 nA	45 nA
Power supply voltage (max.)	44 V	32 V
Short-circuit output current	25 mA	20 mA

would affect the measurement of the output voltage. So that the op-amps can operate with negative voltages relative to ground a negative auxiliary supply is required, which is derived from the input voltage with the aid of diode D1.

The divided-down, amplified and compensated measurement voltages are finally taken to the inverting inputs of op-amps IC1.A and IC1.D via R9 and R14. Op-amp IC1.D, connected as a comparator, compares the actual voltage (at the inverting input) with the desired voltage, and IC1.A does the same for the current. The desired values originate from the PIC16F84 microcontroller (IC3) which can generate two precise analogue voltages thanks to R/C combinations R11/C9 and R12/C8. The voltages are produced using pulse-width modulation of the microcontroller's output pins. These two D/A converters have a resolution of 8 bits.

C6 and C7 cause the two comparators to exhibit a lowpass response. The outputs drive the base connection of the pass transistors via D5 and D6 in a 'wired OR' configuration. If one of the measured values exceeds the desired value, the base is pulled towards ground (or even slightly below) and the transistors are switched off. If neither the desired current nor the desired voltage is reached, constant current source T1 delivers a base current of 2 mA (for a 2.5 A power supply) or 360 µA (for a 1 A power supply), independent of the output voltage.

Such a low base current is only practical because power Darlington transistors (T2, T3 and T4) are used. For the 2.5 A unit three Darlington transistors are fitted. In order that the current is properly shared between the transistors, 0.51 Ω emit-

ter resistors are provided. If the voltage across one of the three resistors rises above 0.65 V (at around 1.3 A), one of the transistors T5, T6 and T7 will turn on and thereby turn off the base current to the Darlington transistors. This affords effective protection against current spikes that may occur if the output is short-circuited and which would otherwise damage the power transistors. In the 1 A power supply only one Darlington transistor is fitted. The emitter resistors and protection circuit can therefore be dispensed with. For the 2.5 A power supply a 0.6 K/W heatsink is required, and for the 1 A power supply a 2.4 K/W heatsink is fitted. At maximum load — that is with a short-circuited output at the highest current possible — a temperature of 80 °C will be reached. The two versions of the power supply are therefore (without active cooling) suitable for continuous use at full load.

Values set by the microcontroller

The connecting link between the analogue and digital domains is the PIC microcontroller IC3. In order to accurately measure and produce voltages an accurate and stable reference voltage is of course required, which it derives from its supply voltage. For this reason a few components are added around D2 (pre-regulation to 12 V) and IC7, a fixed voltage regulator. The pre-regulated +12 V supply is also used to feed IC2.

Using R3 and P1 the voltage at the regulator output can be set to 5.12 V (in practice 5.14 - 5.16 V). R3 provides a basic load so that a current of at least 33 mA always flows through P3. This current is chosen to be about 10 times as great as the

current in the ground connection of the voltage regulator. Load-dependent variations in the common-pin current therefore only have a very small effect. Moreover, the load current varies proportionally less owing to the high basic load current.

As a result of these measures, the reference voltage is very stable and changes only as a consequence of the normal ageing of the components. It is therefore recommended, as with any other electronic test equipment, to recalibrate the device after a few years.

The reference voltage reference voltage is also used for the delta-sigma A/D converter built around IC2. Using this conversion technique a high-precision converter can be built with little circuitry, and, independent of component tolerances, very accurate measurements can be achieved with good reproducibility. However, 1 % resistors have been used to simplify offset calibration using P2. The microcontroller also plays a part, of course, in the analogue-to-digital conversion. Conversion proceeds in the following stages:

In the initial state, microcontroller pin A2 (set as an input) is high impedance and pin A3 (an output) is at 0 V. The voltage to be measured is present at the non-inverting input of IC2.B, and, since the op-amp is connected as a buffer, also at its output. Let us suppose that this voltage is exactly 1.28 V. Then the output of the integrator IC2.A will be at the level of the positive supply. Pin A2 on the microcontroller will interpret this as a high logic level. When a measurement is to be carried out, the microcontroller changes the state of pin A3 from low to high (i.e. to 5.12 V) and waits until the voltage on A2 changes to logic low. Now, by toggling pin A3 the microcontroller holds the output of the integrator in the middle of its range. The varying output signal of the integrator will be interpreted by the microcontroller as high or low. The mark-space ratio of the integrator's output is now measured. It can be seen that pin A3 must be held high for three times as long as it is held low: this is so that, when combined together with the voltage being measured, a voltage can be produced at the inverting

input to the integrator which on average is exactly the same as the voltage on its non-inverting input, namely 2.56 V.

The offset with P2 is required, because this type of A/D converter does not operate with negative voltages: the microcontroller's algorithm would fail. As well as allowing for compensation for component tolerances, P2 also provides a small positive offset. A TLC272, with MOS inputs, is selected for IC2 because the A/D converter will only work accurately when the input currents are considerably smaller than those achieved with bipolar ICs. This benefit is bought at the cost of a relatively high offset voltage. Here however, where an adjustment must be made anyway, this is no real disadvantage.

IC4 is an analogue switch that connects either the voltage at pin 11 (for voltage measurement) or at pin 8 (current measurement) to buffer IC1.B.

Interfaces

The microcontroller has several interfaces at its disposal. The keyboard interface is implemented using IC5 and the LCD panel is connected via IC6. These are 8-bit shift registers (type 74HC164) with serial input and parallel outputs. Digital values are

loaded into the register by the microcontroller using pins B5 (data) and B6 (clock). In the case of IC6 these values are control commands and character codes which are transferred to the LCD module, running in 8-bit mode, using a strobe signal on pin B7. In the case of IC5 these form a bit pattern which allow the microcontroller to identify (via pin B4) when a button has been pressed. P3 is the potentiometer required for adjustment of display contrast. The wiper being at the ground end corresponds to a viewing angle of between 10° and 20° above vertical: this is the recommended setting when the unit is to be used on the bench.

Microcontroller pins B0, B2 and B3 comprise an RS232 port. Using the well-known MAX232 the signal levels are shifted between ±10 V on the RS232 side and TTL levels on the microcontroller side. In addition to the required connections (RXD and TXD), the CTS (clear to send) signal is also connected. The RS232 interface offers remote display as well as remote control. This will not concern us further here: a description of the software and operation of the unit will be presented in the second part of this series, in the next issue. Let us turn instead to the construction of the power supply.

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The construction of the Digital Benchtop PSU will be described in next month's issue.
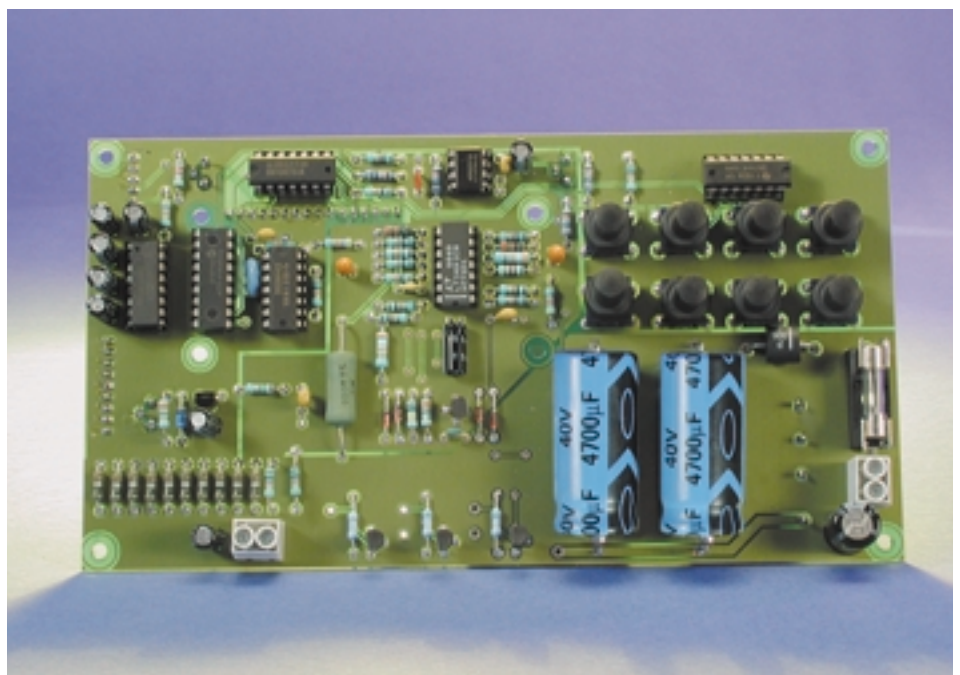
PICSTART Plus

Development Design Tool Package

Microchip's PICSTART Plus DDTP (Development Design Tool Package) is a complete development tool for all members of the PIC microcontroller family.

A compact box with a lot inside: this is how Microchip likes to describe the development package they offer to designers working with the PIC microcontroller family. The new version of PICSTART Plus includes the PICC Lite C compiler, which is also suitable for beginners and programmers not already familiar with C. This compiler supports the popular PIC16F84(A) flash microcontroller, a sample of which is also included in the kit.

The development package is distinguished by its relatively low price (199 USD) and its flexibility. As a program development tool, it is suitable for all 8-bit Microchip microcontrollers, which encompasses no fewer than

105 types including the widely used PIC12CXX, PIC16CXX and PIC17CXX microcontrollers. The main component of the package is the MBLAB integrated development environment, which contains all the tools needed for editing, simulation and compilation.

Let's open the box and have a closer look at what it has to offer. The first thing we notice is that Microchip have filled the box with a considerable amount of paper, in the form of several user's manuals. There are both full and condensed manuals for

the complete development package, as well as a manual of more than 200 pages for the assembler (including the linker and librarian). On top of these there is a quick reference card (all naturally in English). Contrary to usual practice, you should not just return the manuals to the box to never to be seen again; a more or less thorough perusal of this literature could certainly prove advantageous!

The software is contained on four CD-ROMs and consists of:

– MPLAB IDE V5.30
– CD-ROM Microchip Technical Library (parts 1 & 2)
– PICC Lite

You should verify that the software in the box is at the current version level, since the programs are updated fairly often. A glance at the Microchip web site (www.microchip.com) will show you the current versions of the software. For its part, PICC can run under Windows 3.1 or higher.

The development package is rounded out by a small programming adapter with a ZIF socket, a PIC16F84A, a serial interface cable and a mains adapter (with a UK plug).
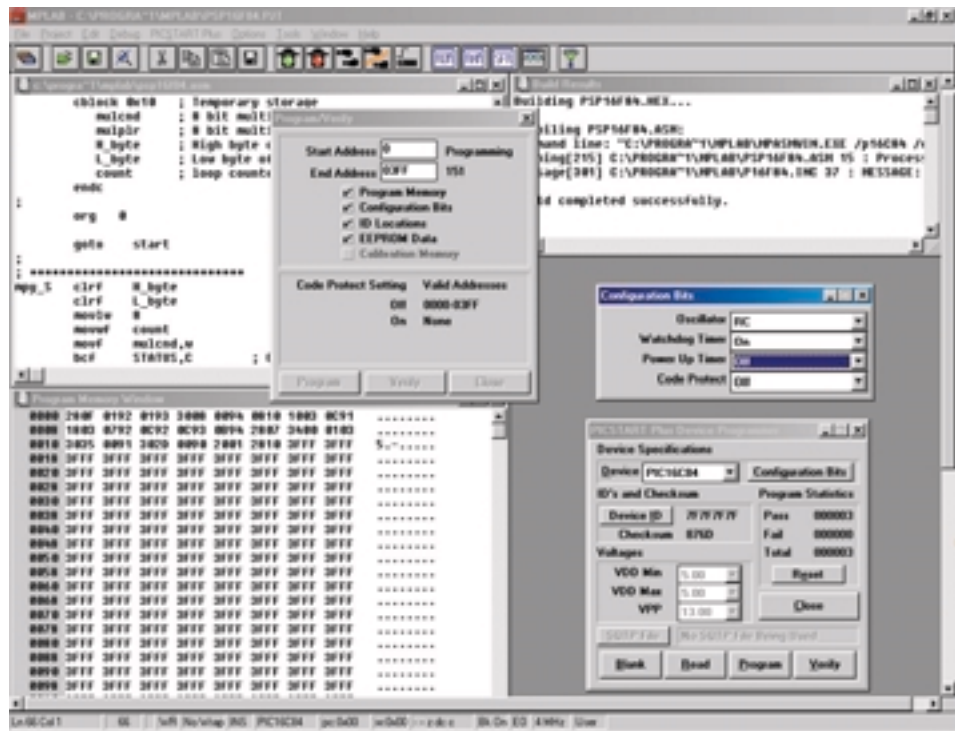
MPLAB development environment

MPLAB allows you to develop microcontroller programs by working with a user interface that supports the developer with configurable tools

and status information for editing and troubleshooting. The MPLAB integrated development environment (IDE) encompasses the following components:

– A project manager that manages all the programs belonging to the IDE.

– An editor for generating and editing text files (source texts and linker scripts).

– An assembler to generate assembler files from source texts without requiring the user to leave the development environment. The assembler is complemented by a linker, which produces the final application by connecting together relocatable modules generated by the assembler or the compiler. The MP librarian manages software modules produced by the software developer so they can be reused.

– A C compiler for C17 and C18 microcontrollers.

– A simulator that simulates the program code according to the I/O of the microcontroller. The simulator can handle not only the core functions of the PIC microcontroller family, but also most of the peripheral functions.

– An emulator, which together with some supplementary hardware can substitute for the programmed PIC microcontroller in real time, with or without a target system.

– A Pro Mate II programmer.

Installing the MPLAB IDE is child's play. After the CD-ROM has been inserted in the drive and the autostart dialogue has appeared, just press the *Install MPLAB IDE v5.xx* button. In the options box, you should select at least MPLAB IDE and MPASM/MPLINK, and the simulator and help files are also quite useful. A full installation requires just under 30 MB of hard disk capacity.

PICC Lite C compiler

Now we come to the PICC Lite C compiler. Installation is just as easy as for the IDE, but now we have a job for the printer, since there is no printed manual for the complier in the box. This means that it is not only recommended but practically essential to transfer the 228-page PDF manual to paper, since you are repeatedly referred to the manual when using PICC Lite. The electronic manual is very well put together and provides numerous examples to help you familiarise yourself with the secrets of all the compiler's functions. Consequently, even beginners to this programming language can easily work with PICC Lite.

Although PICC Lite is a third-party product, it is exceptionally well integrated into the IDE. However, since this compiler is suitable for only one specific type of microcontroller, it is only useful for an introduction to high-level-language programming for PIC microcontrollers. If you frequently have to deal with other types of PIC microcontrollers, you will have to rely on *otools*. If you wish to receive a list of available third-party tools, send an e-mail to listserv@mail.microchip.com with the message *subscribe otools erika mustermann*. This list may well include C compilers for other types of PIC microcontrollers.

With PICSTART Plus, you have a complete development tool for an enormously popular microcontroller family (whose use is by no means limited to *Elektor Electronics* projects). Consequently, at a price of less than £200 this package is quite economical in comparison with similar products — and with a bit of luck you might even obtain it for free (see the sidebar!)

(017054-1)

Raffle!

Napier Partnership Ltd., the Press Relations and Advertising agency for Arizona Microchip, are raffling off several PICSTART Plus kits. All you have to do is provide your name and address by telephone, fax or e-mail to Napier Partnership Ltd. at:

Tel.: (+44) (0)1243 513434
Fax: (+44) (0)1243 513435
e-mail: ukcompetition@napier.co.uk
(Contact person: Veronica Batchelor)

With a bit of luck, you could be the proud owner of this interesting development package!

ISAC (2)

part 2: the ISAC Cube

By Prof. Dr. B. vom Berg, P. Groppe and M. Müller-Aulmann

This cube is the basic module of the Elektor Electronics ISAC (Intelligent Sensor/Actuator Controller) project and includes a compact core system using an Analog Devices ADuC812 MicroConverter, which was described in last month's introductory instalment. The tiny SMD circuit board can be used like a large IC in an application circuit or in the prototype board presented here.

The ISAC cube is a flexible and modular microcontroller system for both simple and complex applications. Producing a plug-in circuit board allows easy upgrades to existing applications by simply exchanging the cube for a newer one, if and when Analog Devices bring out new devices in the MicroConverter series with enhanced facilities.
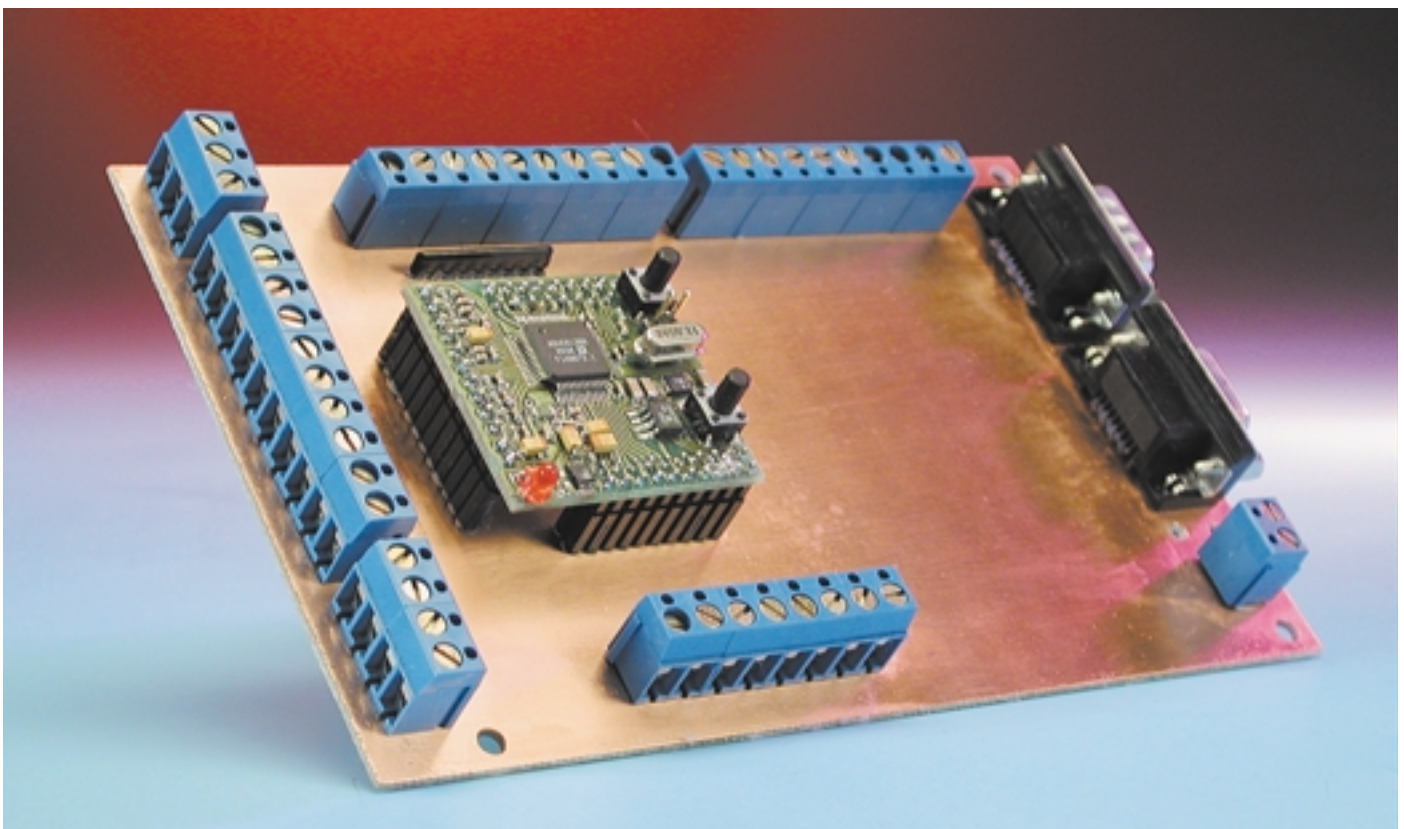
As can be seen from a glance at the picture of the circuit board of the ISAC cube, only a very few components are required to construct a minimal ADuC812-based system. The biggest problem is fitting the MicroConverter device itself, with its many pins; this problem can be solved by obtaining the SMD circuit board with components already fitted.

Circuit diagram of the ISAC cube

The ADuC812 circuit shown in **Figure 1** is more or less as recommended in the data sheet [1]. A standard 8051 microcontroller-style crystal circuit using the familiar 11.0592 MHz crystal frequency allows (among other things) easy generation of baud rates for the serial communications interface. The analogue inputs are fitted with low-pass filters with a cutoff frequency of around 300 kHz. Bypass capacitors are fitted according to Analog Devices' recommendations.

All other important system connections are brought out to multi-way pinheaders X1, X2, X3 and X4, to allow the ISAC cube to be connected to the outside world. It is however worth noting that all the external connections are **unprotected**: the ADuC812 can be damaged by excessive voltages or short-circuits on the analogue or digital

Table I
Characteristics of the ADM707 reset circuit:

– Two separate reset outputs providing an active-low and an active-high reset signal
– Generation of power-on reset
– Manual reset possible by simply connecting a push-button
– Additional input (PFI) to monitor any desired system voltage, such as low-battery indication in battery-powered applications, with corresponding alarm output PFO
– Low quiescent current consumption: 190 μA.
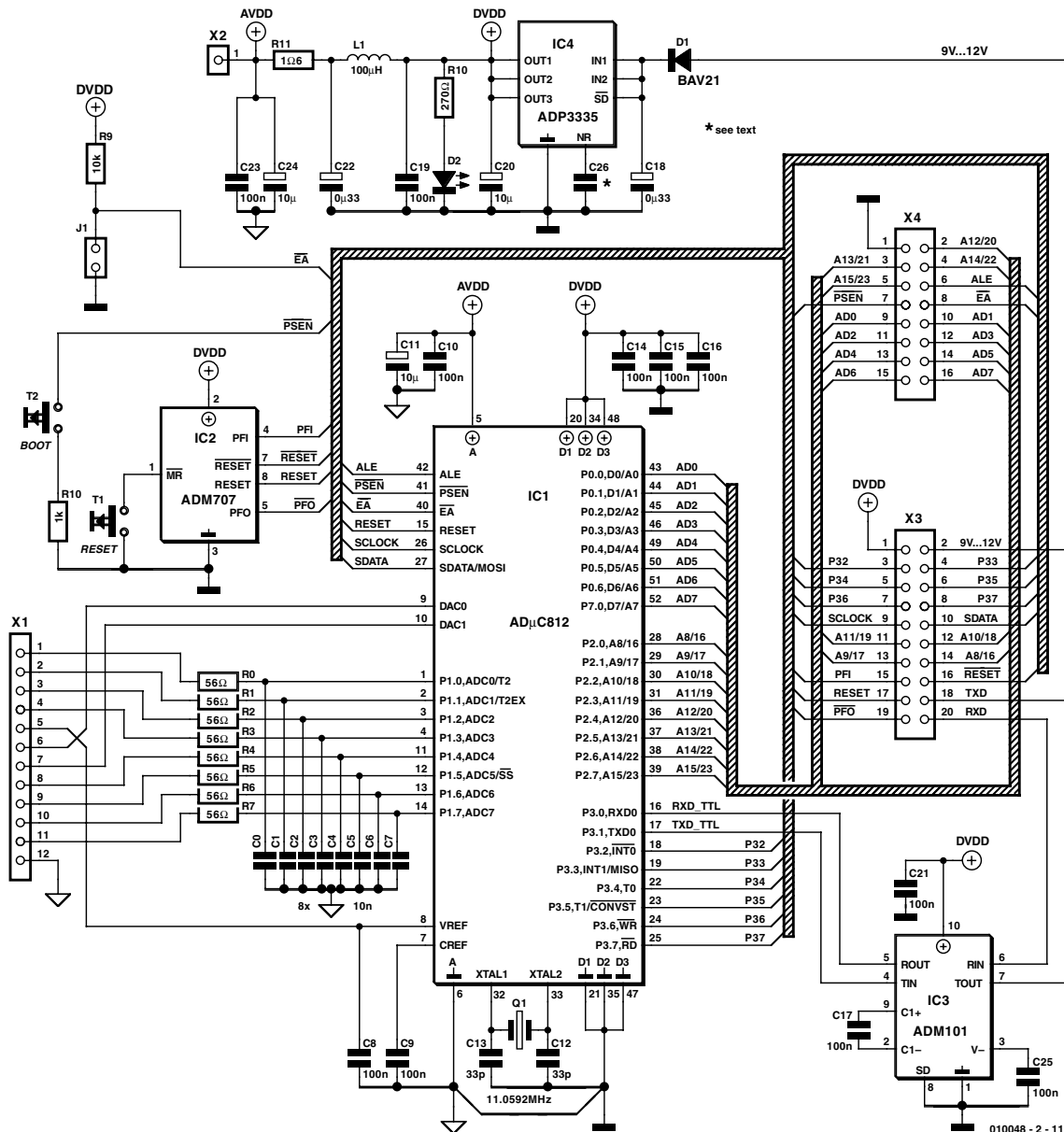– Complete data sheet available for download via the Analog Devices homepage [2]

Figure 1. Circuit diagram of the ISAC cube.

COMPONENTS LIST
(ISAC Cube)

(case shapes in brackets)

Resistors:
R11 = 1Ω6 (SMD 1206)
R0-R7 = 56Ω (SMD 0603)
R10 = 270Ω (SMD 0603)
R8 = 1kΩ (SMD 0603)
R9 = 10kΩ (SMD 0603)

Capacitors:
C12,C13 = 33pF (SMD 0603)
C0-C7 = 10nF (SMD 0603)
C8,C9,C10,C14,C15,C16,C19,C23 = 100nF (SMD 0603)
C26 = not fitted
C17,C21,C25 = 100nF (SMD 1206)
C18,C22 = 330nF (SMD 1206)
C11,C20,C24 = 10μF (SMD 1206)

Inductor:
L1 = 100μH (SMD 1206)

Semiconductors:
IC1 = ADμC812 (LPQF-52)
IC2 = ADM707 (SOIC-8)
IC3 = ADM101E (μSOIC-1)
IC4 = ADP3335 (MSOP8)
D1 = BAV21 0.25 A (lead pitch 5mm)
D2 = LED, red, 3mm (lead pitch 2.5mm)

Miscellaneous:
Q1 = 11.0592MHz quartz crystal (HC-49/U)
T1, T2 = PCB mount pushbutton, make contact, 6x6mm
X1, X2, J1 = 15-way SIL pinheader, 2.5mm lead pitch
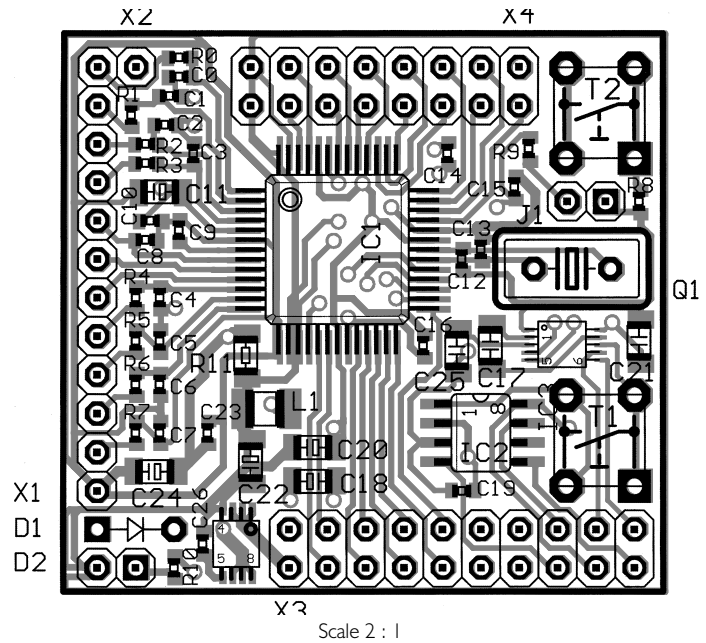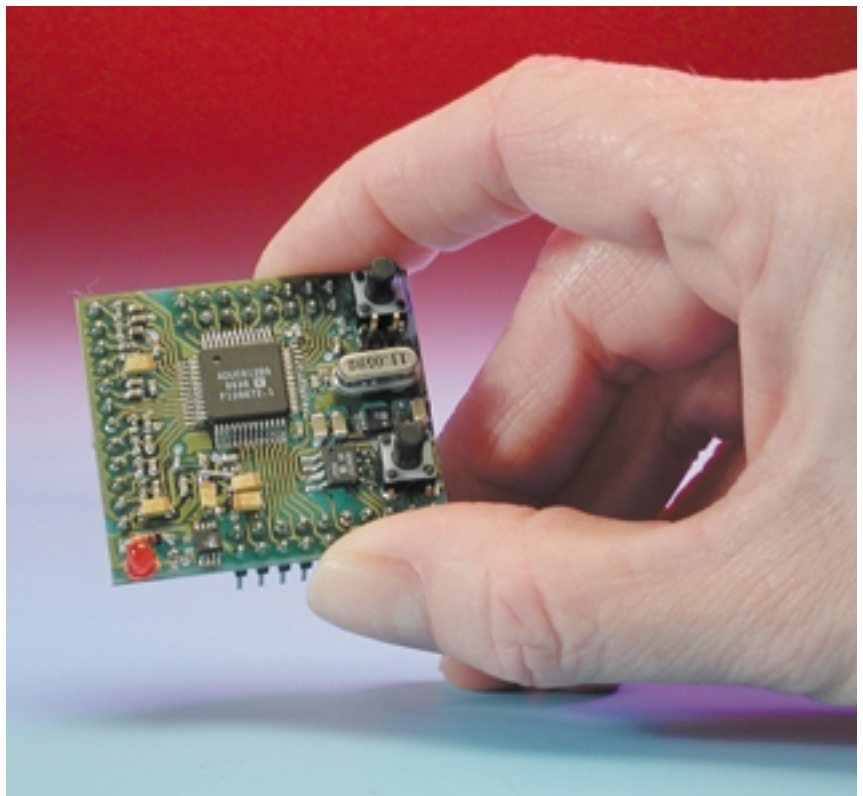X3, X4 = 36- way double-row pinheader, 2.5mm lead pitch
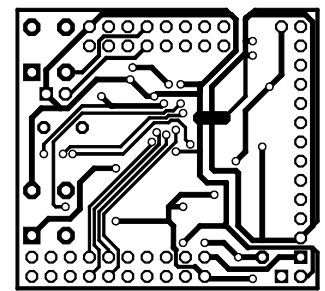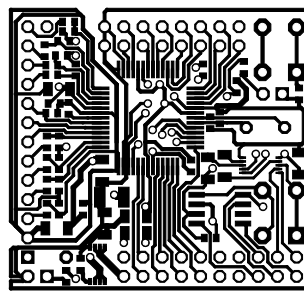
Figure 2. The SMD circuit board is available ready built and tested from the authors.

port pins. If this is to be prevented by protection circuitry, this must be provided in the external application circuit.

The reset circuit is built using IC2, whose important characteristics are summarised in **Table 1**. The ADuC812 is automatically reset when power is applied or when button T1 is pressed.

IC3, an ADM101E, is responsible for level shifting in the serial interface (for communication with the development PC) from TTL levels to RS232 levels and vice versa. The device is a single-channel level shifter which simply requires the connection of three external capacitors. The full data sheet for this IC can be found via the home page of Analog Devices [2].

The power supply for the cube is provided in the usual fashion by an ADP3335 (IC4),

Table 2
Connector pinout of the ISAC cube:

XI			X3					X4			
XI.1	ADC0		X3.1	DV$_{DD}$	9V...12V	X3.2		X4.1	GND	A12/20	X4.2
XI.2	ADC1		X3.3	P32	P33	X3.4		X4.3	A13/21	A14/22	X4.4
XI.3	ADC2		X3.5	P34	P35	X3.6		X4.5	A15/23	ALE	X4.6
XI.4	ADC3		X3.7	P36	P37	X3.8		X4.7	PSEN\	EA\	X4.8
XI.5	VREF		X3.9	SCLOCK	SDATA	X3.10		X4.9	AD0	AD1	X4.10
XI.6	DAC0		X3.11	A11/19	A10/18	X3.12		X4.11	AD2	AD3	X4.12
XI.7	DAC1		X3.13	A9/17	A8/16	X3.14		X4.13	AD4	AD5	X4.14
XI.8	ADC4		X3.15	PFI	RESET\	X3.16		X4.15	AD6	AD7	X4.16
XI.9	ADC5		X3.17	RESET	TXD	X3.18					
XI.10	ADC6		X3.19	PFO\	RXD	X3.20					
XI.11	ADC7							**X2**			
XI.12	AGND							X2.1	AV$_{DD}$		

after which a rather extravagant further smoothing circuit is required: the ADuC812 incorporates both a 12-bit A/D converter and a 12-bit D/A converter, and these two high resolution converters make stringent demands on their supply voltage (AV$_{DD}$ und AGND). The digital supply DV$_{DD}$ is provided directly by the ADP3335, and this supply is passed through a special filtering and decoupling circuit (C19, L1, C22, R11, C23 and C24) to provide the AV$_{DD}$/AGND analogue supply for the ADuC812.

Further, the two grounds (analogue ground AGND and digital ground DGND) must be suitably connected to prevent interference. Design guidance for PCB layout of the power supply network is provided in the 'ADuC812 User Manual: Hardware Design Guide' available for free download over the Internet from Analog Devices [2].

It is worth noting that the ADP3335 voltage regulator is of the 'low dropout' variety, and that at the maximum load of 500 mA an input voltage of only 200 mV above the output is required to provide the components of the ISAC cube with a supply accurate to ±0.9 %. This allows the use of the ISAC cube in battery-powered applications with efficient use of the battery's capacity.

The pinout of the headers on the ISAC cube is shown in **Table 2**.

The current consumption of the cube is around 40 mA (with a 9 V supply and LED D2 connected).

Construction of the ISAC cube

Even for the experienced constructor, building the ISAC cube is not an easy job. Surface mount connection and packaging technology continues to progress, ICs get smaller and smaller and their pins get closer and closer together. Without specialised SMD handling tools or access to a

fully fitted-out SMD soldering station assembling the ISAC cube circuit board shown in **Figure 2** is not practical.

To make this pioneering project practical, the authors have decided to offer ready-assembled and tested cubes to interested readers, so that the SMD daughter board can be used as a ready-made module in the same way as a large, powerful IC would usually be used in an application circuit. The cube's pins are set at the standard 2.54 mm (0.1 inch) pitch.

The ready-built cubes are fitted with a pre-programmed ADuC812, so that an initial functional test can easily be carried out. For this purpose a simple prototyping board has been developed with a socket for the cube. **Figure 3** shows the board with ISAC cube fitted. The circuit diagram is shown in **Figure 4**, and the layout and component mounting plan are shown in **Figure 5**. With this simple circuit board, elementary programming experiments and applications can be realised. A more powerful motherboard is planned for future projects.

Set-up and test

To set up your ISAC cube and carry out an initial test, you require only a 9 V power supply and a PC (with a terminal program) connected to the cube or to the prototyping board as shown in **Figure 6**. First measure the current consumption, which should not exceed 40 mA.

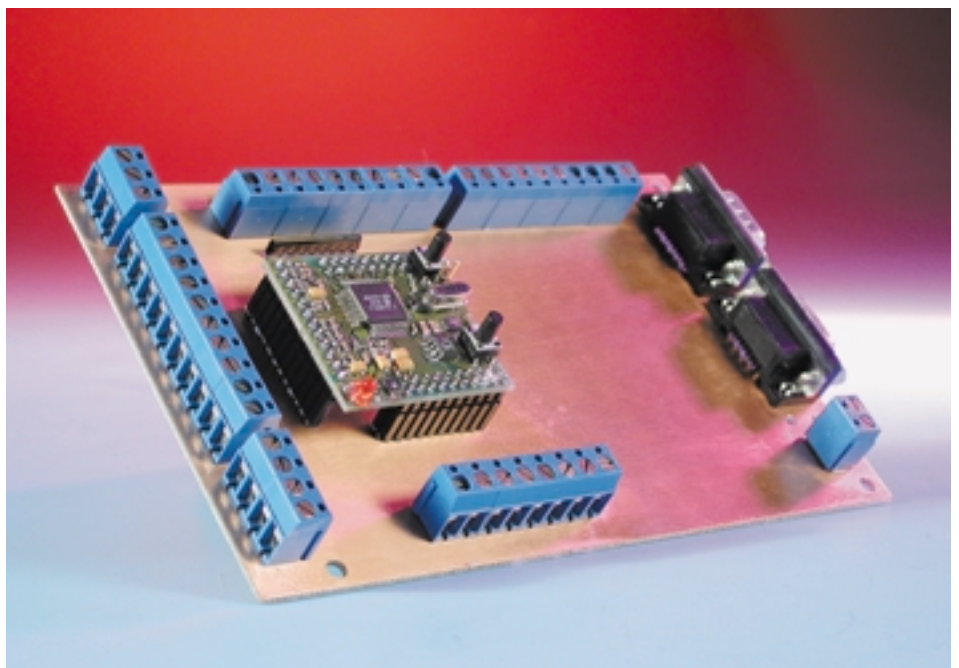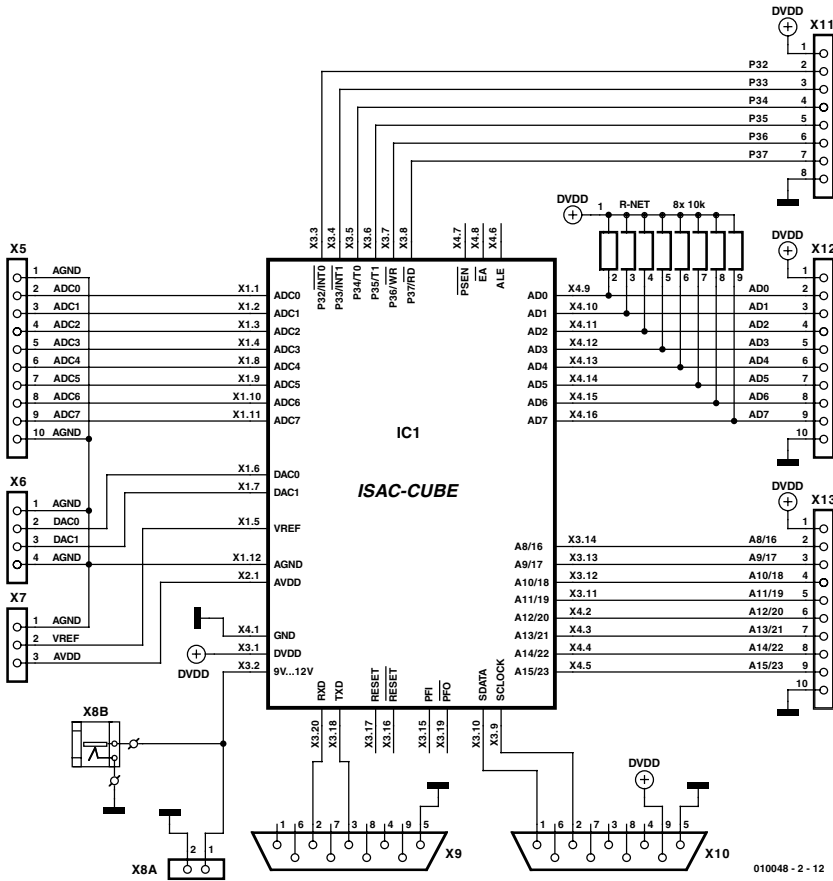On pressing the reset button a welcome

Figure 3. The prototyping motherboard with ISAC cube fitted.

Figure 4. Circuit diagram of the simple prototyping motherboard.

COMPONENTS LIST
(simplest version)

Resistors:
R-Net = 8-way 10kΩ SIL array

Miscellaneous:
X5,X6,X7,X8A,X11,X12,X13 =
    PCB screw terminal block, 47-
    way, one row, lead pitch 5mm
X9 = Sub-D plug (male), 9-way,
    angled pins, PCB mount
X10 = Sub-D socket (female), 9-
    way, angled pins, PCB mount
X8 = jack socket, 3.5 mm, mono,
    PCB mount
15-way SIL pinheader
36-way pinheader (double row)
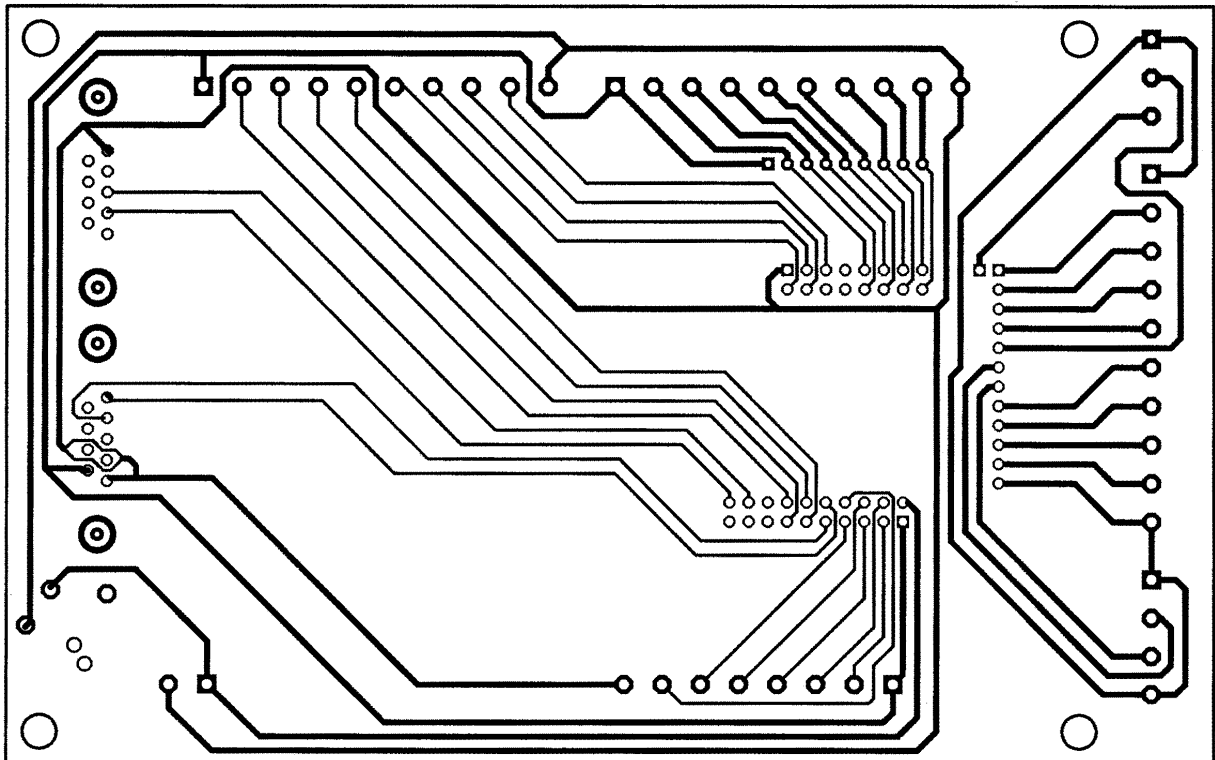
Figure 5. Layout of the prototyping motherboard.
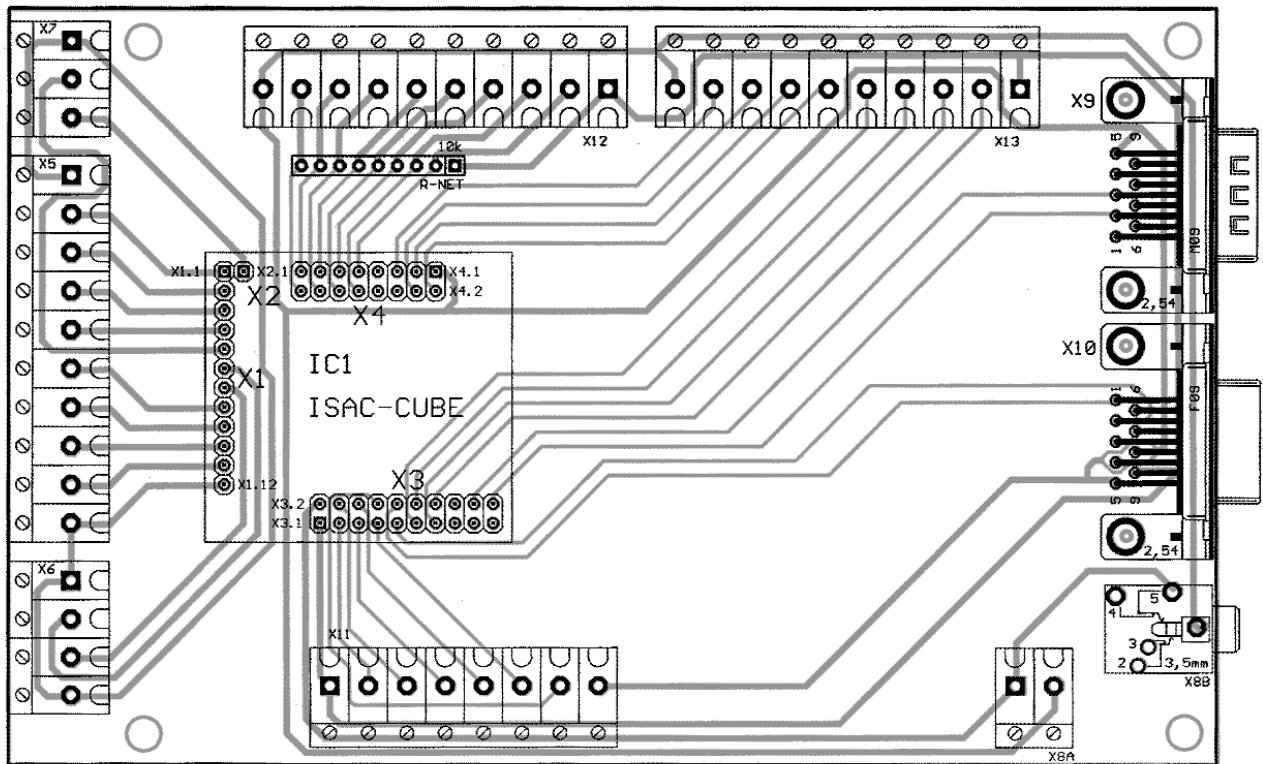
message from the ADuC812 should appear on the PC's monitor. This switch-on message only appears when using a ready-built cube, in which the ADuC812 has already been programmed with a small amount of code. If you build your own cube, the ADuC812 is initially blank and must have a suitable program downloaded into it.

You can use any terminal emulation program to receive these communications on the PC, such as the HyperTerminal program that is provided free with Windows. In any case, the required communications settings are: 9600 baud, 8 data bits, no parity, 1 stop bit and no handshake.

We have now described all the

hardware required to use the ADuC812. In the next instalment of this series we will discuss the software development environment and write our first program.
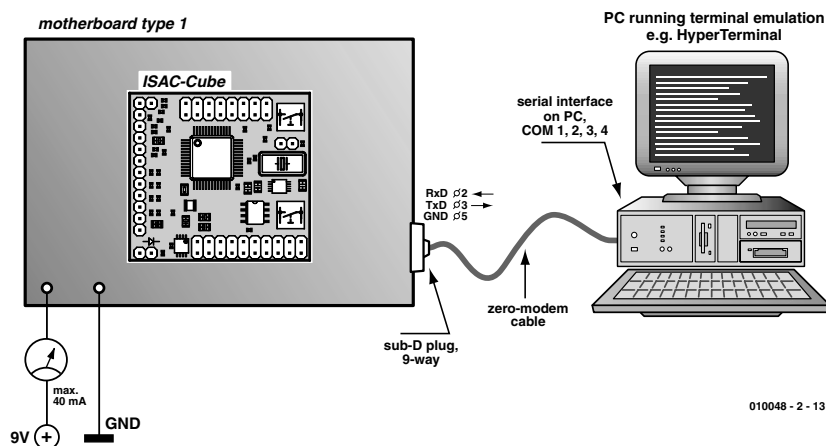
(010048-2)

Figure 6. Connecting the ISAC cube for its first test.

Miniature PCM Remote Control (2)

part 2: the software protocol

In this second and final part of the remote control design we put it all together and take a closer look at the workings of the transmitter and receiver software.

As with any communication system it is necessary to decide on a suitable message format to convey the information. This system does not need to comply with any existing communication standard so we are free to design our own. The main objectives are to enable a high data rate together with good reliability and error detection. The specification of the transmitters and receivers must also be considered to ensure, for example, we do not exceed the maximum clock rate or channel bandwidth. With these constraints in mind a message protocol is used (**Figure 1**) that is suitable for transmission using either IR or RF.

Start bit

The start bit allows the receiver software to synchronise on a new message. The length of the high and low phase of the start bit ensures that it cannot be confused with any part of the rest of the message.

Channel address (2 bits)

The channel address is used to indicate which channel the A/D value is intended for so that moving a joystick on the transmitter will cause the correct servo to move at the receiver. Two address bits allow four channels to be encoded.
For example:
Left joystick up/down value: Address 00
Left joystick left/right value: Address 01

A/D value (8 bits)

The angular positions of the joysticks are read from the potentiometer values mounted in the joystick. These values are converted into 8 bit digital values in the A/D converter and transmitted in the message. The corresponding
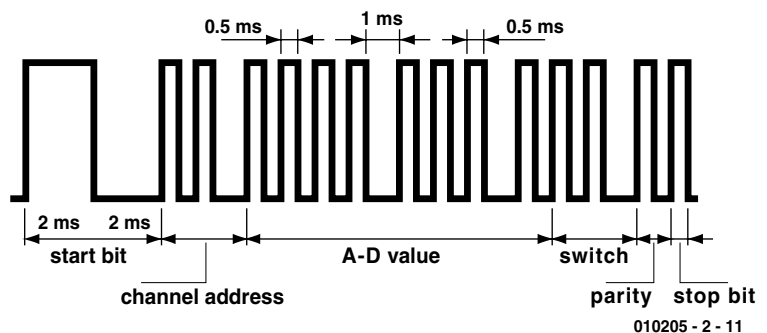

Figure 1. Message protocol.

channel number is also sent in front of each value.

Switch bits

The status of the two momentary action pushbuttons at the transmitter is sent using these two bits. A toggle action is implemented in software so that each time the switch is pressed the status of the corre-
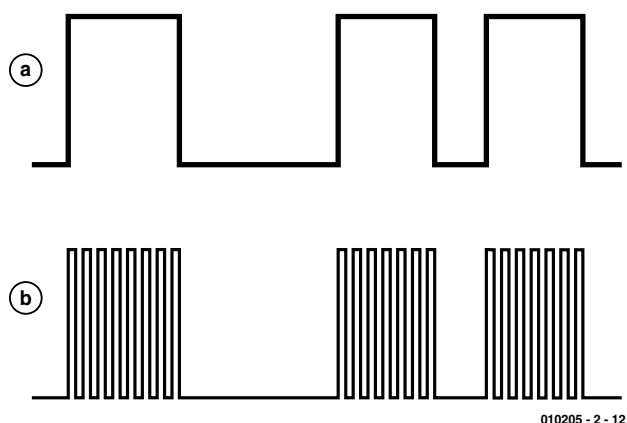

Figure 2. Control of the RF module (a) and the IR LED (b).

Operating Range

RF Module

Radiometrix quote the free-field range of the modules used here as 300 m. This should be more than adequate for a radio-controlled car.

Infrared

The range of the infrared version is somewhat less than the RF variant. The IR link needs a line-of-sight path from the IR transmitter diode to the receiver either directly or indirectly by bouncing off a reflective surface. The IR receiving diode should therefore be mounted on the roof of the model or somewhere where it will be more likely to see the IR signal from any direction.

The transmitting IR LED beam propagation pattern is cone shaped with an angle of ±15°. If the receiver is not subject to direct sunlight then you can expect a range in the order of 5 m.

sponding bit will change state and stay at this level until it is pressed again.

Parity bit

The parity bit allows the receiver to detect single bit errors in the transmitted message. The transmitter software counts all the '1's in the transmitted message and if the count is odd then the parity bit will be set (1). If the count is even the parity bit is reset (0). The receiver simply counts all the '1's in the received message (including the parity bit) if the result is odd it knows that the message was corrupted:
Message = 0010101100, Parity = 0
Message = 0011101100, Parity = 1

Stop bit

The stop bit marks the end of the message. It conveys no other information.

A complete message is not sent every cycle. To achieve smooth, high speed servo positioning and reduce transmitter power consumption, information is only transmitted if there is a change in the position of the joysticks or if a switch is pressed. The transmitter software reads in the joystick and switch values, compares them to their previous values and prioritises any changes before a message is sent. If you tried sending all the data in every message with the data rate that is available in this system, the servos would have a very jerky response. The software also averages out the joystick position. It reads an A/D converter output four times, adds the values together and then divides the result by four. This process smoothes out changes and helps to reduce supply current. If you have an oscilloscope handy you will be able to see that the transmitter sends hardly anything when the transmitter controls are left untouched and its only when a switch is pressed or a joystick

moved that a message is sent. This feature prolongs battery life, especially when the IR transmitter option is used. The receiver always stores and uses the last value sent until it is overwritten by a new value. The digital message stream is connected to the RF modules modulation input pin where it frequency modulates the 433 MHz carrier. If the IR option is selected the data must be modulated at 36 kHz (**Figure 2**).

The Transmitter and receiver programs

The program flow for both the transmitter and receiver software is very simple and can be represented as a list of tasks:

Transmitter

1. Initialisation of ports and internal controller hardware.
2. Watchdog reset.
3. Check the battery voltage level and control the LED correspondingly.
4. Input values from the four joysticks.
5. Check for pushbutton presses.
6. If any changes then send a message:
   For infrared:
   Modulate with a 36 kHz carrier.
   For RF: Modulate the transmitter frequency with the message bit pattern.
7. If in infrared mode then wait 10 ms.
8. Return to 2.

Receiver

1. Initialisation of ports and internal controller hardware.
2. Watchdog reset.
3. Check the battery voltage level.
4. Sample the receiver module output and check the signal tolerances.
5. Check the message parity.
6. Service the switch output signals, the soft-start switch and the speed regulator.
7. Calculate the servo pulse width from the 8-bit value.
8. Load the timer with the servo pulse width value.
9. Return to 2.

A time of 200 µs is used to check the pulse length tolerance.

The software for this project is available on floppy disk only. Due to contractual agreements with the author, the programs are not available as free downloads from the Publishers' website.

Construction

Your chances of success in building a fully functioning control system are greatly

Transmitter to receiver control action.

Transmitter	Receiver output
Left joystick up/down	Servo at Pin P1.7
	Speed controller at Pin P0.1 (jumper coding!)
Left joystick left/right	Servo at Pin P0.4
Right joystick up/down	Servo at Pin P1.6
Right joystick left/right	Servo at Pin P1.4 Switch 1 on
Left joystick (Pin P1.1)	Switch output on Pin P1.0 Switch 2 on
Right joystick (Pin P1.0)	Switch output on Pin P1.1
	Soft start on Pin P0.1 (coding!)

increased if you use the professionally made PCBs available from *Elektor Electronics.*

Transmitter

The transmitter component placement is shown in **Figure 3.** The A/D converters need a stable supply voltage so the extensive earth plane helps to isolate the A/D converters from the large current pulses drawn by the IR LED. Fitting the components to the PCB begins by first soldering the five wire links in position. The microcontroller should be mounted on an IC socket. Ensure that the trim pots P1 to P4 will fit the unit.

To achieve maximum range from the RF transmitter module it should be sited as far away as possible from any metal so when mounting it on the PCB try not to shorten the modules' connection leads. A 1 cm length of PCB track forms part of the aerial so that 14.5 cm length of insulated wire connected to pin A1 should be sufficient to act as the transmitter aerial. The infrared LED is mounted and bent at 90° so that the IR light is beamed out of the front of the unit.
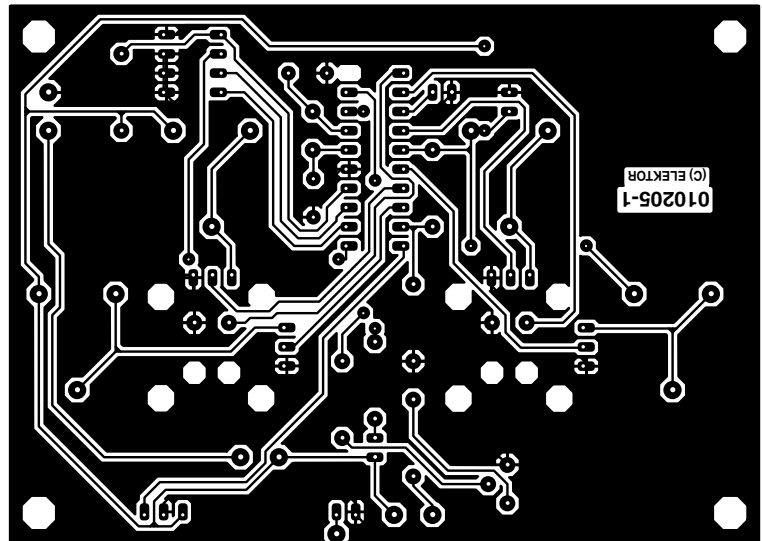

Figure 3. Layout and component placement of the transmitter PCB.

COMPONENTS LIST
Transmitter

Resistors:
R1 = 470Ω
R2,R3 = 18kΩ
R3 = 10kΩ
R4 = 1kΩ
R5 = 10Ω
R6 = 100kΩ
P1-P4 = potentiometer, 20kΩ, linear
P5-P8 = joystick (CTS # 252A104A60TB
    with internal switch)

Capacitors:
C1 = 220µF 16V
C2,C3 = 15pF

Semiconductors:
D1 = TSUS5201 or LD271
D2 = LED, red, 3mm
T1 = ZTX603 (Zetex) or TIP110
IC1 = 87LPC768FN, programmed, order
    code **010205-41**

Miscellaneous:
X1 = 6MHz quartz crystal
S3 = on/off switch, 1 make contact
S4 = 4-way DIP switch
JP1 = 2-way pinheader with jumper
UT1 = 433MHz transmitter module type
    TX2 from Radiometrix (Farnell)
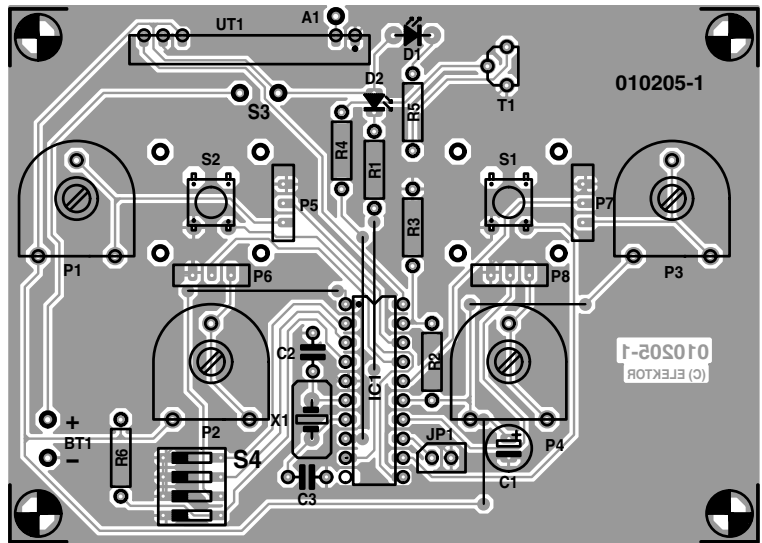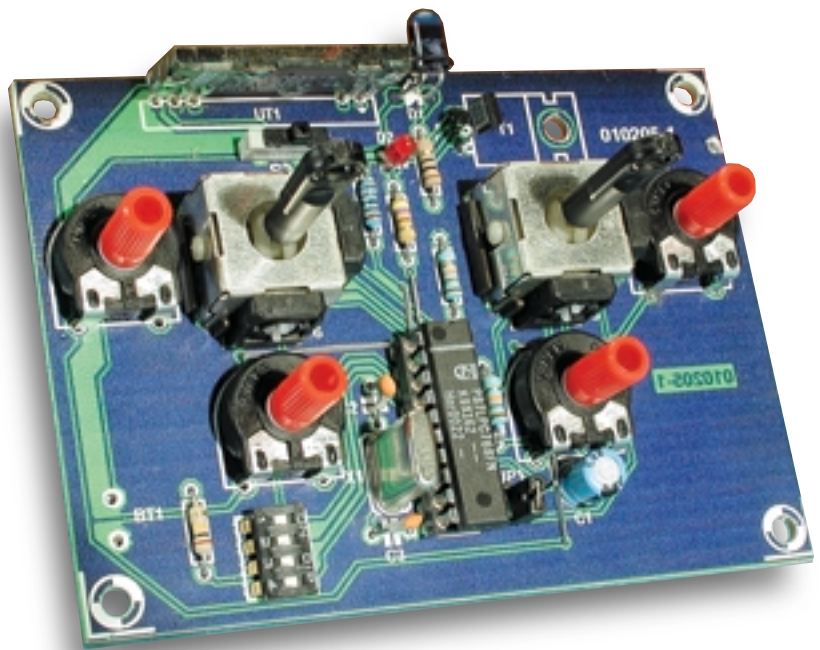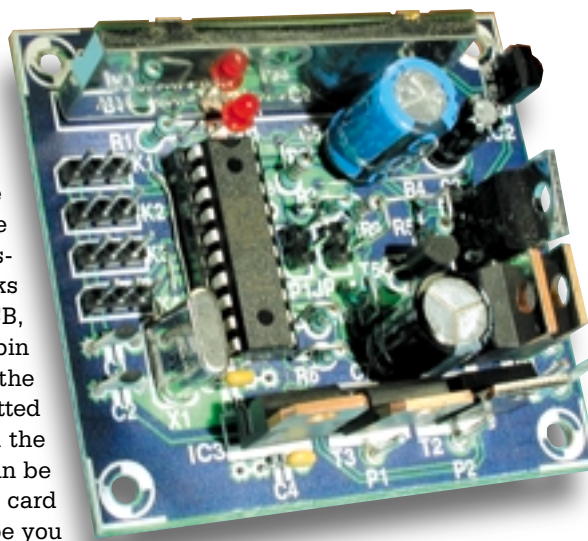Battery holder for 3 AA cells
PCB, order code **010205-1**

Receiver

The receiver PCB layout is shown in **Figure 4.** To keep the receiver as compact as possible, all the components are mounted a little more snugly than in the transmitter. The six wire links are first fitted to the PCB, followed by the 20-pin socket for IC1. Once all the components have been fitted (except for IC1, IC2 and the radio module), power can be applied to the receiver card and with a DVM or scope you can check the voltages around the PCB. If everything is in order then the rest of the components can be fitted. Make sure that the metal screen on the RF module does not cause a short circuit with components on the board. Finally, a 15.5 cm length of insulated wire is
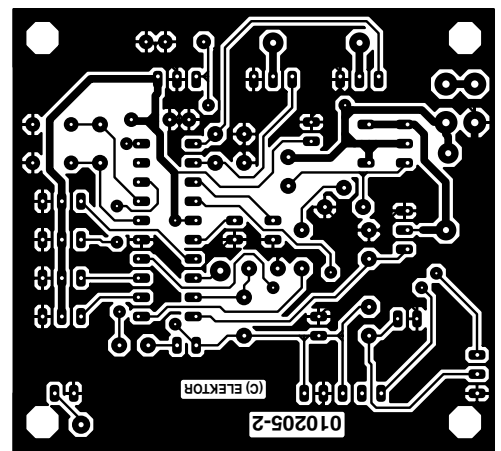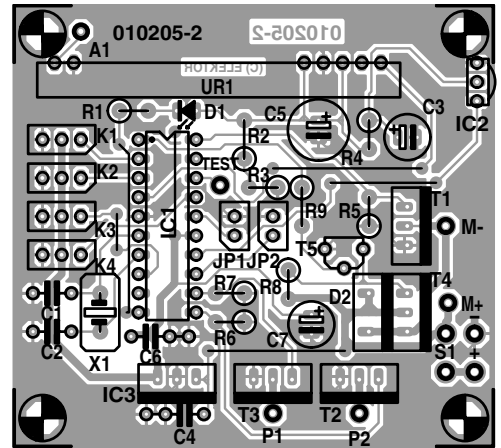

Figure 4. Layout and component placement of the receiver PCB.

COMPONENTS LIST
Receiver

Resistors:
R1 = 470Ω
R2,R9 =27kΩ
R3,R8 = 10kΩ
R4 = 100Ω
R5,R6,R7 = 100kΩ

Capacitors:
C1,C2 = 15pF
C3 = 10µF 16V
C4,C6 = 100nF
C5 = 470µF 16V
C7 = 220µF 16V

Semiconductors:
D1 = LED, red, 3mm
D2 = MBR745
T1 = SUP75N03, IRL2203
T2,T3 = BUZ11

T4 = IRF4905L (International Rectifier)
T5 = BC547
IC1 = 87LPC762BN, programmed, order code **010205-42**
IC2 = SFH5110-36 (Siemens)
IC3 = LM2940

Miscellaneous:
X1 = 6MHz quartz crystal
S1 = on/off switch, 1 make contact
JP1,JP2 = 2-way pinheader with jumper
4 servo connector plugs, 3-way
UR1 = 433MHz RX2 receiver module from Radiometrix (Farnell)
PCB, order code **010205-2**
Disk, project software, order code **010205-11**

Addresses

The European branch of CTS Corporation is at High Blantyre Glasgow G72 0XA
Tel. 01698 824 331
www.ctscorp.com

CTS resistive products are also supplied by Quiller Electronics Ltd. Bournemouth BH6 5EU
Tel. 01202 417744

Joystick: *www.ur-home.com*
Microcontroller:
   www.semiconductors.com/mcu/
LM2940:
   www.national.com/pf/LM/
   LM2940.html
MBR745:
   www.fairchildsemi.com/pf/MB/
   MBR745.html
SUP75N03: *www.vishay.com*
RF Module: *www.radiometrix.com*

soldered to point A1 on the PCB to act as an aerial. To make the unit a little more robust, this connection and the RF module should be secured to the PCB with the aid of a little hot glue or silicon adhesive. The current consumption of the receiver unit alone is approximately 40 mA.

Diagnostics

For debugging purposes a diagnostic output is available from pin P0.3 on the receiver controller. This test point can be fitted with a solder or test pin. The receiver controller uses this pin to output a signal every time it detects an error anywhere in the received message. It checks the received message values after the start bit and flags an error when they are not within tolerance. Using this signal it is possible to optimise the receiver siting away from sources of interference. Comparing this signal with the received telegram on a scope will indicate which part of the telegram has been corrupted.

(010205-2)

Crystals and Oscillators

when stability counts…

By Owen Bishop

A survey of these essential electronic systems, how they work, and how they are used. Practical component values are given for each oscillator.
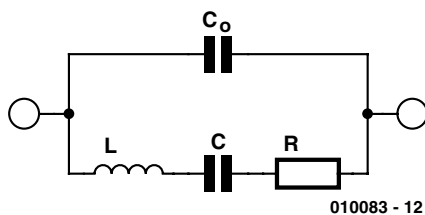

Figure. 1. The electronic equivalent of a quartz crystal.

The stability of the better RC oscillators is about 0.1%, while LC oscillators are stable up to 0.01%. If we require greater stability, the choice falls on a crystal oscillator. Certain crystalline substances, of which quartz is a prime example, have the property that they produce an electric field when they are subjected to stress and, conversely, become physically distorted when they are subjected to an electric field. This is known as the piezo-electric effect. Consequently, it is possible to cut a crystal so that it will physically vibrate at a given frequency when it is subject to an alternating electric field. Instead of the electro-magnetic resonance of the LC network, we have the electro-mechanical resonance of the piezo-electric crystal. The difference is that crystals can easily be machined to high precision, with natural frequencies as close as 10 parts per million. (ppm)

Although quartz is the most often used material, other substances such as lithium-niobate, lithium-tantalate, bismuth-germanium oxide, and aluminium-phosphate are used in various applications. In addition, there are ceramic materials such as the PZT ceramics, consisting of solid solutions of lead, zirconium and titanium. Another piezo-electric group comprises polymers such as polyvinyl chloride and difluorpoly-ethylene. For these, the piezo-electric property depends on their processing. A thin plastic foil is warmed and exposed to a strong electric field, then cooled to room temperature. This causes polarisation of the material, which then has piezo-electric properties.

Electronic equivalent

From the electronic viewpoint an RLC circuit (**Figure 1**) may model the behaviour of the crystal. The inductor L corresponds to the mass of the quartz slab. The capacitor C models the stiffness of the slab. The resistor R represents losses of energy occurring when the crystal is flexed or flexes. The second capacitor, C_o, is the capacitance between the electrodes plated on either side of the slab. Typically, L is a very high inductance while C is very low. For example, in a crystal cut to oscillate at 200 kHz, L is 27 H, C is only 0.024 pF, R is 2 kΩ and C_0 is 9 pF. Values such as these are used when modelling the action of a crystal in computer simulations. The ratio of L to C is very much higher that we could obtain by using real components, giving the crystal a very high Q (quality factor). A crystal may have Q of up to 100,000. Compare this with Q of only a few hundred for a typical LC network.

Crystals can be driven in **series resonance** or **in parallel resonance**. At the series resonance frequency, the crystal acts as a capacitor and inductance in series. The impedance across the crystal is at a minimum (equal to R only). At the parallel resonance frequency, which is slightly higher, the crystal acts as an inductor and capacitor in parallel. Its impedance rises to a maximum at this frequency. Crystals are usually cut so as to operate best in one or other of these modes. Additionally, they may be cut to operate in fundamental mode or harmonic (overtone) mode. The overtones are the odd harmonics of the fundamental so that, for example a crystal cut to oscillate at 100 kHz will also oscillate at 300 kHz, 500 kHz, 700 kHz and higher harmonics.

One of the limitations of crystals is that a crystal cut to have a high-frequency fundamental may be very thin and therefore easily subject to mechanical damage. The upper limit for fundamental mode crystals is about 70 Hz. Crystals for frequencies in the hundreds of megahertz ranges

are cut to have a relatively low fundamental but are operated in harmonic mode. A maximum frequency of about 500 MHz is obtainable by this means.

Thermal stability is important in some applications of oscillators. The temperature coefficient depends on the way the crystal is cut. For example, the popular AT-cut gives a crystal with a coefficient of ±0.002% over the range −55°C to +105°C. This compares with several percent for most capacitors. For greater stability the crystal may be enclosed in an 'oven'. The crystal is cut so as to have a minimum temperature coefficient at a particular temperature higher than room temperature. The oven is then maintained at this temperature. There are the disadvantages of providing power for the oven, the large volume of the oven, and the time it takes to warm up. Against this, there is the improved thermal stability, in the region of ±5 parts per ten million.

With the increasing use of high-frequency communications channels, and high clock speeds in digital equipment, greater use is being made of resonators in place of crystals. These are small discs of PZT ceramics or similar piezo-electric materials that are capable of operating at frequencies in the Gigahertz range.

Crystal oscillators

Crystals are used to replace or to partly replace the resonant circuit in all the oscillators that normally rely on an LC circuit. For example, the crystal-controlled version of the Colpitts oscillator has a crystal and a capacitor in place of the inductor L1. With a crystal fitted instead of the inductor, the frequency is more precisely fixed. In such a circuit, the crystal is being operated in parallel resonance, having maximum imped-

ance at the resonant frequency and therefore producing an output signal of maximum amplitude.

The Pierce oscillator (**Figure 2**) is an instance of the use of series resonance. Feedback is routed through the crystal and is a maximum when the crystal is resonating in series mode, with minimum impedance. Note that this oscillator has no need for a tuned circuit, relying only on the crystal to determine its oscillating frequency.

Crystal oscillators are not only the most precise but also among the fastest of the oscillators in common use. Modern digital circuits require fast clocks to drive them, clocks with frequencies measured in tens or hundreds of megahertz. The circuit for using a crystal to provide feedback from the output of a CMOS inverter gate is too well known to need repeating here.

Some of the fastest oscillators make use of **surface acoustic wave** (SAW) devices. These are small strips of piezo-electric material with an array of electrodes plated on them at both ends (**Figure 3**). At one end (the input end) an electric field between the electrodes causes the surface of the strip to become distorted. This creates a wave that passes along the surface of the strip. It is an acoustic wave and travels through the strip at the speed with which sound travels in that material (about 3000 m/s). A fraction of a second later, when the wave reaches the other (output) end of the strip, the electric field associated with the wave produces a pd between the electrodes there. SAWs are used as bandpass filters, for the spacing between the electrodes at each end determines which frequency will be most strongly fed into the SAW and recovered at the other end. The time taken for the wave front to pass along the strip gives the filter the
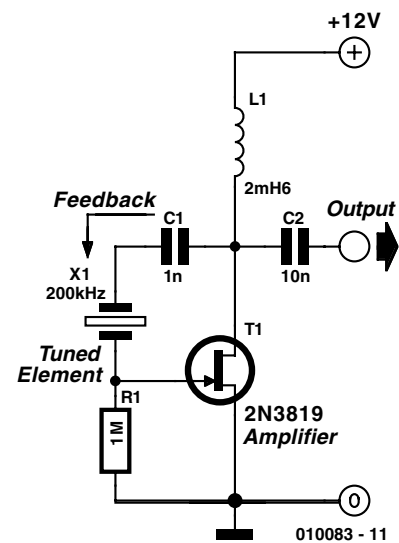

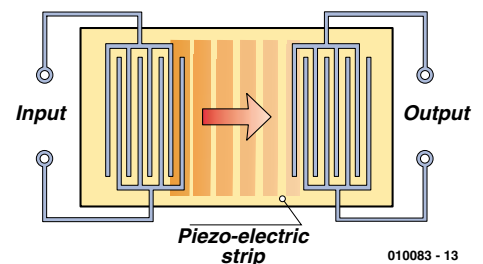Figure. 2. Pierce crystal oscillator.

Figure. 3. A surface acoustic wave (SAW) device.

properties of a delay line. As a component of an oscillator, a SAW delay line is used in the same way at the RC network of a phase shift filter. The time taken to introduce a phase shift of 180° is extremely short and so the frequency of such oscillators is extremely high. Typically, they range up to about 2 GHz. Oscillators employing dielectric resonators in the feedback loop exceed even this figure. At this point we are well into the microwave ranges, with their specialised features, and will bring this discussion to a close.

(010083-1)
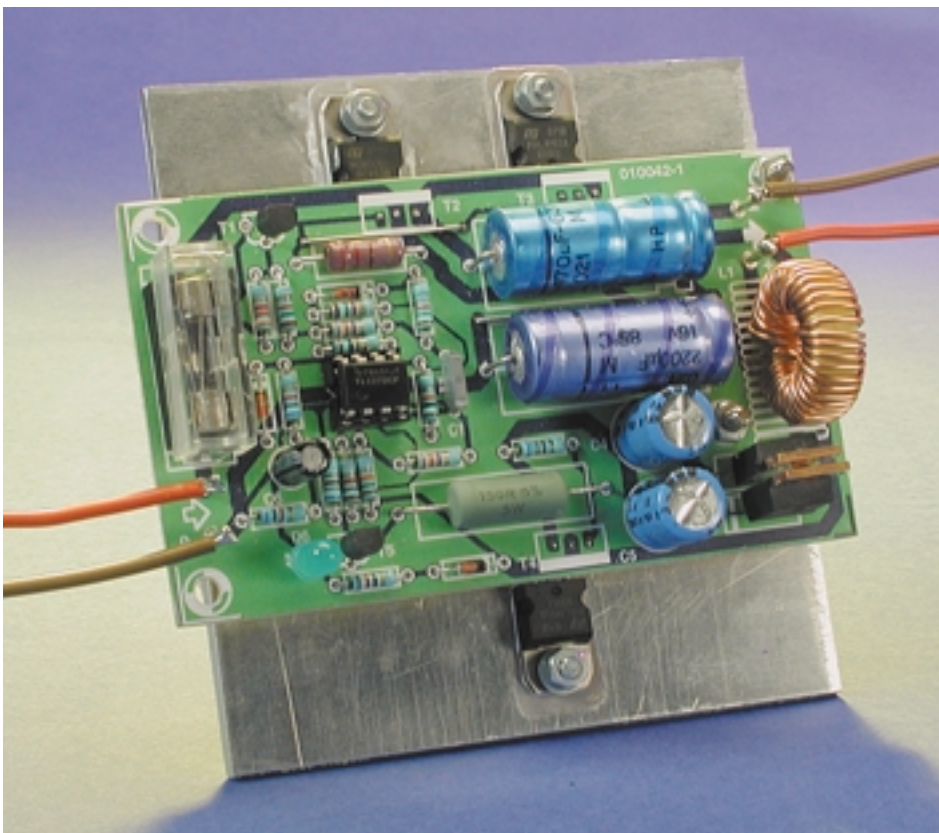
Vehicle Adapter for Notebook PCs

19 volts from a car battery

Design by R. Badenhausen

Notebook PCs are great but stray too far from a source of power and it's not long before low-battery warnings start to appear. Mains adapters come as standard but car adapters are expensive accessories. Good enough reason to get the soldering iron out!

This adapter design is suitable for notebooks requiring a dc input voltage in the range of 14 V to 19 V. It can provide a continuous current of 2 A with short duration peaks of around 2.5 A. The efficiency of the design is in the order of 60 to 80 % depending on the output voltage and current. A big advantage of this design is its low quiescent current of only 75 mA (more on this later).

The circuit diagram of the unit is shown in **Figure 1.** The operating principle is relatively simple. A free-running oscillator is used to drive a voltage doubler circuit. A voltage comparator controlling a series pass transistor regulates the output voltage. The input and output earth is common to the car earth potential.

The astable multivibrator is formed by IC1.B. Components C1 and R4 in the feedback path give an operating frequency of 15 kHz approximately. D1 and R7 ensure that the output square wave has a 50:50 mark/space ratio. The type of capacitor used for C1 should have good stability with a low temperature coefficient (e.g. ceramic). The temperature characteristics of D1 ensure that the output square wave is maintained at all levels of output load and

Designs for switchmode power supplies or inverters always pose a problem for home constructors because they usually include inductive elements, transformers, chokes or ferrite cores that are difficult to procure. This dc-to-dc converter design uses just one standard inductor. In the prototype this inductor was part of the notebook's existing supply lead, here it is built onto the PCB.
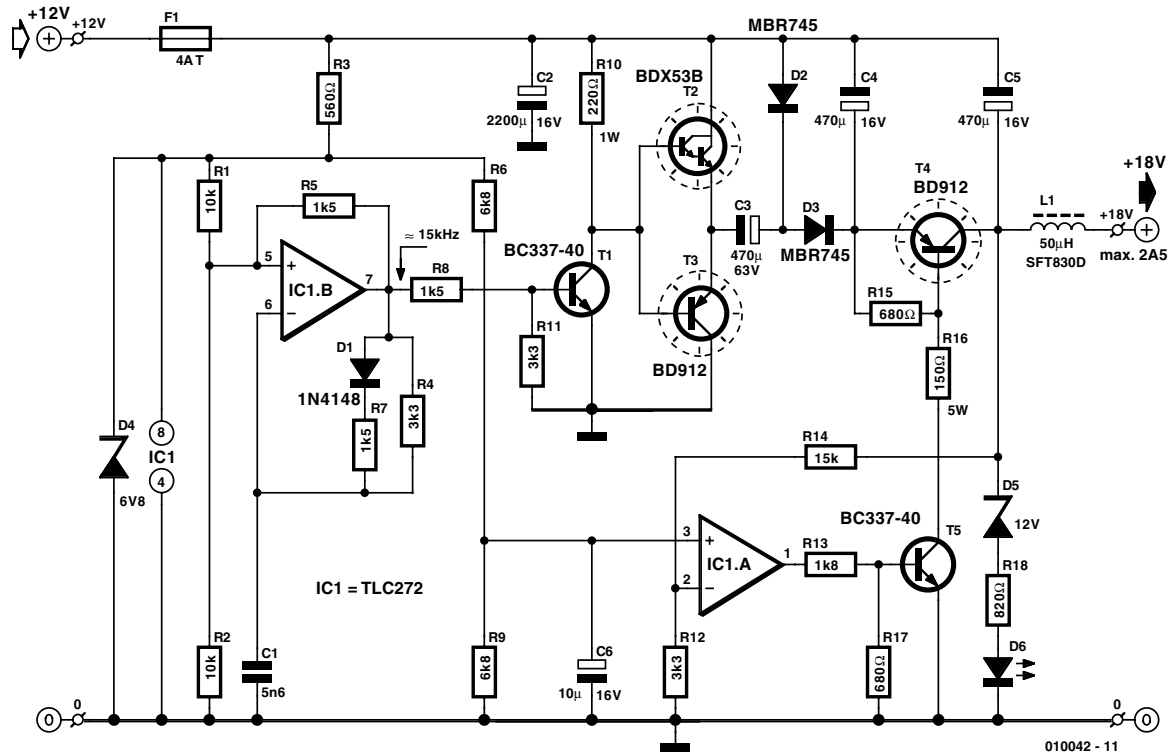
Figure 1. The adapter circuit diagram.

circuit heating. The square wave output from IC1.B switches T2 and T3 alternately. When T3 is conducting C3 charges up to 12 V via D2. When T3 stops conducting and T2 is switched on the negative end of C3 is suddenly connected to the +12 V supply. The charge in C3 cannot change instantly, so when the negative end of C3 steps up by 12 V the positive end must also step up. The voltage on the positive end of C3 will be 'pumped up' to around twice the supply voltage. In practice, losses in the diodes and transistors mean that it will always be slightly less than twice the supply voltage. Schottky diodes are used here to reduce the forward voltage drop. D3 rectifies the voltage and C4 stores it. Capacitor C3 must be able to transfer the total output current so it's important to use a good quality device here. Choose either the 'S+M' from the B41010 series (designed for use in switched mode power supplies) or the LL from the B41588 series of electrolytic capacitors both from Siemens. Certainly you cannot expect the same performance if you fit a bargain basement 'no name' capacitor. The output voltage regulation is performed by op-amp IC1.A

The voltage at the collector of T4 is sensed by a potential divider formed by R14 and R12 and compared in IC1.A with the reference voltage formed by R6, R9 and zener diode D4. The output voltage level is set by the value of R14 (see **Figure 2**), 15 kΩ giving an output of approximately 19 V. The output ripple performance at full load is shown in **Figure 3.**

Increasing the value of capacitor C6 will mean that the reference voltage rises more slowly at switch on, thereby giving the adapter output voltage a soft-start characteristic. The switch on delay is visible from LED D6.

The graph in **Figure 4** shows the adapter output voltage at different values of load and input voltage. It can be seen that low input voltages are best avoided. The supply from a cigarette lighter socket is typically 13.2 V at rest and 14.4 V with the engine running, so at high levels of load current the output voltage will only reach 19 V if the car engine is running.

Fan Assistance

During tests it was established that with a loading of 2 A it was not only

the three power transistors but also capacitor C3 and Schottky diodes D2 and D3 that were becoming hand hot after a few minutes use. Adequate cooling of these devices is therefore essential. The transistors and Schottky diodes are all packaged in TO220 outlines so it is relatively simple to mount them on a heatsink. If you look at the PCB layout in **Figure 5**, all of these components are mounted along the edge of the PCB so that they can be fixed to (but electrically insulated from!) the metal case. You may notice from the photo of the prototype that the layout has been modified. Additional heatsinks are also necessary along the case sides to improve heat dissipation. It may not so easy to find a heatsink with exactly the right dimensions so it's best to cut two suitable lengths from a standard extruded heatsink profile and fit them to the (unpainted) case sides.

The heat produced in the capacitors is a little more difficult to deal with; you cannot simply bolt on a heatsink. Ventilation slots need to be made in the free PCB area beneath the capacitors to allow air circulation (watch out for the tracks), and a small fan is mounted in the case lid for ventilation. The lid has a 30-mm flat area suitable for mounting the 25?25?10 mm 12 V fan. It should be centred over IC1 and slots or holes cut into the lid and narrow side of the case to allow adequate air circulation. Modern fans produce very little noise and at 30 dB(A) this is not much more

COMPONENTS LIST

Resistors:
R1,R2 = 10kΩ
R3 = 560Ω
R4,R11,R12 = 3kΩ3
R5,R7,R8 = 1kΩ5
R6,R9 = 6kΩ8
R10 = 220Ω, 1W
R13 = 1kΩ8
R14 = 15kΩ
R15,R17 = 680Ω
R16 = 150Ω, 5W
R18 = 820Ω

Capacitors:
C1 = 5nF6
C2 = 2200µF 16V axial
C3 = 470µF 63V axial *
C4,C5 = 470µF 16V radial
C6 = 10µF 16V

Semiconductors:
D1 = 1N4148
D2,D3 = MBR745
D4 = zener diode 6V8 0.4W
D5 = zener diode 12V 0.4W
D6 = LED, high efficiency
IC1 = TLC272CP
T1,T5 = BC337-40
T2 = BDX53B
T3,T4 = BD912

Miscellaneous:
F1 = fuse, 4A, time lag, with PCB mount
  holder
L1 = 50µH 3A suppressor coil (SFT830D,
  Conrad Electronics #534412)
Metal enclosure, size 119×65×39 mm
2 heatsinks
12V miniature fan (Conrad Electronics
  #532614)

* see text

Fi˅˅˅˅ 2. Resistor R14 sets the output voltage.
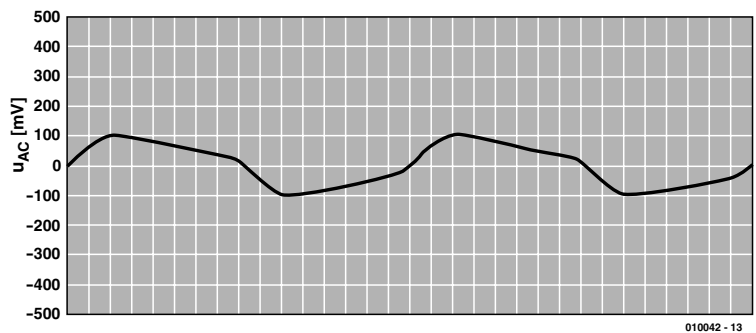
Figure 3. ±100 mV output ripple at full load.
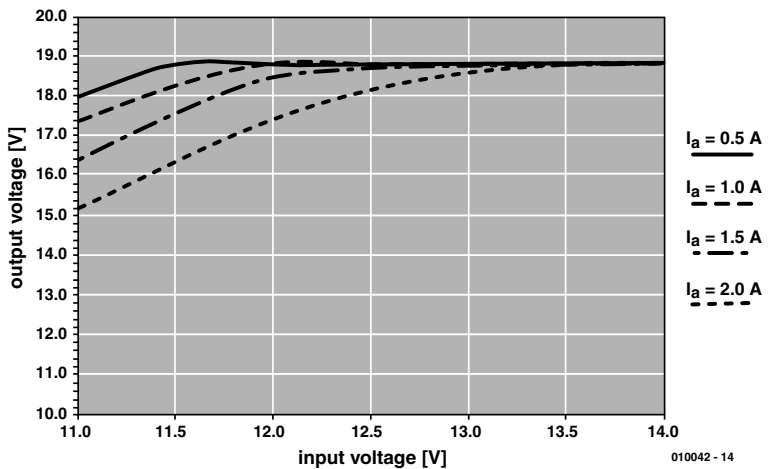
Figure 4. The adapter output load characteristics.

than a whisper. A disadvantage of this solution is the current drawn by the fan. It consumes 70 mA thereby jacking-up the quiescent current of the adapter to 145 mA. This figure is small and once charged there should be no fear of the adapter draining the car battery overnight.

The circuit diagram does not show the fan but it should be connected to the PCB between an earth track and the +12 V input track after fuse F1.

Fitting components to the PCB (**Figure 5**) should not cause any difficulty provided you are careful and double-check anything you are unsure of. Inductor L1 is a standard component available from many outlets. To give it extra rigidity it is a good idea to fix it to the
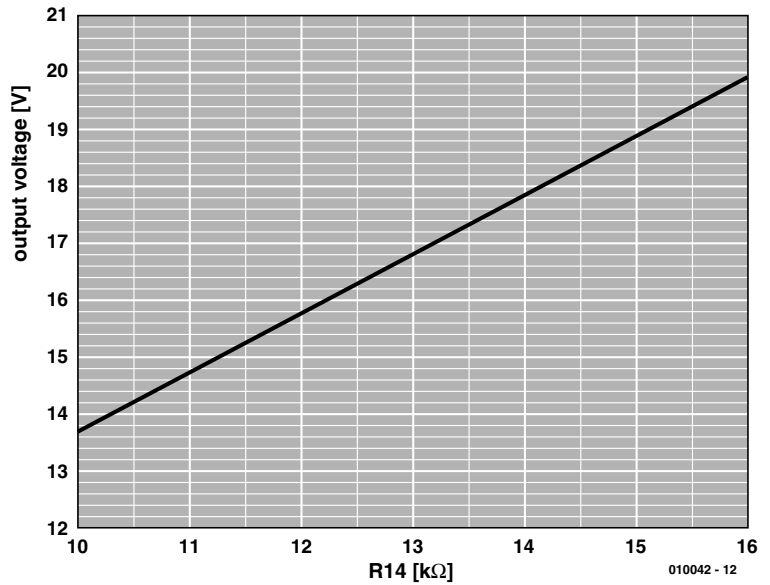
PCB with a generous blob of silicon adhesive after it has been soldered in place.

Mechanical fixing of the PCB into the case is more important for mobile equipment because of the

increased risk of accidental knocks and bumps. Allow adequate spacing between the tracks running along the edge of the PCB and the inside of the case and to be really sure it is a good idea to fix thin insulating strips of phenolic resin (Pertinax/Bakelite) along the inside of the case.

The spacing under the PCB should be no greater than 5 mm otherwise the tops of the TO220 packages and the inductor will be too close to the lid.

The input and output cabling can be attached to the PCB using solder pins. The cables should have a cross sectional area in the order of 1.5 mm^2 and strain relief grommets should be fitted to the entrance and exit holes in the case. It is better to use the adapter in unfused cigarette lighter sockets because the fuse gives an additional voltage drop at the input to the adapter, better still fit a good quality accessory socket on the dashboard for connection of the adapter.
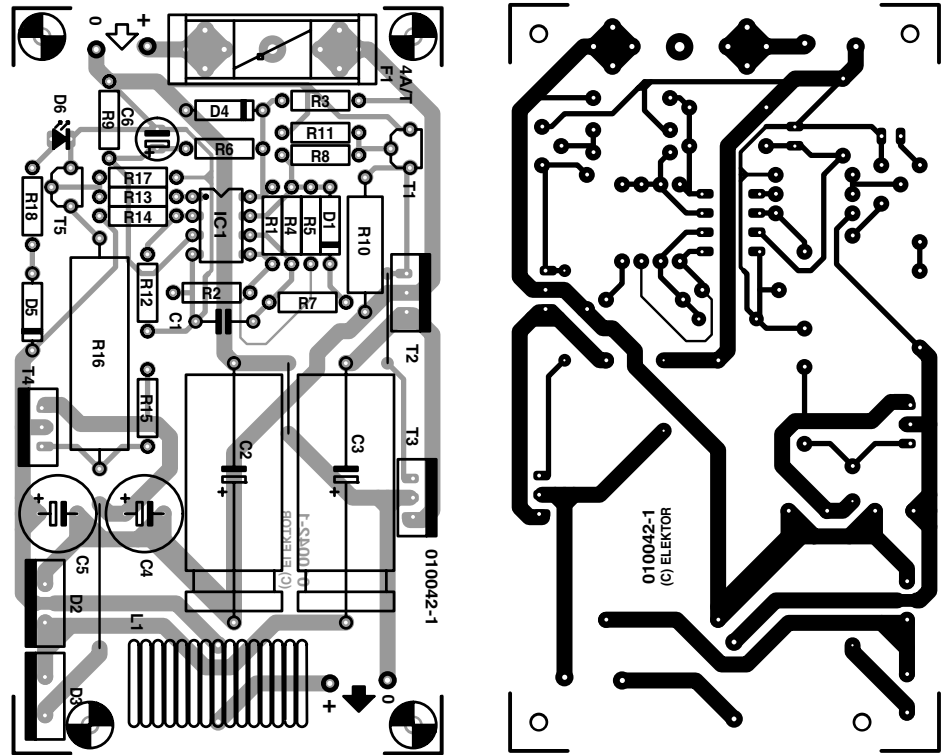
(010042-1)

Figure 5. The PCB with two small heatsinks (board not available ready-made).

Atmel AVR Micro Programmer
September 2001, p. 52,
010005-1

The acronym 'AVR' should not have been used in the project title. The programmer only supports the 89Cxxxx series which are derivatives from the generic 8051.

Simple IR Receiver
July/August 2001, p. 86,
014121-1

The circuit diagram is correct. On the PCB, pin 3 of IC should be connected to +5 V.

High Voltage Supply
January 2001, p. 62,
000186-1

The transformer materials may be difficult to obtain from Block. Alternative types from Farnell are given below, together with their order codes.

2 off ETD29 half core, # 305-6375
1 off ETD29 bobbin, # 178-506
2 off ETD29 steel clip, # 178-507

Fuse Failure Indicator
July/August 2001, p. 90,
000157-1

An additional diode type 1N4007 or similar has to be inserted between terminal L1' and the green LED (D2). The cathode of the 1N4001 is connected to the anode of D2.

MIDI-DMX Interface
September 2001, p. 36,
010003-1

The program SoftController is not included on project disk no. 010003-11.
The program is exclusively available from the author, email:
bbouchez@netcourrier.com

Personal Mini Webserver (1)
September 2001, p. 68,
010036-1

To prevent problems with the RS232 serial interface, pin 5 on connectors K3 and K4 has to be connected to ground. Pins 1 and 3, and pins 2 and 4, of Tr1 have to be swapped. These errors apply to the schematic and the PCB.

Keyboard/Mouse Switch
July/August 2001, p. 102,
014048-1

The PCB layout and parts list are correct. In the circuit diagram, the collector of T1 should not be connected to pin 1 of IC1. Instead, it is connected to +5 V via R1. Capacitor C2 is connected between ground and the junction of R1 and the collector of T1. The values of R1 and C1 are given in the parts list.

Infrared Remote Control for PCs
July/August 2001, p. 110,
000170-1

Two decoupling capacitors between the positive supply line and ground are missing from the circuit diagram, C1 = 100 nF and C2 = 10µF, 16V. The PCB and parts list are correct.

Simple EEPROM Programmer
July/August 2001, p. 38,
014102-1

The electrolytic capacitor at the 5 V side of IC2 should be labelled C4, not C3. The value of C4 should be 47 mF, although 4.7 mF (as stated in the parts list) will also work.

Measures capacity up to 9999 mAh and samples the voltage

Battery Discharger/Capacity Meter

Part 1: design and control module

Design by B. Stuurman

This circuit can measure the capacity of individual cells as well as battery packs with an open circuit voltage of up to 35 V. The only requirement is that the discharged cell voltage has to be between 0.5 V and 2.5 V. During the discharge period, the instantaneous voltage is measured at one minute intervals and stored in memory. This allows the voltage curve to be drawn once the discharge process is completed.

As can be seen from the title photograph, the appearance of the battery discharger is simple and clearly arranged. There is a small keyboard with 12 keys for the input of data. All information is displayed on a 16-character LCD. The battery is connected to the two instrument terminals, a black one and a red one. In addition there are two slide switches, one is for on/off, the other one we will describe later. On the back is a sizeable heatsink onto which the discharge transistor is mounted. There are also eight large holes in the front panel, because the enclosure contains a cooling fan that blows air over the heatsink during the discharge period. This allows the power dissipation capacity to be nearly doubled.

The discharger is perfectly serviceable as a stand-alone unit, but

as will become clear later on, a PC will be indispensable in certain situations. For this purpose, on the left side of the enclosure, there is a nine-way connector, which may be connected to the serial port of a PC. A diskette with the pertinent software will be available from *Elektor Electronics* Readers' Services.

Operation

Once the device as been switched on, the text 'NiCad Discharger' appears on the LCD. Pressing the '*'-key causes option menu 1 to be displayed, pressing the key again results in option menu 2, etc. There are six option menus in total. The '#'-key is the confirmation button,

which may be compared (functionally) with the Enter-key on a PC-keyboard. Once the desired option menu has been reached by pressing the '*'-key one or several times, pressing the '#' activates the option. If this is a menu where data can be entered and the '#'-key remains depressed, then the current data is displayed on the LCD. When the '#'-key is released, question marks appear and new data can be entered using the number keys on the keyboard. The entry has to be confirmed by pressing the '#'-key.

While operating the keyboard, a time-out routine runs in the background. If there has been an entry error, or when just viewing the current value, the message 'NiCad Dis-

charger' will reappear on the LCD after a few seconds.

The menus

There are six option menus. We will briefly describe them because in one fell swoop all the possibilities (and impossibilities) of the discharger will become immediately clear. The purpose of the 'Set'-menus is for the entry of data and behave nearly identically, the other menus are switching menus.

Set loadcurrent? If the '#'-key is pressed and held the currently set discharge current is displayed on the display. When the key is released the message 'Current: ???? mA' appears and a new value can be entered. If you do not want to change the value, you can either wait a while or press the '#'-key (as
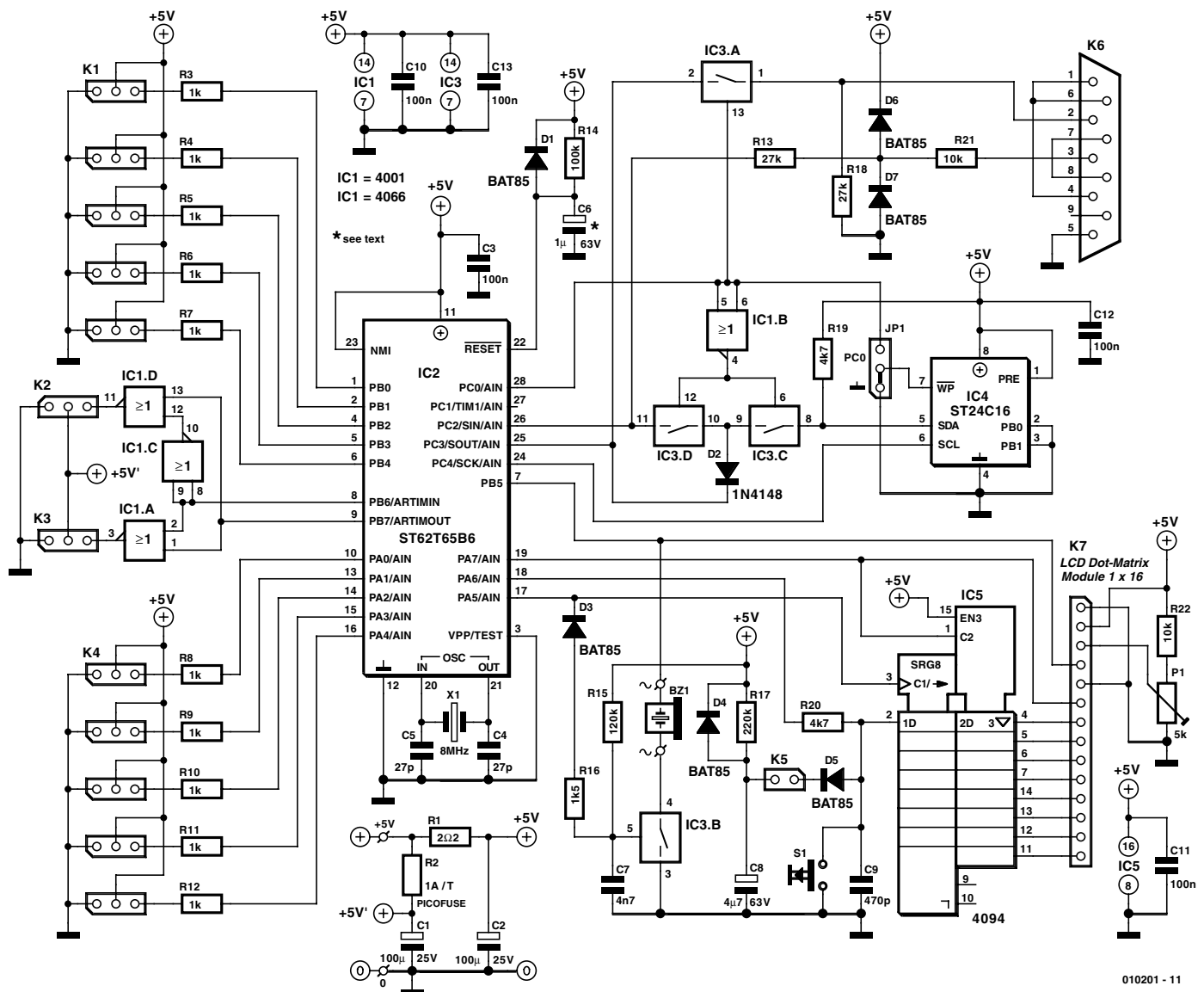

Figure 1. The 'heart' of the control module is formed by a microcontroller of the type ST62X65.

COMPONENTS LIST
Control board

Resistors:
R1 = 2Ω2
R2 = fuse, 1AT (time lag) Picofuse (e.g., Farnell 446-944)
R3-R12 = 1kΩ
R13,R18 = 27kΩ
R14 = 100kΩ *
R15 = 120kΩ
R16 = 1kΩ5
R17 = 220kΩ
R19,R20 = 4kΩ7
R21,R22 = 10kΩ
P1 = 5kΩ preset

Capacitors:
C1,C2 = 100µF 25V radial
C3,C10-C13 = 100nF ceramic
C4,C5 = 27pF
C6 = 1µF 63V radial*
C7 = 4nF7, lead pitch 5mm
C8 = 4µF7 63V radial
C9 = 470pF

Semiconductors:
D1*,D3-D7 = BAT85
D2 = 1N4148
IC1 = 4001
IC2 = ST62T65, programmed, order code **010201-41** (see Readers Services page)
IC3 = 4066
IC4 = ST24C16
IC5 = 4094

Miscellaneous:
K1-K4 = 12 x 3-way pinheader
K5 = 2-way pinheader
K6 = 9-way sub-D socket female), angled pins, PCB mount
K7 =14-way SIL-header
JP1 = 3-way pinheader with jumper
S1 = pushbutton type D6 (ITT/Schadow)
X1 = 8MHz quartz crystal
Bz1 = AC buzzer
LCD dot matrix module, 1x16 characters, 80x36x10 mm (e.g., Farnell # 142-542)
14 way female PCB connector for LCD
PCB, order code **010201-1** (see Readers Services page), supplied with discharger board **010201-2**)

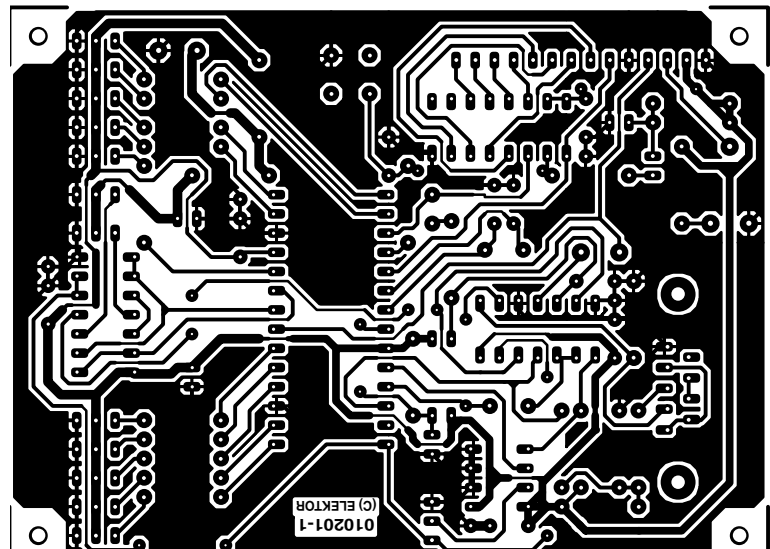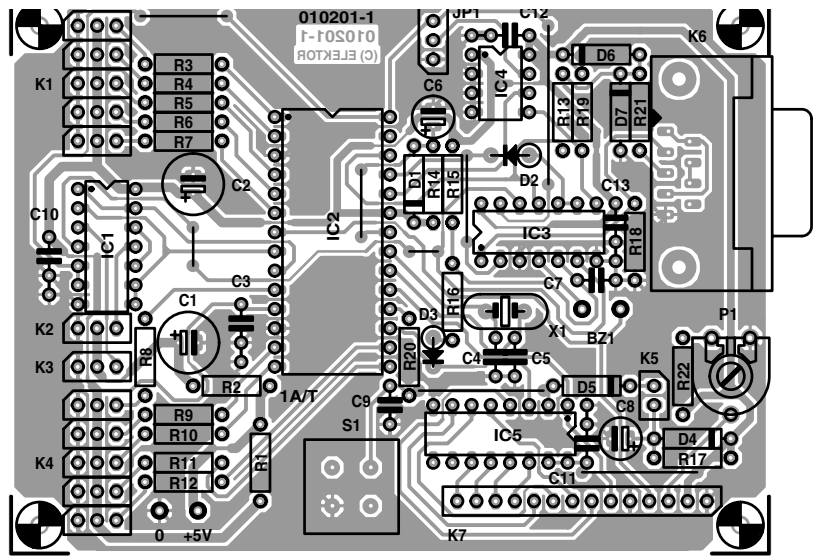*) not fitted when using ST62T65 type C

Figure 2. Copper track layout and component overlay of the control PCB.

confirmation) the message '! not accepted !' will appear on the display, followed almost immediately with the return to the option menu. The minimum current is 100 mA, the maximum is 2500 mA. The adjustment is in steps of 10 mA. Values less than 5 are rounded down and values greater than 5 are rounded up.

Set nr of cells? The number of cells in the battery pack can be entered here (maximum of 20).

Set volts/cell? The purpose of this option is to adjust the voltage at which a cell is considered discharged. The value must be in the range 0.5 - 2.5 V. For NiCd- or NiMH-cells which are being discharged at a current smaller than 0.5 C, 1.1 V is an appropriate switch-off value. At higher discharge currents a value of 1 V or even 0.9 V may be selected to counteract the voltage drop as a consequence of the internal resistance. Battery holders with spring contacts can have considerable contact resistance and can cause adverse effects! The wide voltage range allows lead-acid batteries to be discharged as well.

Start discharge? After confirmation with the '#'-key the voltage of the battery is compared with the shut-off value (= number of cells x voltage/cell). If it is higher, the discharge process commences. First, the sampling memory is cleared ('Clearing memory!'), then the current is raised to the selected value ('Setting Current!'). When this value has been reached, the cooling fan is turned on and the time is reset to zero. During the discharge the elapsed time and discharged capacity appear alternately on the display. The option menus remain active during the discharge process, with the understanding that the values can be displayed but cannot be altered. The
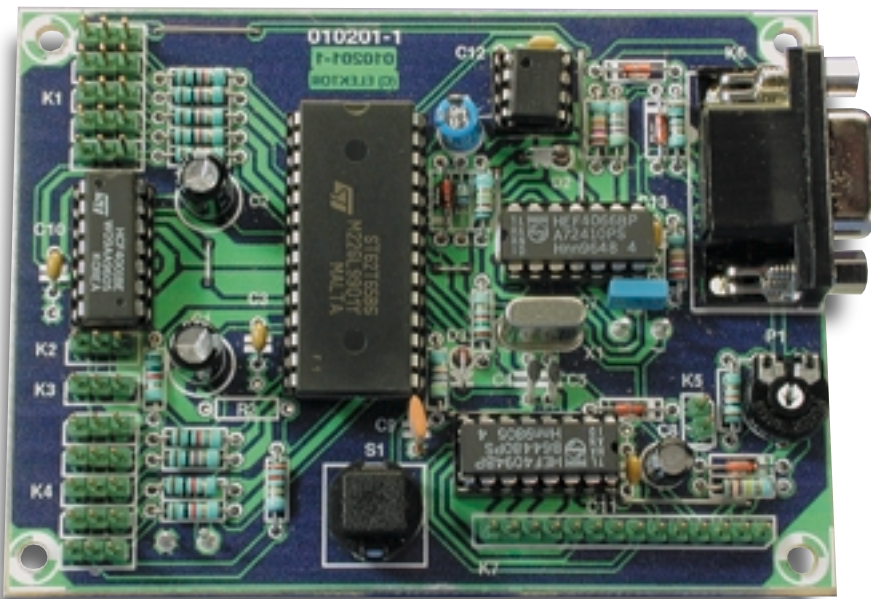
Figure 3. Photo of the completely assembled control board.

discharge process continues until the set voltage is reached or...

Stop discharge? This allows the discharge process to be terminated prematurely.

See last result? Once the discharge process has been completed, the discharge time and measured capacity are alternately shown on the LCD and an audible signal is given. This information disappears when any key is pressed. This option menu allows the measured results to be displayed again.

Plan of attack

A two-stage approach has been chosen. For starters, a small control module has been built which has acquired the name 'Chip' and contains all the principal hard- and software components. The 'heart' is formed by a programmed microcontroller. This microcontroller does not contain the software to control the discharger, but instead contains an 'interpreter' which reads and executes programs in a higher programming language. The 'higher programs' are stored in an EEPROM and can be directly downloaded from a PC.

The program for the discharger is written in the 'Chip'-language and built with a 'Chip'-assembler.

Control Module

Figure 1 shows the schematic for the control module 'Chip'. A central position is occupied by the microcontroller ST62T65 from ST-Microelectronics (IC2). The microcontroller contains a number of extra components, such as a standard timer, an auto-reload timer, an analogue/digital converter, and a serial interface, abbreviated to 'SPI'. The standard timer is used as a clock and keeps track of seconds, minutes, hours, day of the week and weeks in the year. Various software timers are also controlled by the standard timer. The auto-reload timer can be used, among other things, to control two servos independently, but can also be reprogrammed to generate a voltage. The fine adjustment of the clock is achieved with a software-byte and can be performed by the user. This value is loaded in the timer once a minute.

Inputs and outputs

Five digital outputs (Out0 -Out4) are available on K1, fitted with series resistors to protect the microcontroller. These outputs can be set or cleared and the state of each output can be read back. The servo outputs K2 and K3 are for use with regular servos or a voltage can be obtained here. Terminal block K4 makes five

inputs available (Input0 - Input4), which can be read in either digital or analogue mode.

Sub-D connector K6 allows communication with a PC. The input signal is clamped by R21, D6 and D7 and, via R13, applied to the input of the SPI (Sin). The serial output signal (Sout) reaches the output pin of the connector via analogue switch IC3A. When the analogue switch is open, R18 pulls the output low. The signal levels do not comply with RS232 standards, but this circuit works reliably nonetheless, provided the connecting cable is not too long. During serial communications, PC0 is high and IC3A is closed, while IC3C and IC3D are open. By pulling PC0 low, EEPROM (IC4) is connected to the SPI and write enabled via WC. Software routines can now access the EEPRROM for read and write operations using the I^{2}C-protocol. The actual data transfer is handled by the SPI with a clock frequency of 308 kHz.

LC display

Connector K7 allows the connection of a one-line 16-character LCD. A serial to parallel converter (IC5) is used to drive the data bus of the LCD, so that only three outputs from the microcontroller are necessary for communication. PA5 provides the clock, PA6 the data and PA7 is the strobe. The strobe for IC5 is positive so that PA7 can also be used as (negative) strobe to clock the data into the LCD. PA6 is normally an input. Pushbutton S1 is connected to this input. This button is tested once per second by the operating system and if it is activated the currently running Chip program is terminated and control returns to the command processor. S1 is therefore not a reset button, but functions as a Break button — the real-time clock continuous to run. The connection Reg/Sel on the LCD serves the purpose of selecting between character mode or command mode. This terminal is driven by PB5. PB5 is also used to control buzzer BZ1. At the first falling edge of the clock — to transfer data for the LCD into the shift register — analogue switch IC3B is opened and the buzzer is switched off (D3, R15, C7). After the data transfer is finished, C7 will charge via R15 and IC3B will close. The contrast of the LCD can be adjusted with P1.

A few loose ends

Power-up reset is provided by D1, R14 and C6. It is possible to make the Chip interpreter self-starting by placing a jumper on K5. This way, C8 and D5 'hold down' S1 for a moment when Chip is switched on. R17 charges C8 and causes the pushbutton to be released. If a jumper is not connected to K5, the same result can be obtained by holding down S1 while switching on.

A final remark about the schematic. The part number shown for the controller has the suffix 'B'. The newer version ST62X65C may be used instead. In this case, if the LVD-option (low voltage detection) of this micro-controller is enabled, D1, R14, and C6 may be omitted. So take note of which type you are using.

Construction

Figure 2 shows the (single sided) printed circuit board for the control module and the corresponding component overlay. Incidentally, this PCB is delivered in combination with the discharger module that will be described in Part 2.

First mount the eight wire links, not forgetting the one under the socket for IC2. This is followed by the low profile components and finally it is the turn of the tall components, such as electrolytics C1 and C2. Only fit the ICs in their sockets once the entire PCB has been built and has been carefully checked.

If a different EEPROM (IC4) than the indicated type ST24C16 is used then this has implications for pin 7. The function of WC may be different with other EEPROMs and this may cause the write operation to be blocked. If this is the case, pin 7 may be connected to ground using jumper JP1.

The connection to the LCD may be made with a ribbon cable or a set of individual flexible wires with a length of 15 cm. A 14-pin female PCB header is used to connect to K7. Initially, a 4.5 V flat battery (3LR12) will suffice for the power supply (4.5 to 6 V).

Figure 3 shows a photo of the completed circuit board for control module. It wouldn't be a bad idea to carefully compare your own specimen with this.

The operating system

The control module communicates via the serial interface with the terminal program running on the PC. The interface parameters are set to **19200,7,n,2**. The project software contains the terminal program CHIPTERM.EXE (and the Windows-version 'VBTERM') which can be used to download the programs. The README.TXT file contains the operating instructions.

Only lower-case letters may be used for input. After entry of the command and any parameters, if appropriate, the line is terminated with an 'Enter' after which the command processor jumps into action. Mistakes can be corrected with 'Backspace' and the entire line can be discarded with 'Escape'.

There are seven commands; we will deal with them briefly because they are essen-

tially self-explanatory. When the control module is switched on and the terminal program has been started, pressing Enter will result in the display of 'command?' and on the next line the prompt '?'. By entering the command '?' (terminated with Enter) the entire command set is displayed on the screen (refer **Figure 4**):

prog [address]: this command allows reading and writing of the EEPROM. Only the even addresses are displayed, followed by the bytes that are stored on this and the successive address. Every Chip-instruction comprises two bytes. The lowest address is 000h and the highest is 7FFh. Using the '+' and '–' keys the address can be increased or decreased. When two bytes have been entered they are stored and the address is incremented. Escape is used to return to the command processor.

chip: this command starts the program, written in Chip-language, at address 000h. At this point the command processor ceases to run. A Chip-program can also be started by holding down S1 during power-up or by fitting a jumper on K5. The program can be interrupted by pushing S1. The break instruction or an error in the program will also cause termination of the program.

time: after entering this command a (running) clock appears on the screen. Pressing 'Enter' brings up the week field, the clock can be adjusted. It is a 24-hour clock. Pressing 'Escape' twice leaves the clock unaltered.

page, **mem** and **put:** these commands are used to read and write the registers in the microcontroller. We first have to make a few remarks about the address range 00h-3Fh. The microcontroller has, in addition to the normal RAM, two EEPROM-pages and an extra RAM-page. Using the page command one of these pages is mapped into the address range 00h-3Fh. In EEPROM-page 0 in address range 00h-0Fh we place a start-up message and in address 10h the adjustment byte for the clock. First select with 'mem 0' address 00h of the microcontroller. This address (in the extra RAM-
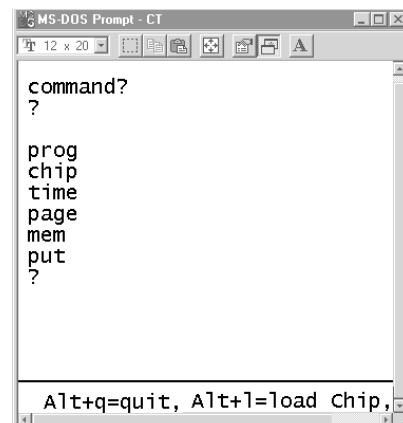

Figure 4. The command set as it appears on the screen.

page) and corresponding byte appear on the screen. With 'page 0' we select the EEPROM page 0. With the command 'put byte', 'byte' can be written to this address. Pressing the + key increments the address (the – key decrements). The start-up message can now be entered into the (microcontroller) EEPROM:

2a, 20, 48, 69, 2c, 20, 49, 27, 6d, 20, 43, 68, 69, 70, 20, 2a

After all bytes have been entered into the EEPROM we press 'Escape' to return to the command processor. If you have a list of ASCII-characters then you will probably already know what the start-up message is. To display this message on the LCD it is necessary to reset the control module by briefly turning the power off and then turning it back on. At address 10h of the same page we place, in exactly the same manner, the adjustment byte for the clock. The clock will probably keep proper time with a value of EAh. Therefore: 'mem 10', 'page 0', 'put ea'. Increasing this value causes the clock to run slower, reducing it will make it run faster. The effect will only be noticeable after 24 hours or more. Don't forget to reset the control module, because this byte is only read when the unit starts up, just like the start-up message.

(010201-1)

In Part 2 we continue with the keyboard, the construction and installing the NiCad discharge program.

PC Surround Sound Power Amplifier

implemented as a six-channel plug-in card

Design by T. Giesberts   From an idea by M. Ghanem

This six-channel amplifier has been designed to fit into either an ISA or PCI slot, with its supply derived from the PC. In conjunction with a set of (possibly home built) loudspeakers this forms the basis of an inexpensive yet good quality PC surround sound system.
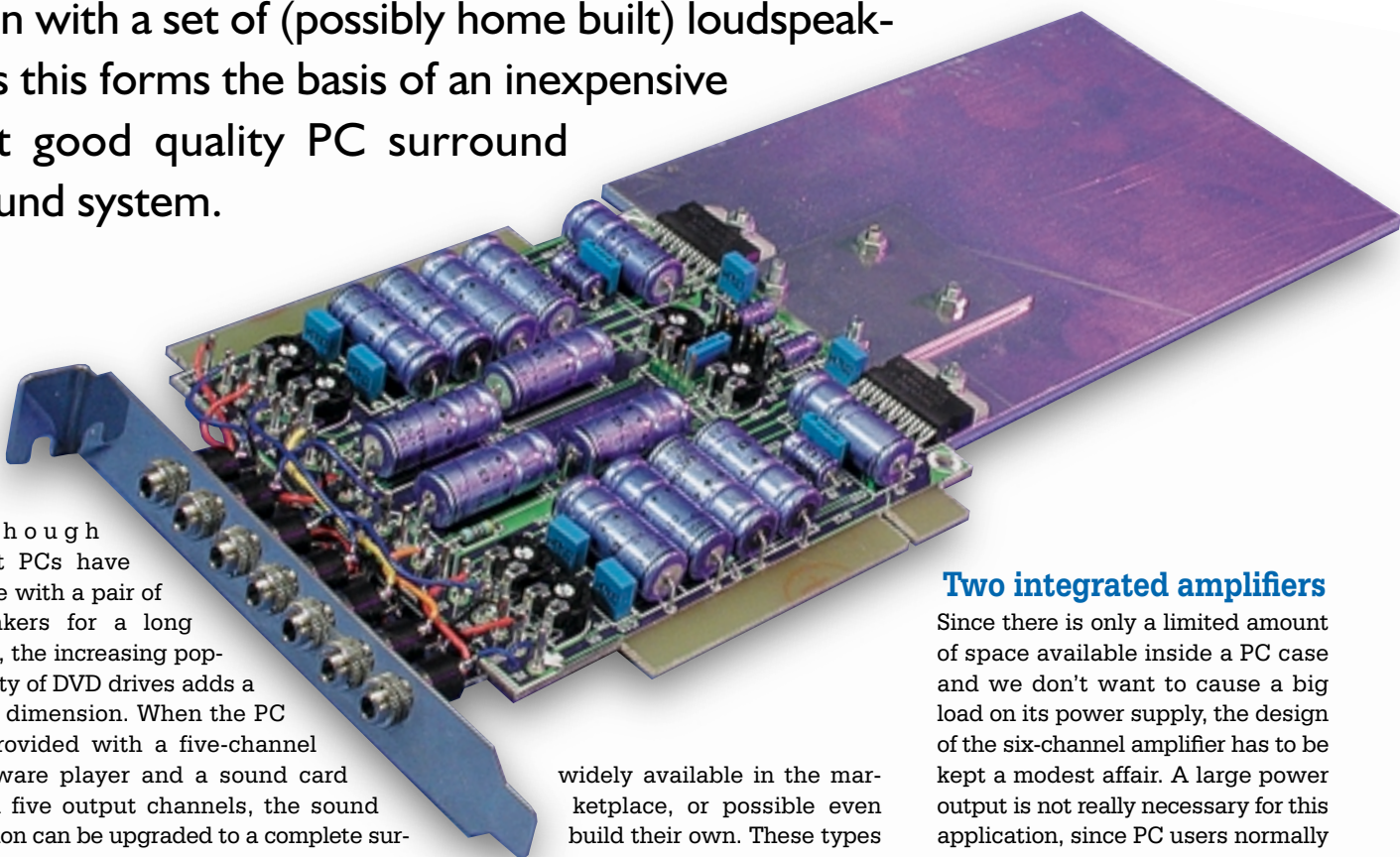
Although most PCs have come with a pair of speakers for a long time, the increasing popularity of DVD drives adds a new dimension. When the PC is provided with a five-channel software player and a sound card with five output channels, the sound section can be upgraded to a complete surround sound system.

It is of course possible to use standard active PC loudspeakers. Most of these are very cheap, but the quality is nowhere near hi-fi. What other options are there? Connecting a full set of living room loudspeakers to the PC is somewhat over the top — both from a financial and a spatial point of view. We would think that most PC owners would rather choose from some of the inexpensive and compact hi-fi loudspeakers that are

widely available in the marketplace, or possible even build their own. These types of loudspeakers are usually not active, which creates another problem: how can we drive such a surround sound system in a simple manner?

Our contribution to all interested PC owners is an easily built plug-in card, which contains six compact power amplifiers, making it possible to connect ordinary passive loudspeakers to the PC.

Two integrated amplifiers

Since there is only a limited amount of space available inside a PC case and we don't want to cause a big load on its power supply, the design of the six-channel amplifier has to be kept a modest affair. A large power output is not really necessary for this application, since PC users normally sit very close to the loudspeakers and the loudness of sound follows an inverse square law. At a distance of 5 metres you would need a power output 25 times greater than that required to produce the same sound pressure at a distance of 1 metre. For PC use it follows that 1 or 2 watts per channel should be sufficient.

In this surround sound amplifier we've decided to use two integrated
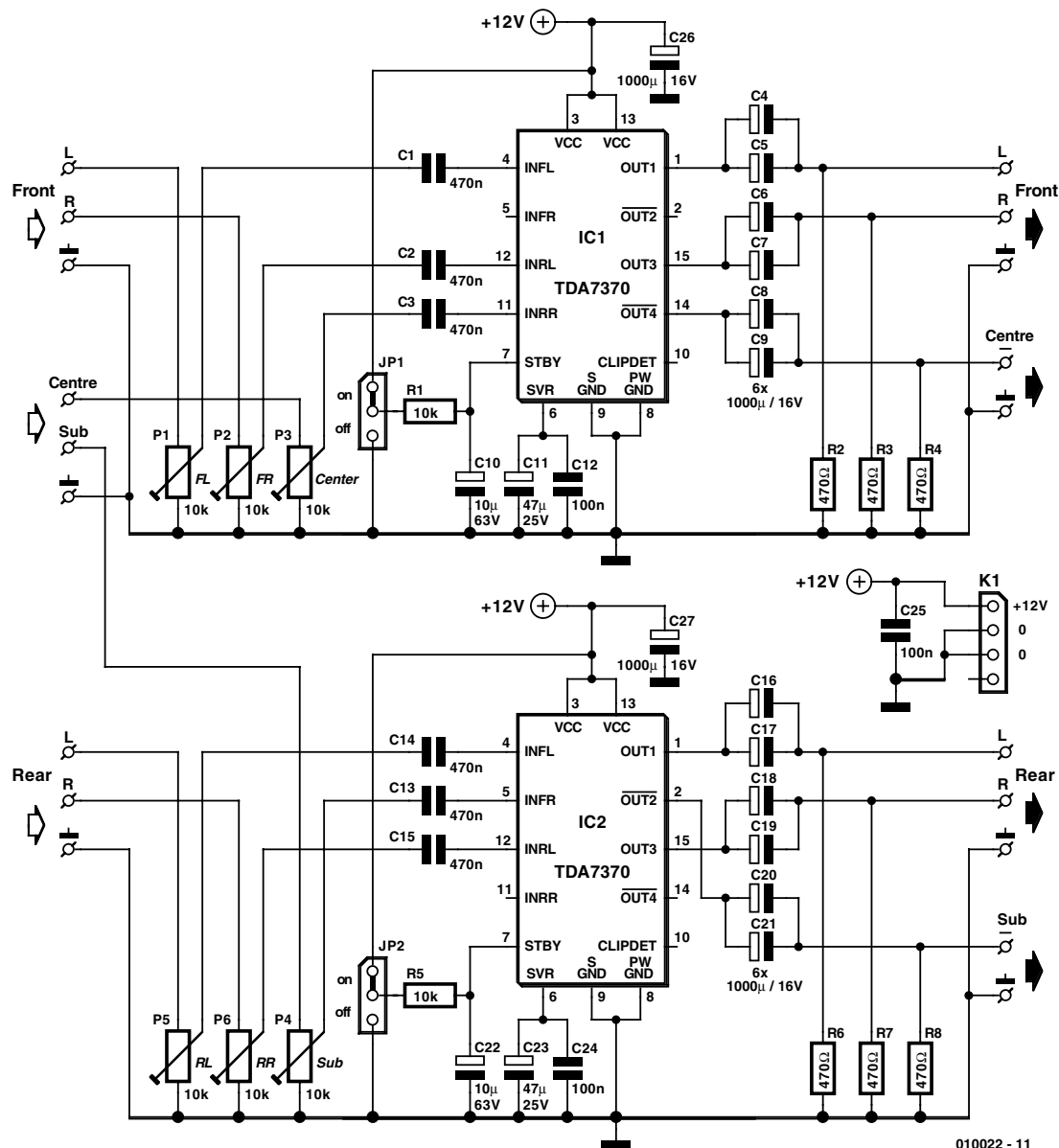
Figure 1. Considering that this is a six-channel power amplifier, the circuit is a model of simplicity.

'quad power amplifiers' (TDA7370B), which were originally intended for automotive use. This has the advantage that they have been designed for use with a supply voltage of 12 V, and can deliver an output power of 3 watts per channel into 4 Ω or 1.5 watts into 8 Ω. This may seem a bit on the low side, but in practice most PC users will find that this is sufficient to produce deafening sound levels.

Simple circuit

The advantage of using integrated amplifiers is that the manufacturer (in this case SGS-Thomson) has

already done all the hard design work and that this type of IC incorporates a range of protection circuits. They are therefore almost indestructible under normal circumstances and they function happily with only a minimal number of external components. The last is a 'must have' when the design calls for the whole circuit to fit on a PC plug-in card.

Just how simple the six-channel integrated amplifier is becomes clear when we look at **Figure 1**, which shows the complete circuit diagram of the design described here. Apart from the two ICs and the inevitable input and output decoupling capacitors, there are only six presets that

are used to set the input level. These are required to compensate for any differences in the loudspeaker efficiencies as well as other possible differences.

Each TDA7370B contains four amplifiers, of which we only use three; after all, we only need six in total. IC1 is used to amplify both Front channels and the Centre channel; IC2 deals with the two Rear channels and the Subwoofer channel.

When connecting the loudspeakers you have to take care with the polarity. The TDA7370B has been designed such that the four amplifier sections can easily be wired up as two bridge amplifiers. It is for this reason that outputs OUT2 and OUT4 are inverted relative to OUT1 and OUT3. In our case this means that the polarity of the Centre and

Specifications

Considering its size and cost, the performance of this mini surround sound amplifier is truly astounding. When we first connected a set of Hi-Fi loudspeakers nobody would believe that such a puny PC card could produce so much sound. The sound produced is very full and you never feel that anything is lacking, neither quality nor volume.

To satisfy those who have a liking for figures, we've taken a few measurements of the amplifier. Not too many of course, since this design was never intended as a high-end amplifier. Furthermore, the compact construction limits the channel separation.

This short list of figures was measured at a supply voltage of 12 V and a load of 8 Ω:

– input sensitivity:	0.38 V_{rms}.
– $P_{max.}$ (THD+N = 0.1%):	1.8 W
– THD+N (1 kHz/1.5 W):	0.04%
(20 kHz/1.5 W):	0.4%
– bandwidth (–3 dB):	17 Hz to 70 kHz
– quiescent current:	0.24 A

For completeness we've added two graphs. Graph **A** shows the distortion as a function of frequency with a bandwidth of 80 kHz. As you can see, it is a steady line without any spikes. The internal protection circuits in these types of IC always cause a slightly higher distortion figure, but they are no cause for alarm.

Graph **B** shows the amplitude as a function of frequency: it's nice and flat with rolloffs occurring at 17 Hz and 70 kHz. The high frequency rolloff is determined completely by the internal circuitry of the TDA7370B. The low frequency rolloff is mainly affected by the input and output capacitors

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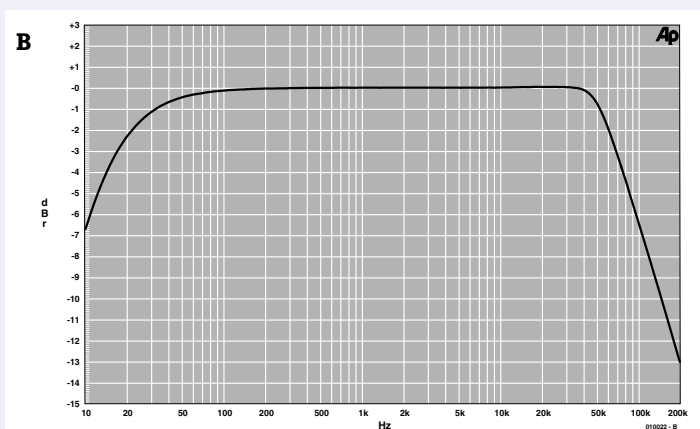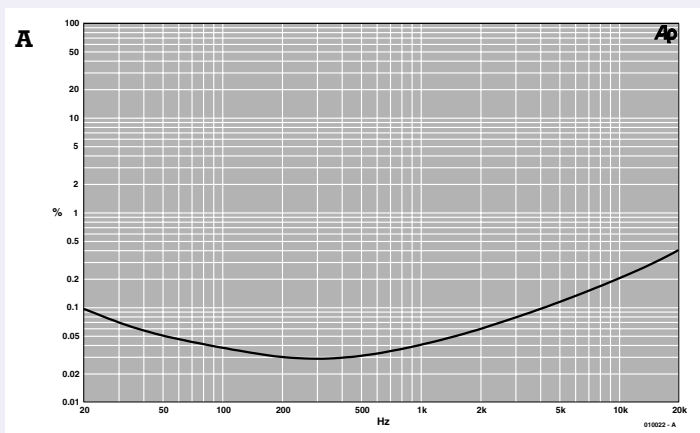
Subwoofer speakers is reversed compared to the rest. Hence the minus symbols shown next to the appropriate outputs.

Just a few more details. There are two reasons for using two components in parallel for the output capacitors. Firstly, this reduces the series resistance and parasitic inductance. But more importantly, the height of the card should be kept as small as possible and the diameter of 1000 µF electrolytics is much less than that of 2200 µF ones. Resistors R2, R3 and R4 and R6, R7 and R8 have been added to provide a load for the output capacitors, which stops those irritating popping sounds from occurring when loudspeakers are plugged into the amplifier when it is already powered up.

Finally, JP1 and JP2 are used to put both TDAs into stand-by mode. This can be useful when the amplifier board won't be used for a long period, since the stand-by current drain reduces to only 1 µA per IC. In today's energy conscious world we would recommend that the jumpers are replaced with a small switch. Switching to and from stand-by mode is with-

out any popping sounds; there is no reason to worry that you'll damage any connected loudspeakers.

PCB

The PCB shown in **Figure 2** has been designed to fit easily into either an ISA or PCI slot of a PC. Populating the PCB is a piece of cake, because all things considered there are very few components. There are eight wire links on the board, and it is best to solder these in first. When it comes to mounting the ICs you have to follow the instructions carefully; this will be explained in detail in the 'cooling' section.

The connectors have purposely not been incorporated on the board so that you can decide for yourself how to implement the input and output connections. In our prototype we've used a blank expansion slot cover and added seven 3.5-mm chas-

sis mounted jack sockets, allowing everything to fit in any PC. We've kept the distance between the centres of the jack connectors to 10 mm. The drawing in **Figure 3** shows the wiring between the board and connectors.

It is obviously not compulsory to mount the amplifier board inside the PC. There is no reason why it can't be turned into a stand-alone piece of equipment with its own power supply and enclosure. This even has some advantages. Firstly it gives the freedom to use a slightly higher supply voltage, increasing the available output power. With a supply of 14.4 V the TDA7370B delivers 5 watts into 4 Ω and at the maximum supply voltage of 18 V that increases to 8 watts. Furthermore, with the board housed in its own enclosure there are far fewer space restrictions and the ICs can be provided with normal heatsinks.

COMPONENTS LIST

Resistors:
R1,R5 = 10kΩ
R2,R3,R4,R6,R7,R8 = 470Ω
P1-P6 = 10kΩ preset

Capacitors:
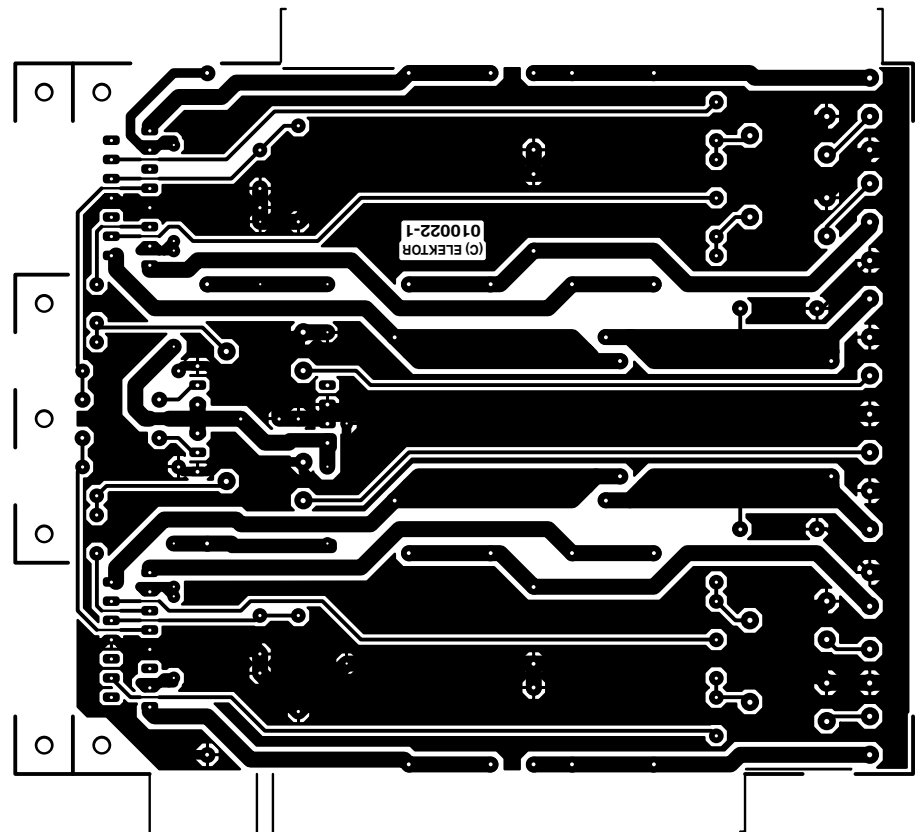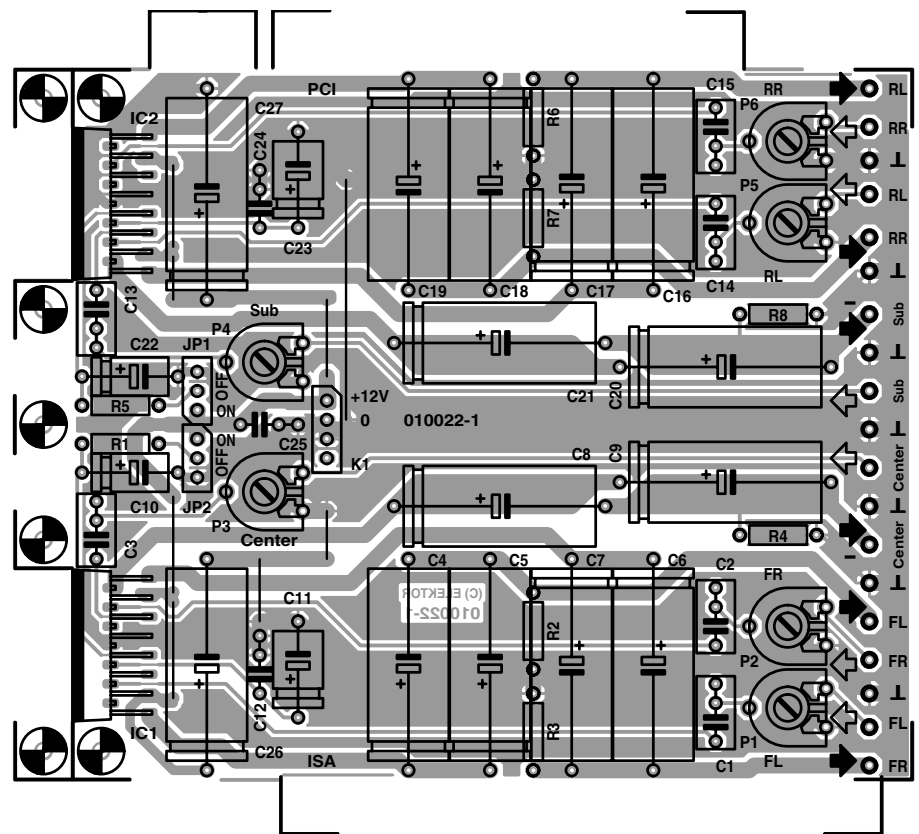C1,C2,C3,C13,C14,C15 = 470nF
C4-C9,C16-C21,C26,C27 =
  1000µF 16V axial, dia. 10mm,
  lead pitch 28mm
C10,C22 = 10µF 63V axial
C11,C23 = 47µF 25V axial
C12,C24,C25 = 100nF

Semiconductors:
IC1,IC2 = TDA7370B (ST Micro-
electronics)

Miscellaneous:
JP1,JP2 = 3-way pinheader with
  jumper
K1 = 4-way pinheader
7 off 3.5mm stereo jack socket,
  PCB mount
PC expansion slot cover

Cooling

Since we are severely limited by the space available on a PC plug-in card, the heatsink for the ICs has to be made to measure. To keep its size to an acceptable level we've designed it to cope with the dissipation caused during typical music playback rather than the maximum caused when all six channels are fully driven by sinewaves — the last is none too realistic anyway.

The photos in **Figure 4** show pretty well what should be done. We've used a 3 mm thick piece of aluminium, measuring 15.5 by 9.5 cm, which the ICs are screwed on to. The whole is screwed to the edge of the board with the help of a small piece of aluminium. The construction itself is not very difficult, but there are a few points that require some attention.

To start with, the pins of the ICs have to be bent backwards, so that

Figure 2. The PCB is designed as a PC plug-in card. The circuit is dominated by the large number of electrolytic capacitors (board not available ready-made).

they can be mounted lying flat. The best way is to bend the back row first with the help with a straight piece of metal, followed by the front row. The pins of the IC should be supported by a thin but strong piece of metal at the point where they leave the IC, so the body of the IC won't be damaged while the pins are bent. When this has been done properly the pins still stick far enough through the board for them to be soldered. This soldering should only be done **after** the heatsink and ICs have been screwed to the board.

The parts of the edge of the board immediately underneath the IC mounting tabs should be cut off with a jigsaw, leaving only the central part with three mounting holes. It's on to this that the previously mentioned small piece of aluminium is screwed, providing for mechanical strength between the heatsink and board. A piece measuring about 40 mm by 9 mm should be cut from the edge of the heatsink, lining up with the piece of board with the three mounting holes. This way the heatsink fits right against the board.

Only when the heatsink has been fixed to the board are the ICs screwed to it after which they are soldered to the board. Remember to put some heat transfer compound between the ICs and heatsink, but isolating washers aren't required since the mounting tab of the IC is connected internally to ground and we also want the heatsink to be at ground potential.

Power supply

For the supply a small PC supply connector is used (K1), which only uses the +12 V connection. When all six channels are fully driven
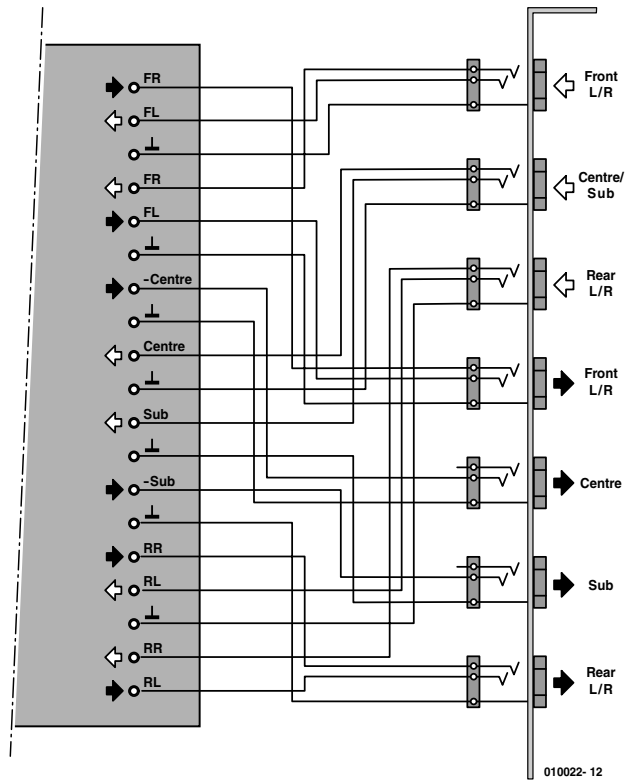

Figure 3. The prototype uses 3.5mm jacks for external connections.

into 8 Ω loudspeakers the average current consumption is about 1.1 A. It should be kept in mind that the peak current drain can briefly rise to 4 A. This is normally not a problem for a PC power supply, but where the PC power supply is already fully loaded it is possible to mount a sup-

ply connector on the expansion slot cover and use an external power supply. But we should reiterate that this is rarely required.
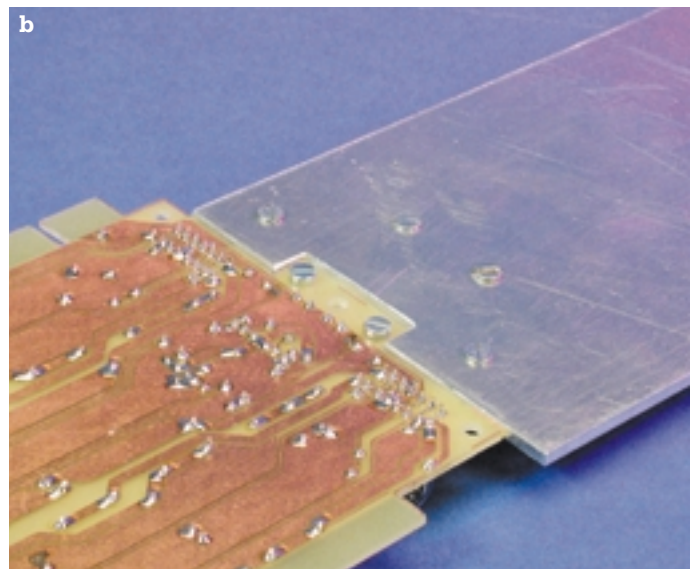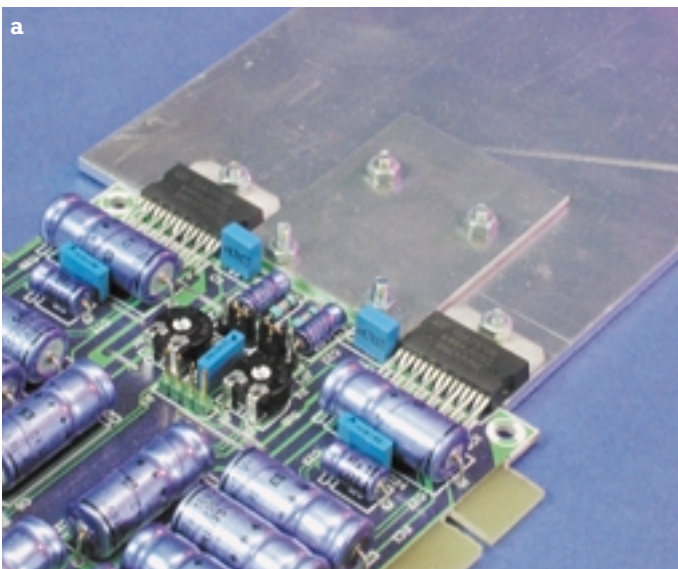
(010022-1)

Figure 4. Mounting of the heatsinks, seen from above (a) and below (b).

NCP1200

a compact switching power supply

By C. Basso (ON Semiconductor)

In designing a product that is powered from the mains, there are various factors that ultimately determine the choice of power supply. Increasingly more manufacturers are choosing a switching power supply, in part because of its light weight and high degree of flexibility.

NCP1200
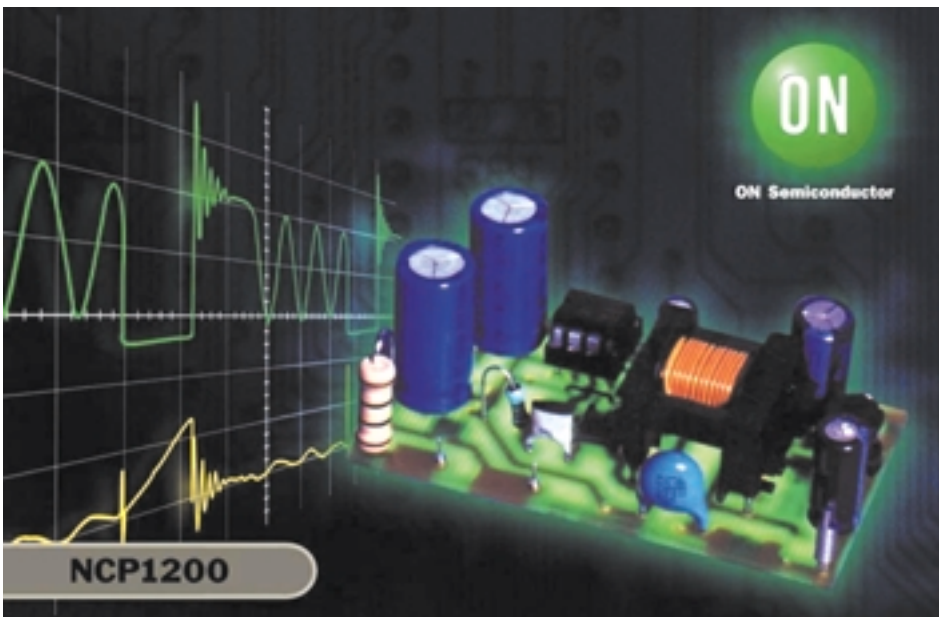
Switching power supplies are often designed to have a 'universal' input, such that they can be directly connected to any desired input voltage (normally an ac voltage between 90 and 260 V). With a traditional solution using a transformer, different taps on the transformer would have to be selected to handle this range of input voltages. However, the less experienced among us are often put off by the idea of a regulated power supply, since it suggests complex circuitry that can generate quite a lot of smoke under the right circumstances! Fortunately, semiconductor manufacturers regularly introduce new chips that make it easy for most power supply designers to

master the technology. ON Semiconductor have made a significant advance in this area with the NCP1200, which has the advantage that most of the functions are integrated into a single chip, while at the same time the designer is given a certain degree of freedom (in choosing the MOSFET and controlling its conductance, for instance). This article describes how this new chip functions, based on the example of the construction of a complete 12 V / 10 W mains power supply with very low quiescent current.

A whole pack of innovations in an 8-pin package

First let's have a brief look at the new features:

– **No need for an auxiliary winding**. ON Semiconductor's high voltage technology (Very High Voltage Integrated Circuit, or VHVIC) allows the power supply to be fed from a power source connected to the mains network. The dc voltage from this source may be as high as 400 V. Only a VHVIC chip can handle such voltages. This technique frees us from the need for an extra transformer winding and associated components.

– **Short-circuit protection**. The NCP1200 is a current-mode regulator with a fixed switching frequency (40, 60 or 100 kHz). During normal operation, the IC continuously monitors the voltage on the FB (feedback) pin. If this voltage exceeds a threshold value for a certain predefined interval, the protection circuitry of the NCP1200 is activated. It remains activated as long as the fault is present, with only brief pulse bursts being delivered in order to limit the average power provided by the supply. This is referred to as 'burst mode' operation. The power supply switches back to the normal operating mode as soon as the fault is no longer present.

– **Low quiescent current**. The International Energy Agency (IEA) regularly prescribes new standards with regards to the standby power consumption of power supplies that are permanently connected to the mains. This includes devices such as chargers for cordless telephones, mains adapters for CD players and video games, television decoders and the like. The idea is to limit the standby power consumption as soon as the power supply no longer provides any power – for example, once the battery of a cordless telephone has been fully charged. Thanks to its 'cycle skipping' technology, in the standby mode the NCP1200 consumes less than 500 mW in the case of a 10W mains power supply (such as that described in this article).

– **No irritating whining**. The manner in which competing devices employ cycle skipping usually results in irritating noises, since the skipping rate (which falls in the audible frequency range) is accompanied by large peak currents. However, in the design of an inexpensive product, the price of a transformer that is quiet and insensitive to these audio-frequency voltages naturally weighs fairly heavy the overall budget. The NCP1200 solves this problem in an elegant manner by performing cycle skipping using only small peak currents. This technique guarantees noise-free operation in the standby mode. Mechanical noises from the transformer are thus held to a minimum. If there is still audible noise, the cycle skipping current level can be adjusted by modifying the voltage on pin 1 (ADJ).

– **An external transistor**. Single-chip solutions are deceptively attractive because they require so few components. However, an on-chip MOSFET transistor will immediately break down if the reverse induction of the transformer pulls the drain below V_{DSS}, with the result that the chip immediately gives up the ghost. Since the NCP1200 drives an external MOSFET, the designer can chose a type that can withstand occasional overloads, and in some cases can

thus do without separate peak current limiting circuitry.

In addition, a series resistor can also be included if you want to slow down MOSFET switch-on.

– **Spice models**. In order to accelerate the development of systems based on the NCP1200, ON Semiconductor offer two Spice models, depending on the desired type of analysis. The normal (averaged) model represents a small-signal current-mode flyback converter and allows a Bode chart to be produced in the blink of an eye. There is also a transient model in which all of the characteristics of the NCP1200 are represented, such as propagation time and current consumption. After the values have been entered into the simulation program, a simulation can be started and graphs appear on the screen to verify the correctness of the designer's calculations. Ready-to-use simulation platforms are available for Intusoft IsSpice4, Cadence Pspice and Spectrum Software Micro-Cap. The files can be downloaded from www.onsemi.com.

Dynamic power supply regulation

Traditional switching power supplies, such as those built around a UC384X, require a minimum load in order to start up. This role is usually assigned to a resistor (start-up resistor) connected directly to the high voltage line that draws several hundred microampères as soon as power is switched on to the equipment. After several cycles of current have been supplied, an auxiliary winding takes over from this resistor to continuously supply power to the regulator. In spite of the attractiveness of this idea, it has two major disadvantages:

1. When the auxiliary winding is powering the regulator, the start-up resistor still remains connected and wastes energy. This makes it difficult to comply with the IEA rules.

2. In battery charging applications, it can happen that a fully discharged battery has a voltage of nearly zero. In such a situation, the auxiliary voltage that is connected to the output in flyback mode disappears. The reg-
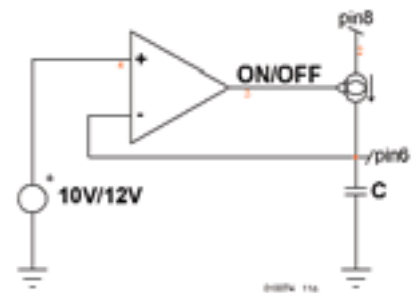

Figure 1a. Working principle of a dynamically regulated current source that provides a constant current to the IC.
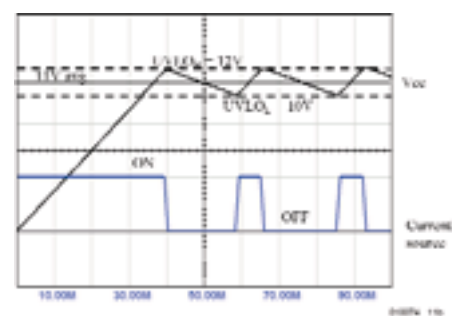

Figure 1b. The current source supplies 4 mA; V_{CC} varies between 10 and 12 V.

ulator receives too little power and can no longer do its job.

In order to permanently eliminate these disadvantages, the NCP1200 uses a dynamic current source that draws power from the high voltage line. The biggest difference between this and a startup resistor lies in the possibility of disabling or re-enabling this current source according to the needs of the regulator. Since the regular draws only a small current (around 1.2 mA), the amount of power that is wasted remains within reasonable limits and the IEA requirement can be easily satisfied. **Figures 1a** and **1b** illustrate the operation of this in detail. As can be seen from Figure 1a, the current source does not just supply power to the regulator circuit; it also charges capacitor C. Due to the design of this circuit, the current source regulates itself and continues to supply 4-mA pulses to the NCP1200 with a variable period, independent of the voltage level on the high voltage line (30–400 V_{DC}). The degree to which the IC contributes to the total power is given by the quantity $V_{line} \times I_{pin8}$.

The power consumption of the NCP1200 itself is governed by its internal structure (clock, comparators, opamps etc.). Another determining factor is the MOSFET connected to
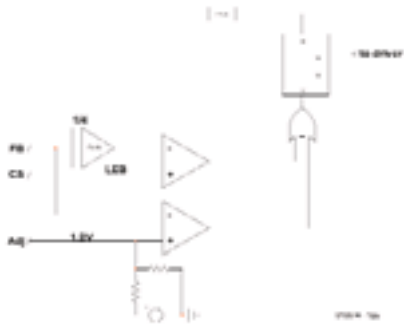
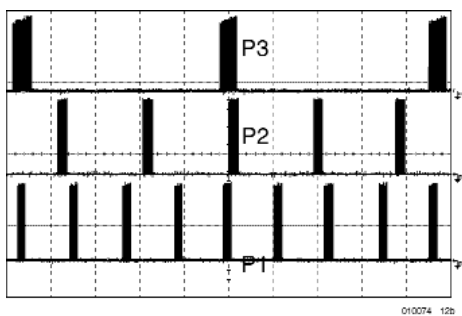Figure 2a. The FB pin is continuously monitored by a comparator.

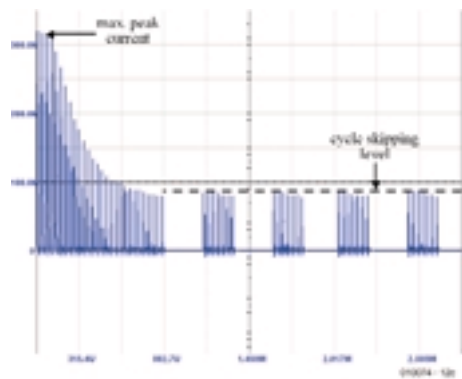Figure 2b. Three different power levels in burst mode (P3<P2<P1).

Figure 2c. Cycle skipping occurs only at low peak current levels.

the output. For example, if a 600-V MOSFET from ON Semiconductor is selected, such as the MTD1N60E, the total drive (total gate charge) is 11 nC. With a 40-kHz version of the NCP1200, this results in an average drive current of 0.5 F_{SW} Q_g = 250 µA, leaving aside considerations of drive efficiency. The variables in this formula are:

F_{SW} = maximum switching frequency (Hz),
Q_g = MOSFET gate charge (Coulomb).

The sum of this current and the normal consumption of the circuit amounts to around

1 mA. The total dissipation is thus approximately (330 V × 1 mA) = 330 mW.

Low standby consumption without objectionable noises

The NCP1200 works with a supply architecture that is referred to as 'current-mode'. The operating principle of this mode is that the peak current I_p flowing through the primary winding (L_p) of a transformer is continuously adjusted to achieve regulation. In the case of a flyback converter, the regulator attempts to satisfy the following relationship:

$$P_{in} = 0.5 \, L_p \, I_p^2 \, F_{sw}$$

It does this by modulating I_p, since L_p and the switching frequency F_{sw} are fixed. I_p is measured by means of a shunt resistor placed in series with the power MOSFET. The voltage so obtained is applied to the Current Sense (CS) pin of the NCP1200. This voltage is then compared with the voltage on the FB pin, which is internally divided by a factor of 4 (see **Figure 2a**).

FB is an electrical representation of the signal on the secondary winding, as transferred via an isolator (often an optocoupler). If the amount of power drawn by the load increases, the level on FB increases (up to 4 V), which results in a higher peak current in the primary winding. By contrast, a low voltage on FB is evidence of low output power. In all cases, the regulator adjusts itself to satisfy the previously given relationship.

If the load on the output is removed, the regulator continues to operate at a very modest level, but still at the same frequency (for example, 40 kHz). However, each cycle for which the MOSFET conducts increases the standby power. The NCP1200 attempts to prevent this as much as possible. One of the simple means to reduce the standby power is to skip cycles when the output power decreases.

The NCP1200 thus operates at a fixed frequency (with normal loading), and in addition it can automatically change over to cycle skipping (omitting cycles) when the output

power is low. All that is needed to utilise this technique is a simple comparator, as is clearly illustrated in Figure 2a. As soon as the voltage on the FB pin falls below 1.4 V, a control element in the IC starts to suppress output pulses. The output pulses are thus modulated with respect to their number and repetition rate ('controlled burst' operation).

Figure 2b shows oscillograms of the NCP1200 output at various power levels. The most significant problem with systems that employ cycle skipping comes from the bundles of 40-kHz pulses, whose repetition rate can lie in the audible frequency range. A transformer is a mechanical element and can give rise to a resonance in the vicinity of this repetition rate. Such a resonance produces a highly irritating whistling noise, whose intensity depends on the peak current through the primary winding. Fortunately, the NCP1200 skips cycles only when delivering very little power. In this situation, the output has to supply only a small current, so there is no resulting noise generation in the transformer. If a given transformer nonetheless generates objectionable noise, the current level at which cycle skipping takes place can be adjusted by connecting pin 1 of the IC to a voltage divider attached to V_{CC} and GND.

A 10-watt power supply

The NCP1200 can be used to build regulated power supplies with capacities ranging from a few milliwatts to 30 W. The project described here shows how the regulator can be used in a mains power supply with a universal input and a power of around 10 W.

Figure 3 shows the schematic diagram of the circuit. As has already been explained, pin 1 of the IC is connected directly to the high voltage line in order to supply power to the IC. The transformer is a very simple type, with a primary winding and a secondary winding but without the usual auxiliary winding. In order to avoid any sort of arcing between the pins, pin 7 is left open to assure secure operation, regardless of the environment in which the circuit is used.
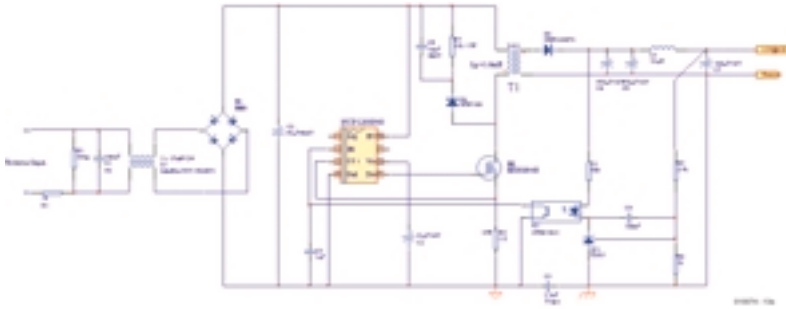
The MOSFET receives its drive sig-

Figure 3. This schematic diagram clearly shows how easy it is to use the NCP1200.

V_{inDC}	P_{out} [W]	P_{in}[W]	μ[%]
126	0	0.245	-
126	10.5	12.6	83.3
356	0	0.462	
356	10.5	13.17	79.7

nal from pin 5 with no intermediate resistor; the output stage already has an asymmetric structure that naturally curbs the transition to the conductive state. A TL431 in combination with an optocoupler provides the feedback. The latter device pulls pin 2 (FB) towards ground when the power demand at the output drops. If the voltage on this pin falls below 1.4 V (the default voltage on this pin), the pulses on the output stop and the regulator begins to skip cycles. If the FB pin is constantly held at ground level by a bipolar transistor, the NCP1200 is fully disabled and passes only the standby portion of the power. Finally, there is provision for peak current protection, since an excessively high voltage on the drain of the MOSFET could destroy the MOSFET.

The performance figures of the circuit are listed below. They provide evidence of both outstanding efficiency and low standby power (less than 480 mW with a mains voltage of 250 V_{ac}).

The circuit is constructed using fully standard components. A ready-made transformer is available for this 10-W version.

In conclusion, we can state that the NCP1200 takes an approach that is different from that used by all other commercially available types of regulator ICs. As a regulator, it forms an extremely compact solution that leaves the user free in the choice of MOSFET and the peak current that flows through it. From an EMC perspective, the fact that the drive to the MOSFET can be precisely adjusted can certainly be considered to be an advantage. Finally, the availability of Spice models provides a considerable time savings in the design phase.

Extensive documentation (technical data, application notes etc.) is available on the ON Semiconductor website (www.onsemi.com) under the heading 'NCP1200'.

(010074-1)

8-Channel DMX Demultiplexer

eight DMX channels = 8 x 0-10 V (with relays to come soon)

Design by B. Bouchez   bbouchez@netcourrier.com

'DMX512' stands for 'Digital Multiplex', which is a technique that allows up to 512 channels to be driven sequentially (multiplexed) using a single cable. The circuit presented here is intended to be used to control DMX512-compatible devices.
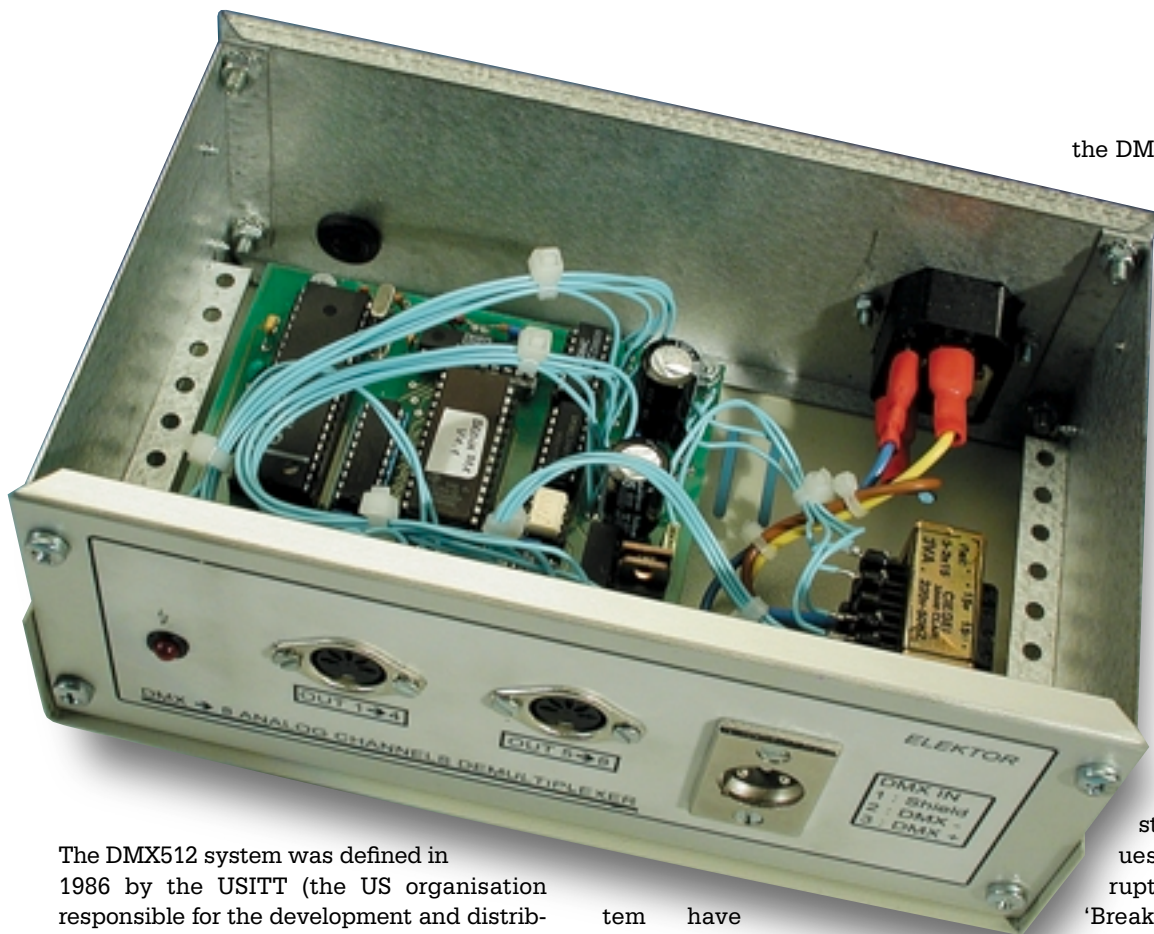
The DMX512 system was defined in 1986 by the USITT (the US organisation responsible for the development and distribution of standards for the theatre world), but it did not really take off until the mid 1990s, after the use of automatic spotlights became popular.

Several articles devoted to the DMX512 system have already appeared in earlier issues of *Elektor Electronics*. The first one appeared in the first quarter of this year. If you want to know more about the technical details of the DMX512 standard, we recommend that you read this article [1], as well as the one on the MICI–DMX interface [2]. Put briefly, the DMX512 protocol allows an RS485 link to be used to connect up to 32 devices over a distance of up to 1000 m. The data are transferred at a rate of 250 kbits/s, with the data format being 8 data bits, no parity, 1 start bit and 2 stop bits. The information needed for the various channels is sent sequentially in the form of 8-bit values ranging from '0' ('off') to '255' ('on'). In order to mark the start of the series of 512 values, communication is interrupted by simply generating a 'Break' (logical '0' level) with a duration of at least two frames. Finally, a 'high' level lasting at least 8 µs is generated to mark the start of the first byte following the break.
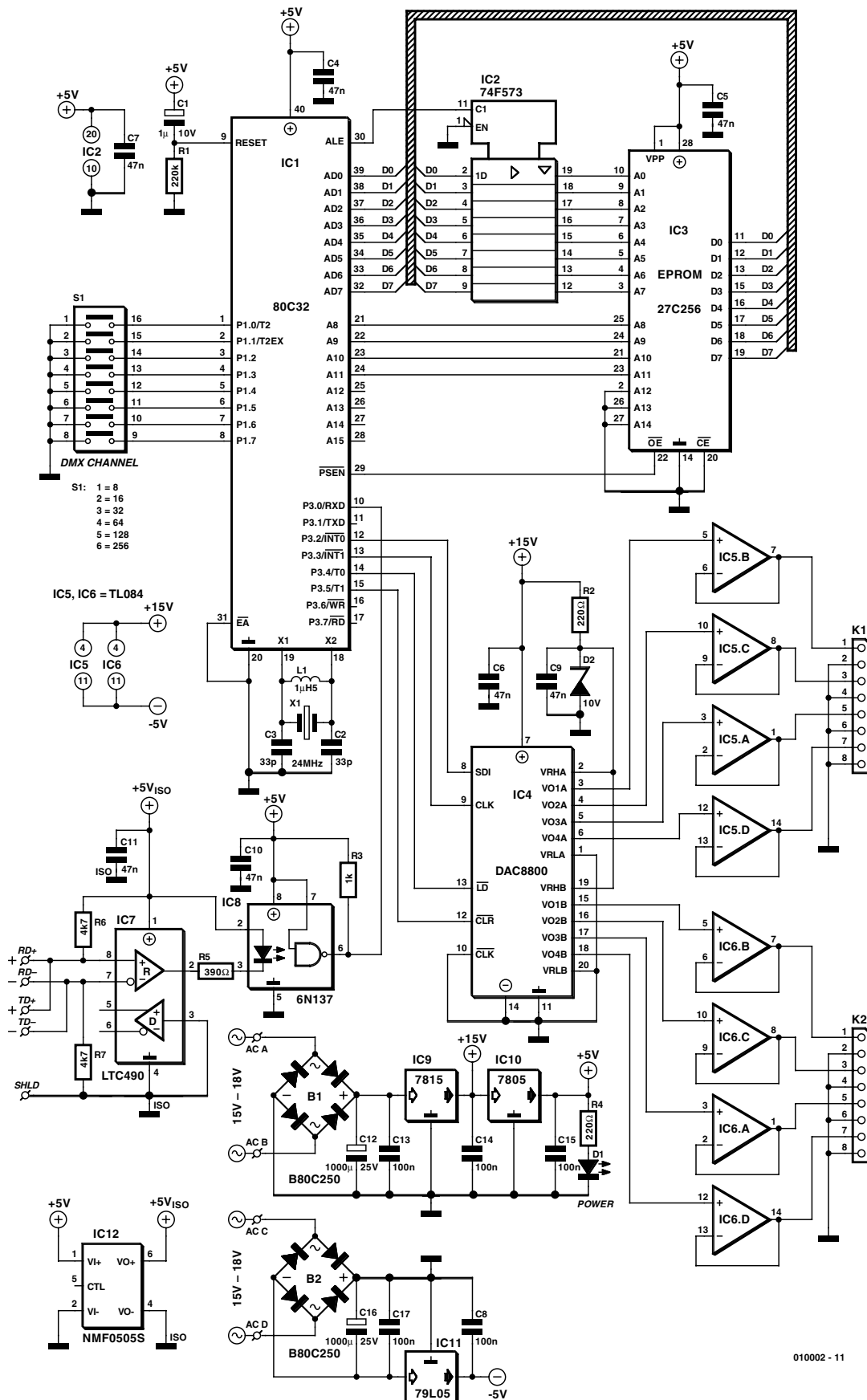
Figure 1. The schematic diagram of the demultiplexer shows that it is a microcontroller system reduced to its simplest form.

Why do we need a demultiplexer?

As already mentioned, 'DMX512' stands for 'Digital Multiplex', since data for the 512 channels are sent sequentially (multiplexed) over a single cable.

Devices that come standard with a DMX512 interface are generally more expensive than equivalent devices that can be remotely controlled by an analogue signal. Besides, for certain types of equipment it is not necessary to have a built-in interface, whether DMX or otherwise. This is particularly true of spotlights used in theatres or television studios that only allow the brightness to be adjusted. This category also includes special-effects devices, such as stroboscopes and smoke generators.

For such simple applications, either simple 0-10 V remote control is used or the control is entrusted to a dimmer.

The task of the demultiplexer is to provide a set of control voltages that allow all of theses types of devices, which previously could only be controlled by a voltage between 0 and 10 V, to be controlled using DMX512. If we add relays to the repertoire of our demultiplexer, it can also control simple 'all-or-nothing' devices (those not having an analogue control input, in other words). With a bit of practical skill, it's even possible to fit our demultiplexer to devices that are not designed for remote control and thus turn them into semi-professional devices, but let's take things one at a time….

The real work…

A quick study of the electronics, whose schematic diagram is shown in **Figure 1**, shows that once again a microcontroller has the leading role. Here we have used an 80C32 in the well-known classical manner, with external program memory in the form of an EPROM. (By the way, we could have just as well used a microcontroller with an on-board EPROM, which would make the schematic diagram even simpler.) Using an EPROM makes it easier to implement a new version of the program in the future. As is usual in such cases, the address bus is demultiplexed by IC2, which provides the eight least significant bits of the address to the EPROM (IC3). As you can see, not all of the address lines of the EPROM are actually used. This is because the program is so compact that it would easily fit into a 27C64. However, these devices are becoming increasingly rare and thus more expensive, which is good reason to use a 27C256 and leave the unnecessary address lines unused. This also makes the circuit
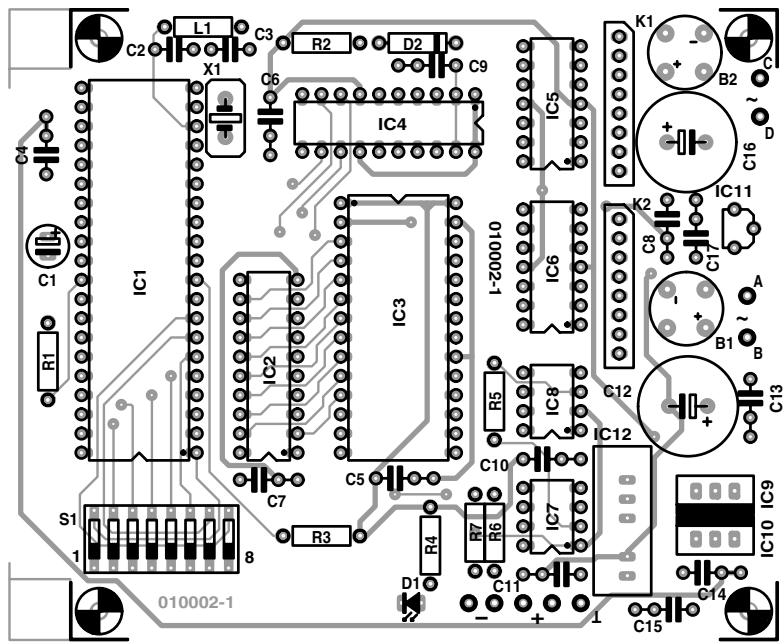

Figure 2. The printed circuit board and component layouts for this project.

board layout easier.

Readers who are familiar with the 80C32 (such as those of you who have followed the microcontroller course in *Elektor Electronics*) may be surprised to see this microcontroller being used in this manner, since its UART cannot detect the Break signals that form the basis for synchronising DMX512 frames. There's no need for concern; the detection of Break signals is definitely within the scope of the 80C32's capabilities. This is because our program simply detects the status of the ninth bit of every byte. Since the DMX512 frames consist of bytes with no parity, the ninth bit is actually the image

Figure 3. A fully assembled example of the DMX demultiplexer.

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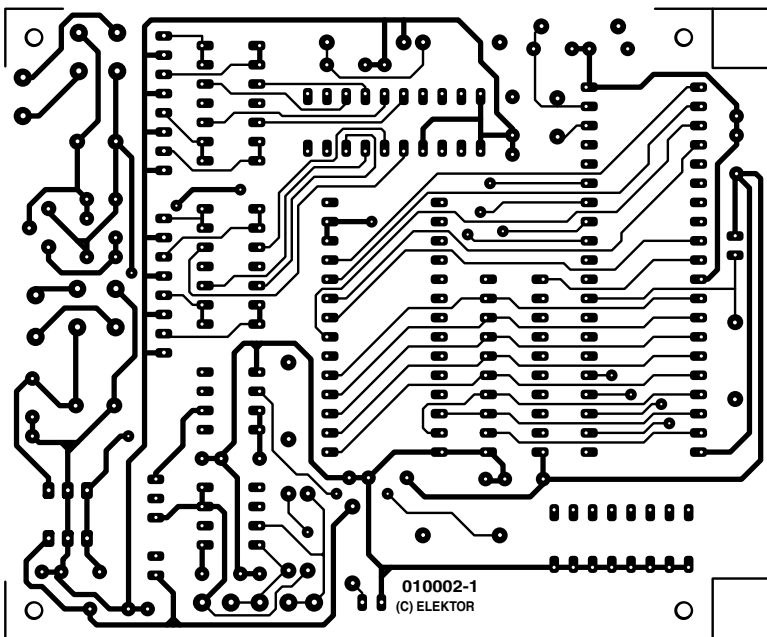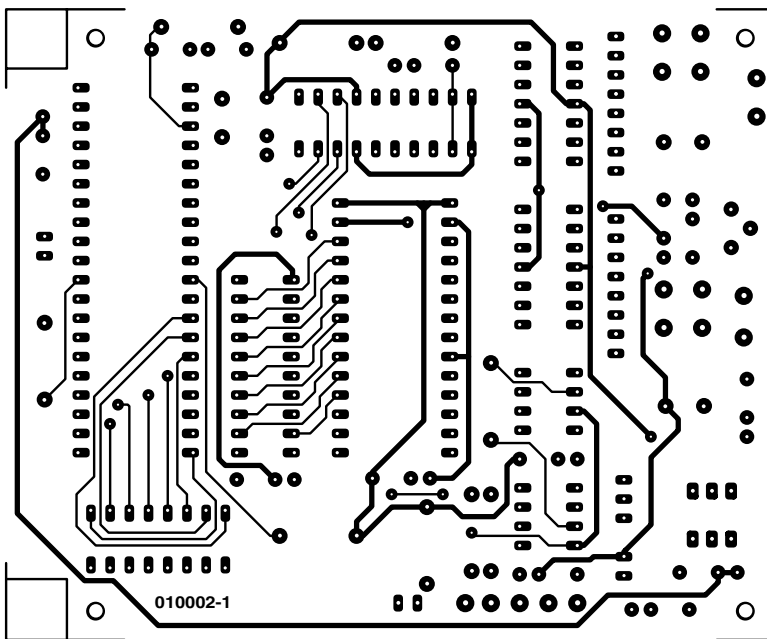
COMPONENTS LIST

Resistors:
R1 = 220kΩ
R2, R4 = 220Ω
R3 = 1kΩ
R5 = 390Ω
R6, R7 = 4kΩ7

Capacitors:
C1 = 1µF 10V radial
C2,C3 = 33pF
C4-C7, C9,C10,C11 = 47nF
C8,C13,C14,C15,C17 = 100nF
C12,C16 = 1000µF 25V radial

Semiconductors:
B1, B2 = B80C250 bridge rectifier (80V piv, 250mA cont.)
D1 = LED
D2 = zener diode 10V 500mW
IC1 = P80C32SFPN (40-pin DIL case, temperature range = 0-70°)
IC2 = 74F573 or 74HCT573 *
IC3 = 27C256 (programmed, order code **010002-21**)
IC4 = DAC8800FP(Analog Devices)
IC5, IC6 = TL084
IC7 = LTC490 CN8 (Linear Technology)
IC8 = 6N137
IC9 = 7815
IC10 = 7805
IC11 = 79L05
IC12 = NMF0505S or TMA0505S

Miscellaneous:
K1, K2 = 8-way SIL pinheader
L1 = choke, 1µH5*
S1 = 8-way DIP switch
X1 = 24MHz quartz crystal
Mains transformer, secondary 2x15V at 3VA
IEC mains appliance socket with earth connection and internal fuse, 25mA
Enclosure, size 200x80x132mm, e.g., Telet type LC270
PCB, order code **010002-1**
Disk, project software, order code **010002-11**

* see text

of the stop bit and thus must be a '1'. If the microcontroller detects a byte in which the ninth bit is a '0', this means that the DMX interface is in the synchronisation phase. Although this is a somewhat unorthodox approach, it works perfectly (we have used this method for several years in professional designs without any problems).

It's not necessary to say much about the peripheral components around the 80C32, thanks to the use of a standard circuit. However, note that

a 24-MHz crystal must be used in order to provide the serial port with a data rate of 250 kbits/s. Normally, it is not easy to find a 24-MHz crystal. Consequently, we have included a small coil (L1) to force the crystal to oscillate at a harmonic overtone. In the section of this article that deals with the practical aspects of the design, we describe how to determine whether this coil is actually necessary.

The address selected using the dip switches is read via the P1 bus.

Since our multiplexer has eight voltage outputs, it occupies eight DMX channels. The DMX address of the demultiplexer is configured 'modulo 8', which means that it can be located only every eight channels (1, 9, 17, 25 etc.). In order to determine the channel number of the first DMA channel, all you have to do is to add the values of all of the closed switches (as marked) and then add 1 to the sum. For example, if none of the switches is closed, DMX channels 1–8 are occupied. If the first and third switches on the interface are closed, the demultiplexer occupies eight channels starting with channel number 41 (=

8 + 32 + 1), or in other words, channels 41–49. You will probably notice that only the first six lines are used to select the DMX address. The other two lines are used to activate certain demultiplexer options. Presently, only P1.6 is used, in order to activate the 'relay output' option.

The connection with the DMX bus is provided by IC7, a standard RS-485 transceiver, whose output is not used here. Resistors R6 and R7 pull the line to a defined level in the quiescent state, which prevents incorrect behaviour if the interface is disconnected from the DMX bus. We have chosen to have the DMX output run via solder pads in order to leave ourselves a free choice of XLR connectors, since both the 3-pin and the 5-pin versions are used. At the end of this article, we provide more information about these connectors.

In order to avoid problems with ground loops, the LTC490 is electrically isolated from the rest of the circuit by means of a fast optocoupler (IC8). This part of the circuit is powered by a static DC/DC converter (NMF0505S) with 5-V input and output.

In order to generate the eight control voltages, we use an 8-channel DAC from Burr Brown (type DAC8800). Besides the fact that it contains eight R-2R converters, the major advantage of the DAC8800 is that it can be driven via a synchronous serial link, which allows the circuit board to remain relatively simple. Without this component, we would have had to connect eight DACs (such as the DAC08) in parallel and use an address decoder, which would make the circuit board layout considerably more complex.

Since the manufacturer of the DAC8800 recommends keeping the supply voltage on pin 7 at least 4 V higher than the maximum output voltage, in order to ensure maximum linearity, the supply voltage for IC4 is 15 V. It should be noted that compatibility with 5-V TTL outputs is guaranteed by an internal voltage regulator.

The reference voltage inputs VHRA and VHRB can be used to set the maximum output voltage of the DAC. Here they are connected to a simple 10-V Zener diode that provides the reference voltage. In spite of the fact that this solution is far from being as precise as a 'real' reference voltage, it has proven to be perfectly satisfactory for our purposes, and besides that it is inexpensive.

Since the output impedance of the DAC8800 is rather high, problems could arise if the outputs were directly connected to devices whose input impedance is only a few thousand ohms. For this reason, each outputs of the DAC are buffered by opamps (TL084). Since the saturation voltage of the opamp
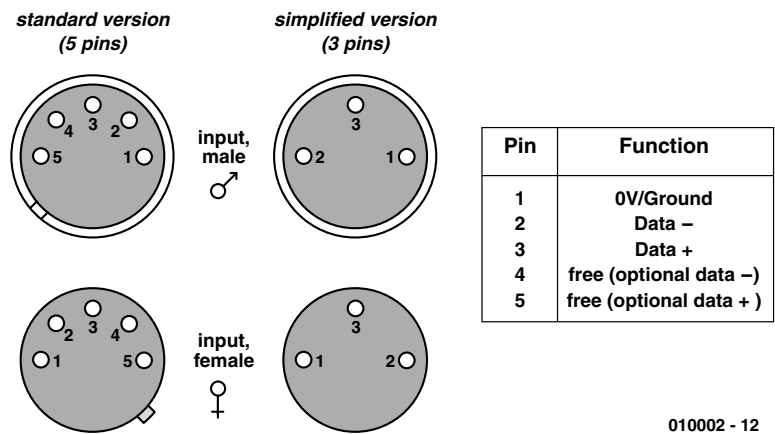
Figure 4. Just for reference: 3-way and 5-way XLR connectors.

output stage prevents the opamp from working down to 0 V if the negative supply pin is connected to ground, it is instead connected to –5 V.

The final item in the schematic diagram is the power supply, which does not need any particular explanation except with regard to the transformer to be used. The 'AC A' and 'AC B' inputs must be connected to a transformer with a secondary voltage of 18 V, in order to ensure that the voltage on the input of IC9 is sufficiently high.

As regards the negative supply, everything depends on the manufacturer of IC11. If you use a MC79L05 (Motorola is now 'ON Semiconductor') or an equivalent device, there is no problem. This is because the MC79Lxx ICs from this manufacturer are specified for 30 V (18 V_{ac}, rectified and filtered, gives a peak voltage of 27 V). With this regulator, you can thus use the other secondary winding of the transformer connected to 'AC A' and 'AC B'. The problem is that some manufacturers of this type of voltage regulator do not specify the input for anything higher than 15 V. In case of doubt, a second transformer with a 9-V output must be used for this part of the supply.

Get out your soldering iron!

Due to the small number of components and the absence of any critical

components, the practical implementation of the demultiplexer, using the printed circuit board shown in **Figure 2**, should not present any problems.

Even if you decide not to use IC sockets for economic reasons, it's hard to overstress the fact that you should always use sockets for IC7 and IC8. Should there be any serious problems on the DMX bus (excessive voltages, electrostatic discharges etc.), it is a lot easier to replace these IC's if they are mounted in sockets. Pay attention when fitting IC3, the EPROM, since its orientation is opposite to that of the rest of the ICs. We would also like to point out that a programmed EPROM can be obtained from the usual reliable source (Readers Services) under order number **010002-21**.

In light of the low power consumption of the circuit, a small piece of aluminium is adequate as a heat sink for IC9 and IC10.

As far as K1 and K2 are concerned, you can choose whatever best meets your needs (screw terminals, DIN connector, XLR connector etc.). In our case, as can be seen from the pictures at the head of the article and in **Figure 3**, we chose to use DIN connectors with the outputs divided into two groups of four each, but you are naturally free to make your own choice.

Once all components have been fitted and checked, you can apply voltage to the circuit. Now you can check the various supply voltages, in

particular that for the isolated part of the circuit board.

To test the interface, you will need a DMX console or a program running on a PC with the proper interface (such as the MIDI–DMX Interface described in ref. [2]). After you have configured S1 to select a starting address (with S1.7 and S1.8 'off' to enable the voltage mode), the DMX master can be used to send instructions for the voltages of the eight channels starting at this address. If the sliders of the control panel are set to their minimum positions, the voltage on each output should drop to 0 V (within a few millivolts). If the sliders are placed at their maximum positions, the output voltage for each output should be 10.0 V (don't forget to calibrate the control panel sliders, to the extent that that is possible!).

If the circuit board does not seem to be working properly, connect an oscilloscope to pin 9 of IC4. Here you should see a pulse train, which indicates that the processor is properly driving the DAC.

The absence of pulses on this line means that there is something wrong at the processor level. Given the high speed of the processor, it is strongly recommended to use a 74F573 (Fast TTL). Although we do not really know why, one of our prototypes proved to work very erratically with an IC from this family. As soon as it was replaced by a 74HCT573, this problem disappeared.

Also check whether a 2-MHz signal is present on the ALE pin. If you see a different frequency here, the crystal is not oscillating or is oscillating at the wrong frequency. If you have fitted L1, remove it and repeat this test. If the circuit works properly without this coil, this means that the crystal naturally oscillates at 24 MHz. In this case, the coil is not needed.

Finally, if you have chosen to program the EPROM yourself, you can check whether IC3 is in fact al 120-ns or 150-ns type (as indicated by a -12 or -15 suffix to the part number). Slower versions are not suitable for this application. You can obtain a diskette (order number **010002-11**) from Readers Services with the source code and hexadecimal file for this circuit.

If the processor portion of the circuit works properly but no action can be seen on the analogue outputs, check the DMX interface. Start by disconnecting all cables that are connected to RD+/RD– and TD+/TD–. Pin 2 of IC7 and pin 6 of IC8 should now be 'high'. Don't forget that IC7 is electrically isolated from the rest of the circuit, so you have to connect the negative lead of your meter to the isolated ground! Next, take a stabilised power supply set to approximately 5 V and connect its negative terminal to RD+ and its positive terminal to RD–. The outputs of IC7 and IC8 should now be 'low'. If this test yields a negative result, check the portion of the circuit around IC7, IC8 and IC12.

On the other hand, if the result of this test is positive and the interface still does not respond to the DMX control panel, you should first verify that the RD+ and RD– lines are not swapped. The manufacturers of some brands, such as Martin, have brought equipment on the market in which the 'hot' and 'cold' connections are reversed with respect to the standard. You also shouldn't forget the RS485 terminators at the ends of the cable, which are absolutely indispensable. Such a terminator simply consists of a resistor of around 100 Ω connected between the RD+ and RD– (or TD+ and TD–) leads. Also check for a possible short circuit between one of the conductors and the screen (SHLD).

If everything works properly, you can move on to the final phase (feared by all electronics types) — fitting the board into an enclosure. This type of interface is usually intended to be used in the vicinity of dimmers or lighting fixtures that have remote control connections. With regard to the enclosure, we make a habit of fitting our demultiplexers into water-tight 'distribution box' enclosures (the example shown in the picture is an exception). In order to avoid problems from external interference, you can treat the inside of the enclosure with a graphite spray. If you use a metallic enclosure, connect it to ground. We usually fit screws and clamps on one side of the enclosure so that it can be attached to a lighting fixture if necessary. LED D3 should be fitted protruding from the

box so you can check whether the supply voltage is OK while standing on the floor.

The last point that needs attention is the DMX connection. The DMX standard prescribes the use of a 5-way XLR connector, male on the RD side and female on the TD side, so that devices can be 'daisy-chained' (connected in series with each other). However, some manufacturers prefer to use the less expensive 3-way XLR connectors. The choice is up to you. **Figure 4** clearly shows the difference between the 3-way and 5-way versions of the connectors.

Now where's the remote control input?

Here we go! Your interface is working! Now you have to connect it to a light or other piece of equipment. If the device that you want to control has a 0-10V control input (which is true of most professional dimmers, stroboscopes and even some simple lighting fixtures), this is no problem, since the connection will work right away. In some cases the equipment wants to see a non-standard voltage, such as 0–5 V or something else, and you will have to use a voltage divider. In the rare case that you have a current-driven control, a series resistor can provide a solution.

However, the vast majority of devices do not have a control voltage input. Usually there is only an on/off input. In this case, you will have to resort to the relay version of the multiplexer, which will be presented in an upcoming article.

If the device that you want to control does not have any sort of control input, or if there is a control input but it does not match the standard supported by our demultiplexer, the only thing you can do is to get out your soldering iron and make the necessary modifications.

Due to lack of space, we can't discuss such modifications here. If there is enough demand from readers, we could devote a complete article to this subject. In the meantime, we'll be seeing you on the DMX bus….

In an upcoming article, we will present a relay extension that can be connected to our circuit. This extension replaces the DAC8800 converter and is connected to the existing circuit board via a flat cable.

(010002-1)

References:
[1] 'DMX512 Revealed', Elektor Electronics, May 2001, pp 44 ff.
[2] 'MIDI-DMX Interface', Elektor Electronics, September 2001, pp 36 ff.

2 × 25 W Power Amplifier for Car Sound Systems

high efficiency with a TDA1563Q

Semiconductor manufacturers are always coming up with new techniques and tricks for making effective use of energy. Final amplifiers for car sound systems are no exception.

In designing power amplifiers for sound reproduction in vehicles, an output power of somewhat more than 6 W can be generated using a conservative class-B output stage. In spite of this relatively small output power, such stages are found in most car radios for the simple reason that class-B output stages have high efficiency (78.5% with a maximum-amplitude sine wave signal); the internal power dissipation is relatively small (20% of the output power). This avoids problems with excessive heat dissipation in the vehicle or the need to use an oversized heat sink, which arises from the fact that the maximum ambient temperature in a vehicle must be assumed to be considerably higher than with a home stereo system, for example, so a car radio cannot be allowed to run as hot.
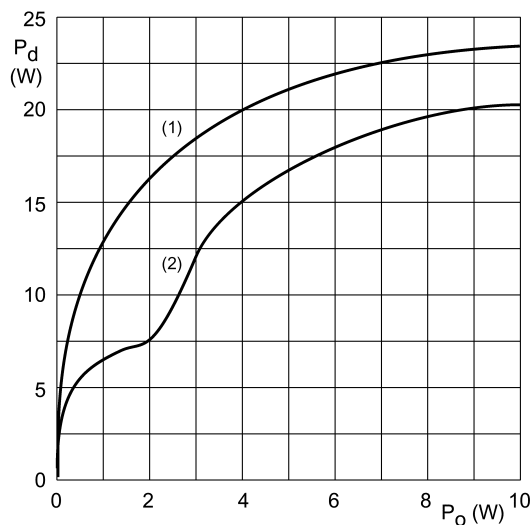
So far, so good. However, nowadays you can't sell a car radio that 'boasts' a measly 2 × 6 W of output power. Manufacturers of car sound equipment have thus come up with several other ideas. The first remedy is to measure the output power under totally unrealistic conditions (100 Hz sine-wave signal, 18-V supply voltage and 10% THD). A quoted power of 30 W, for example, reduces to something more like 7-8 W under realistic conditions (audio signal, V_S = 13.2 V, THD = 0.5%). This is of course outrageous, but it's allowed by the Japanese EIAJ standard.

A second (and honest) possibility is to employ a switch-mode power supply to raise the supply voltage to (almost) any desired level. With this approach, it's no problem to obtain ear-splitting sound levels from the

Input signal 1 kHz, sinusoidal; V_P = 14.4 V.
(1) For a conventional BTL amplifier.
(2) For TDA1563Q.

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Figure 1. Comparison of a conventional bridge amplifier and the TDA1563Q. The new Philips IC clearly has lower power dissipation.

loudspeaker. However, a switch-mode power supply (which is normally housed together with the final amplifier in a single enclosure) takes up a lot of space and requires a hefty heat sink, which must dissipate the heat dissipated by the power supply in addition to that of the output stage. In a standard car radio bay, there is in any case not enough room

for such a device.

Another way to produce more power is to use bridge operation. This requires two output stages, of which one is driven by the normal audio signal while the other one is driven by the inverted signal (via a phase inverter stage). The loudspeaker is connected between the two output stages, so that in comparison with

'single-ended' operation, the voltage swing is doubled and the output power is (theoretically) quadrupled. Unfortunately, the heat dissipation is quadrupled as well, which means a larger heat sink, increased heat dissipation and inefficient utilisation of battery capacity.

Nevertheless, manufacturers of car electronics make considerable efforts to outsmart the rules of physics using more or less sophisticated measures. These are based on the assumption that under normal circumstances the output power of an efficient class-B output stage is fully adequate, even for loud reproduction levels, with the limits being exceeded only by transient peaks. This means that what is necessary is to make sufficient energy available to achieve a higher output power level for brief intervals.

In the March 1995 issue of *Elektor Electronics* we reported an amplifier IC with the part number TDA1560Q, which has a sort of internal charge pump that can nearly double the supply voltage for brief signal peaks. In theory, this allows an output power of 26 W to be produced (although in practice, the value is a good deal lower). As ingenious as this technique may seem at first glance, a look at the distortion figures gives a different impression. When the supply voltage changes levels, the output stage generates strong, clearly audible distortion, which is naturally very irritating at loud reproduction levels (with correspondingly frequent switching between supply voltage levels).

Less energy and smaller heat sinks

Philips has now developed a new concept in the form of the TDA1563Q. The output stage works in class-B mode as much as possible, which means that the ac signal works against half of the supply voltage. In this region, the efficiency is especially high. However, if the effective output voltage rises to more than 3 V, the IC switches to the bridge mode. Although this is not as efficient as the class-B mode, it achieves an output power of up to 20 W per channel with a realistic supply voltage and an acceptable
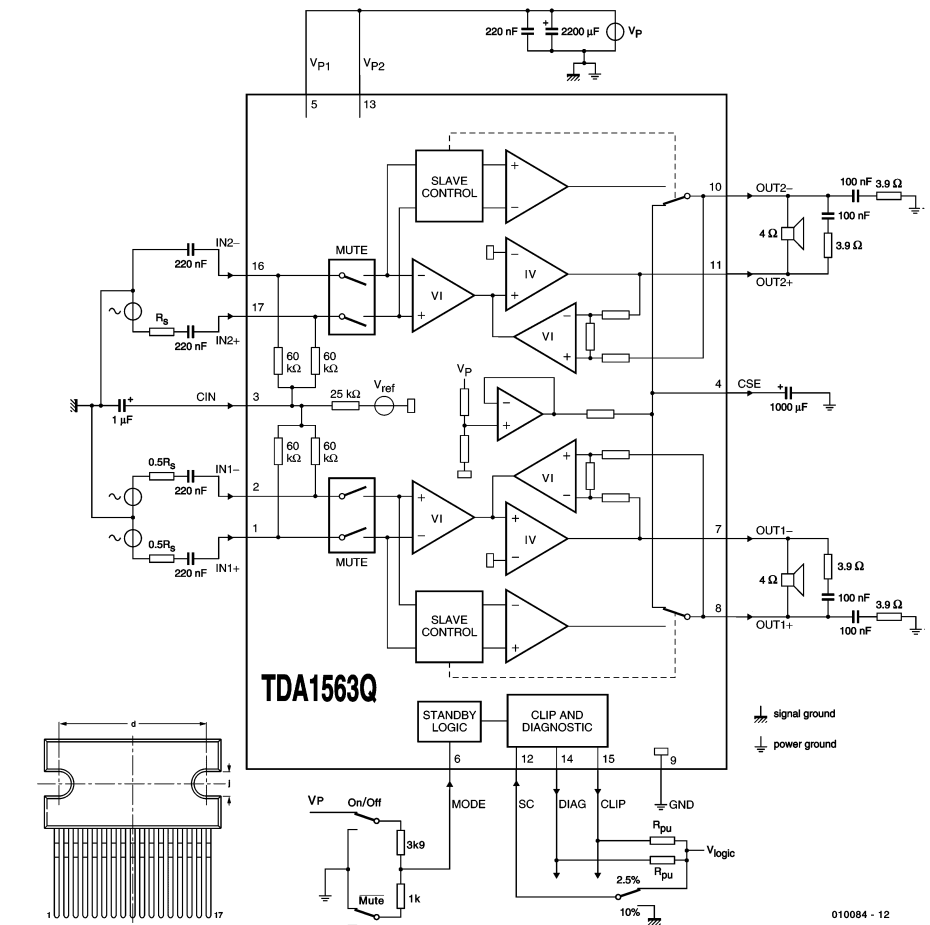

Figure 2. Inner circuitry and sample application for the TDA1563Q.

level of distortion.

Figure 1 shows a plot of the relationship between output power and power dissipation with a 1-kHz input signal. The upper curve is for a conventional bridge amplifier and the lower curve for the TDA1563Q. The kink in the curve resulting from the changeover point is clearly recognisable. For single-ended operation, the power dissipation is less than half that of a normal bridge amplifier. If a Gaussian distribution of the output amplitude is assumed for music signals, the power dissipation of a conventional bridge amplifier lies around 70% higher.

Besides the energy-saving effect, the improved efficiency has other consequences. A conventional bridge amplifier with a total thermal resistance (insulating washer and heat sink) of 1.5 K/W, an allowable die temperature of 145 °C at a maximum ambient temperature of 65 °C and a delivered output power of 6.5 W per

channel requires a heat sink (for a music signal) with a thermal coefficient of

$$\Theta_{HS} = (145 - 65) \div (2 \times 6.5) - 1.5 \approx 4.6 \text{ K/W}$$

By contrast, the TDA1563Q with its 70% more efficient operation can manage with a heat sink having a thermal coefficient of

$$\Theta_{HS} = 1.7 \ [(145 - 65) \div (2 \times 6.5)] - 1.5 \approx 9.0 \text{ K/W}$$

The heat sink can thus be kept significantly (!) smaller.

Figure 2 shows the internal circuitry of the TDA1563Q and a standard application circuit. The signal source (either balanced or unbalanced) is connected to IN+ and IN–. The manner in which an unbalanced (asymmetric) signal source is connected is shown in the upper diagram. The inverting input is tied to ground via a capacitor. The connections shown for the other channel are suitable for a balanced signal source. The resistors labelled 'R$_S$' simply represent the internal resistances of the signal sources. Since the combination

of the internal resistance and the capacitor forms a high-pass filter, R_S is only of interest for calculating the lower cut-off frequency. The audio signal is applied to two amplifier stages that generate mutually inverted signals. One loudspeaker terminal is always connected to one of the output stages, while the other terminal is switched between the other output stage (for bridge operation) and the CSE (single-ended) pin by the Slave Control block. The CSE pin is held at half of the supply voltage level by a reference voltage source buffered by a 1000 µF electrolytic capacitor. An additional opamp, whose inputs are connected to the loudspeaker outputs, prevents dc offset voltages from appearing at the loudspeaker outputs.

Protection and diagnosis

That's enough for now on the subject of signal handling. The TDA1563Q, like many car audio output stages, also has a number of diagnostic and protection functions.

– **Thermal protection**. If the die temperature of the TDA1563Q rises above 150 °C, the output power is automatically limited to 5 W per channel.

– **Short circuit protection**. The amplifier is protected against short-circuiting of the outputs to ground, the positive supply voltage and each other. In case of a long-term short circuit to a supply voltage, the output stages are switched off for the duration; in case of a short-circuited loudspeaker the output stages switch alternately on and off. The 'on' time is short enough to avoid excessive power dissipation.

– The TDA1563Q has **three operating modes**, namely the Standby mode with a current consumption of less than 50 µA, the Mute mode (audio signal interrupted at the amplifier input) and the normal operating mode (On). The voltage applied to pin 6 (MUTE) determines the operating mode:

    < 1 V: Standby
    2–3 V: Mute
    > 4 V: On

If an audio signal is present, an integrated zero-crossing detector prevents switching from Mute to On or from On to Mute at any time other than a zero crossing. This prevents 'plopping' when switching modes. However, if the supply voltage drops below 6 V (for example, when starting the motor), the IC immediately switches to the Mute mode.

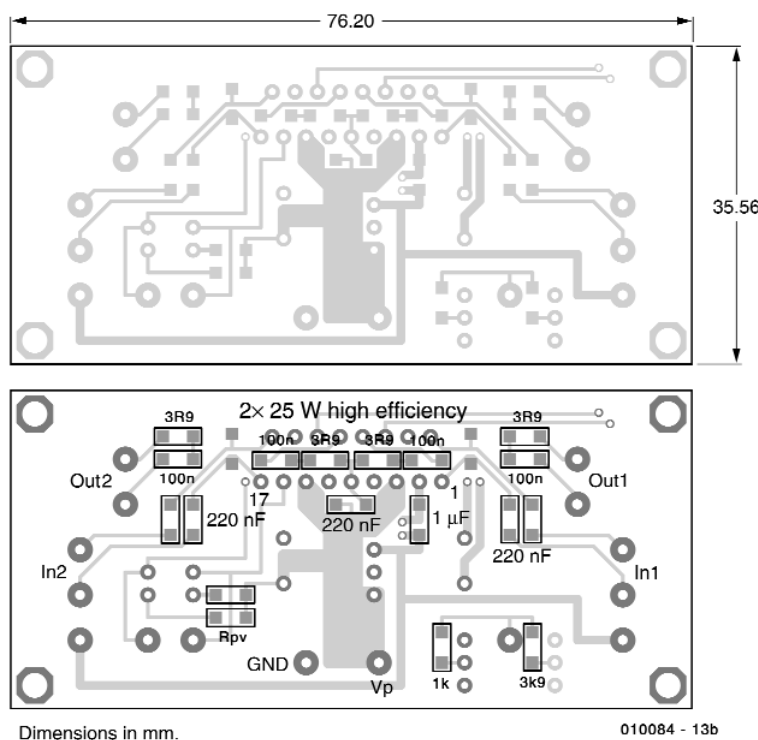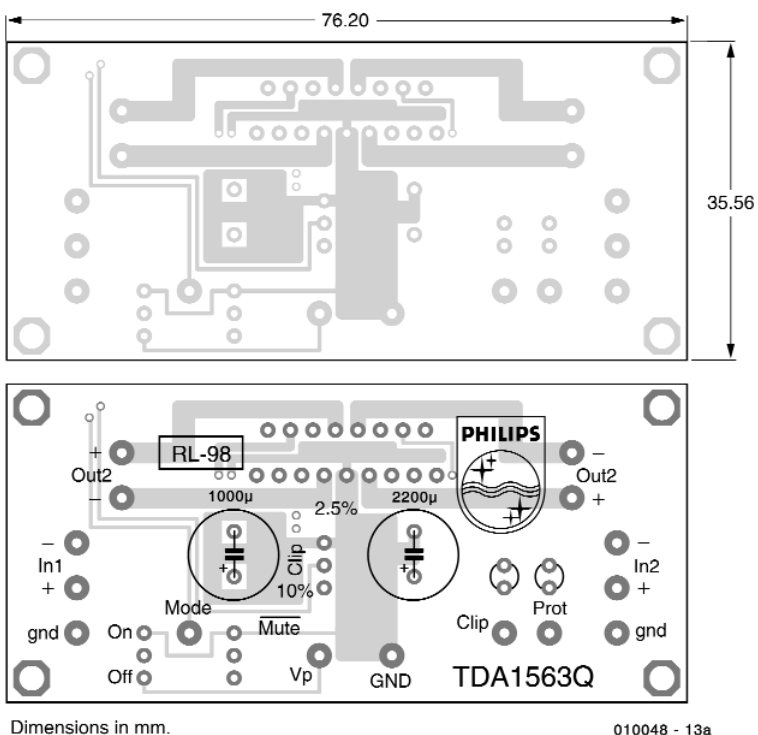– The TDA1563Q has **two diagnostic outputs**. Both pins are open-collector outputs and

require pull-up resistors. The CLIP output is Low when the THD figure is greater than 2.5% (if the SC input voltage is between 1.8 and 18 V) or 10% (if the SC voltage is less than 0.5 V).
The second output (DIAG) is Low

when a short circuit is present, for the duration of automatic muting while the IC is being switched on or off and if the temperature warning threshold of 145 °C has been reached (at 150 °C, bridge mode operation is disabled).

Figure 3. This printed circuit board can be use for more than just experimenting!

Application example

Figure 3 shows the layout of a double-sided circuit board for the application circuit shown in Figure 2. The layout comes from the Philips data sheet. Except for the two electrolytic capacitors, all components are SMD types, which not only saves space in the radio bay but also reduces sensitivity to interference. Nevertheless, fitting the components is not partic-

ularly difficult. Be careful not to overlook the through connections! No values are given for the two resistors R_{PU} connected to the diagnostic outputs. These values must be chosen according to the logic voltage used and can be easily calculated from the fact that the current sunk by an active output is 2 mA.

The operating mode is controlled by two switches (On/Off and /Mute). The component values for the volt-

age divider are selected to apply a suitable voltage to pin 6 for each mode.

Due to its compact construction, this application example is suitable for use in active car sound systems, in which each loudspeaker needs its own amplifier. The TDA1563Q forms an ideal match for an efficient loudspeaker (such as a horn), and such a combination can be operated all day from a car battery without any charging current from the motor.

(010084-1)

PC Dot Matrix Display

a minimal user interface

By B. Oehlerking and P. Cohrs

In situations where a PC is used as a dedicated controller the user-interface can often be simplified. Just a few input buttons together with this neat alphanumeric display may be all that is necessary…

The relative low-cost and versatility of today's Personal Computer (PC) and the proliferation of programming tools means that its increasingly more common to find PC's or just PC boards used as the control element in a dedicated application. Whether it is an MP3 player or an industrial controller it is often unnecessary or impractical to use a CRT monitor or LCD panel to display status information. The HIDs (Human Interface Device) for some applications need consist of little more than a few pushbuttons to input and LEDs to output information.
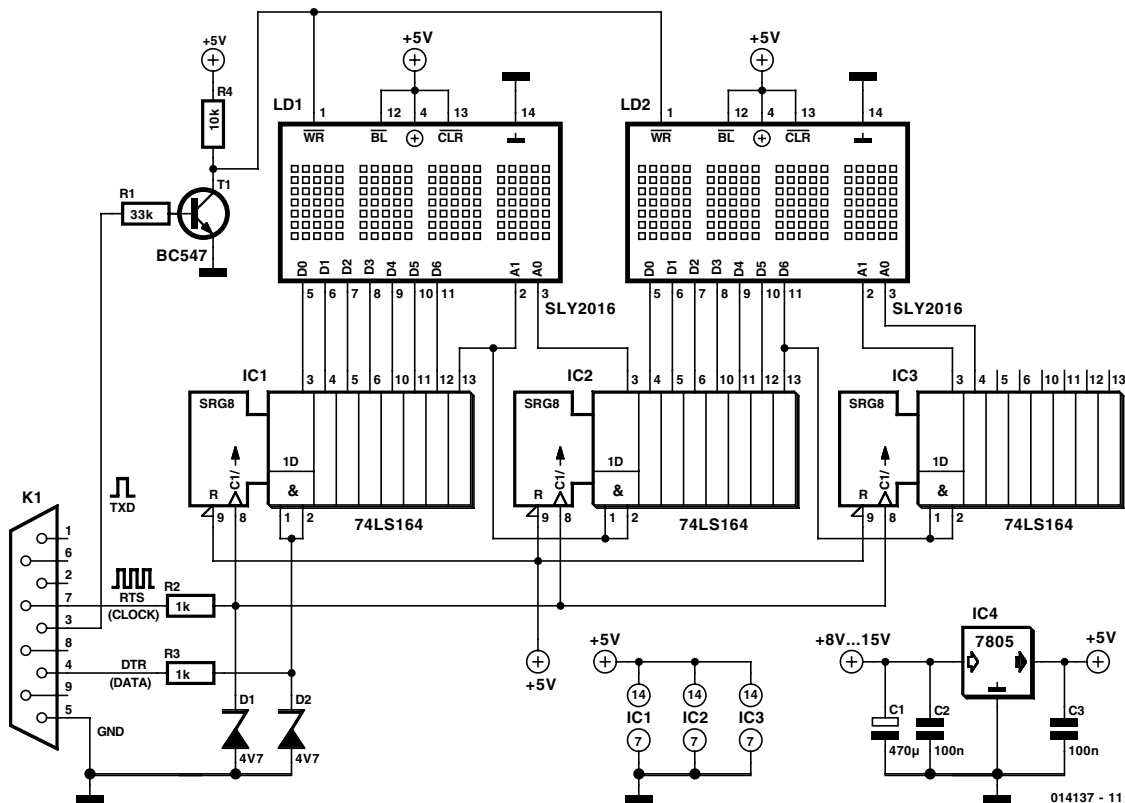

Figure 1. The circuit diagram.

Display 2

POS 3   POS 2   POS 1   POS 0

D0 D1 D2 D3 D4 D5 D6   A1 A2

0 1 0 0 0 0 1   0 0

"B" POS 0

Display 1

POS 3   POS 2   POS 1   POS 0

D0 D1 D2 D3 D4 D5 D6   A1 A2

1 1 0 0 0 0 1   0 1
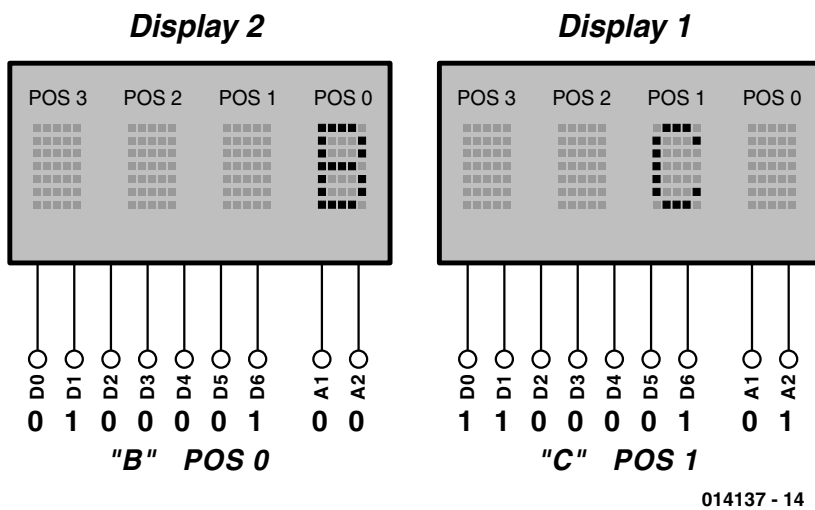
"C" POS 1

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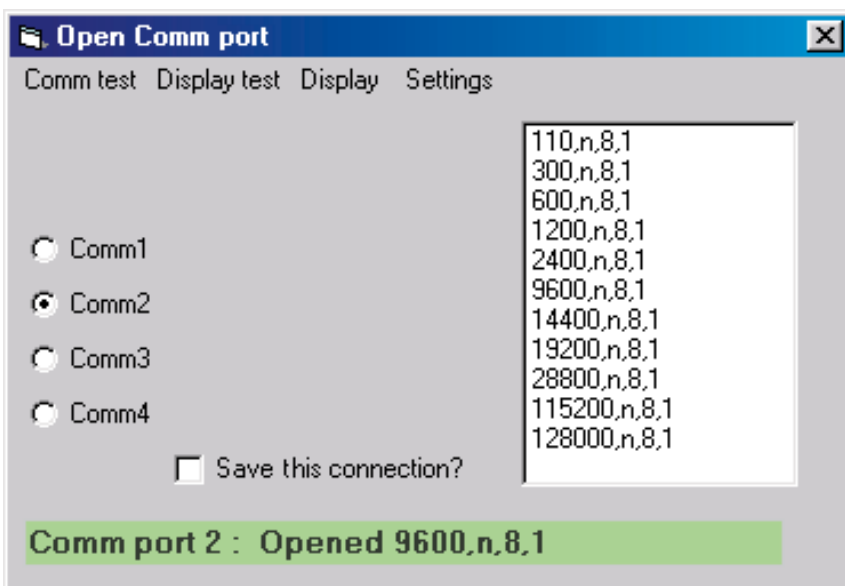Figure 2. Addressing the displays.

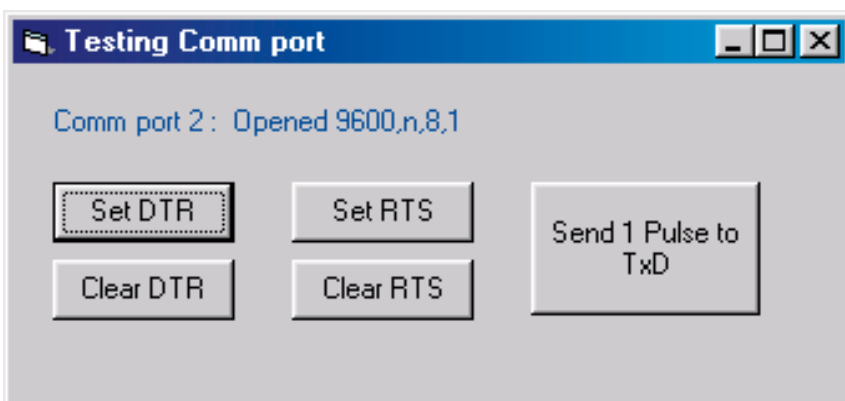Figure 3 Port initialisation using the Start module.

Figure 4. Interface test module.

This project describes a simple and economic display solution. A small alphanumeric dot matrix display connecting to the serial COM port of a PC provides a versatile display ideal for many applications. Some typical uses would include:

– Selecting parameters in an embedded application.

– Displaying operating conditions of the PCs processor (CPU clock speed, temperature and Loading etc). The display functions even when the PC monitor is switched off.

– Displaying measurements, counter values date and time or alarm information.

Visual BASIC is used to program the display. The display is connected to a PC using only three signals lines of the serial COM port so that no connection to the PC internals is necessary The display together with the small amount of circuitry can be fitted neatly into a plastic front panel with little difficulty.

The hardware

The display device for this circuit is a four-position LED dot matrix from Siemens (type SLx2016). Each display position consists of a matrix of 7x5 LEDs. The displays are horizontally or vertically stackable. Software enables longer text strings to be displayed in a running text format on the eight-display positions. Software also allows the text speed to be altered from a leisurely jog to a gallop and variably delayed before repeating. The SLx2016 is available in four different display colours. A paragraph giving the most important technical specs on the display accompanies this article.

Figure 1 shows the dot matrix display circuit diagram On-board voltage is regulated to +5 V by IC4. An external mains adapter supplying an output between 8 V to 15 V will be suitable. Each of the digital ICs has a of 0.1 µF capacitor fitted to its supply rails to decouple supply noise. Zener diodes D1 and D2 ensure that the voltage of the serial port signals is kept below Vcc. The displays specified for this circuit are available in red, high efficiency red, green and amber. The displayed characters have good visibility even in conditions of high ambient light and have a much better viewing angle than LCDs.

The SLx2016 has a built-in character generator addressable by seven input signals D0 to D6 allowing up to 2^7 or 128 possible characters to be selected by entering a value in the range from 0 to 127. Two address input

Dot matrix display SLx2016

The SLR/SLO/SLG/SLY2016 is a four-digit alphanumeric display with built-in CMOS drivers and decoder circuitry. It is vertically and horizontally stackable (X/Y stackable) and contains an ASCII-Decoder with 128 symbols, a multipexer and LED drivers. The binary code on address pins A1 and A2 selects which of the four display positions the character will be written to. The chip has a total of 14 pins.

Each display position is addressed individually and retains the code that was loaded last until it is overwritten by a new value. The loading process is asynchronous so it can be used by both fast and slow systems. The address and data values must be stable at the input pins before the $\overline{WR}$ signal is pulsed low. The value of the two address bits is latched in on the falling edge of the WR signal while the rising edge latches in the data.

The layout of this display also allows it to be simply mapped to the address space of a processor. Several displays could be stacked together to form a larger display. In this case the data inputs of all the displays are connected in parallel and all the $\overline{WR}$ signals are connected together, this leaves the two address lines to be used for decoding so that the display becomes a write-only area in processor memory.

The $\overline{CLR}$ input can be pulsed low to clear all the stored values and a low on the blanking input $\overline{BL}$ turns the display drivers off without losing the stored data. A pulse-width modulated signal on this pin will control display brightness. Both features are not used in this project so these inputs are tied high.

The built-in character generator uses standard ASCII codes for alphabetic, numeric and punctuation characters but uses all the codes from 00 to 1F (normally non-printing control codes in ASCII) for special characters found in the English, German, Italian, Swedish, Norwegian and Danish languages. The display colour is available in red, high efficiency red, green and amber.


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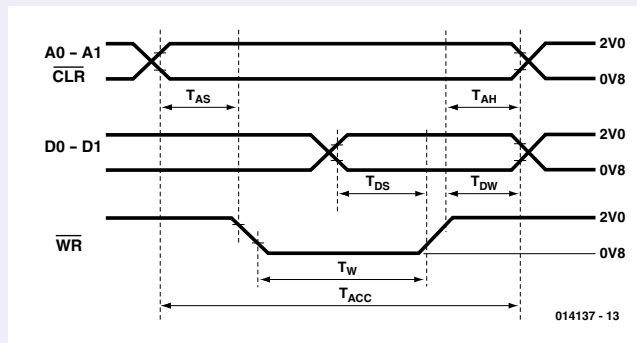
Technical specification:

– Vcc operating voltage:	4.5 V to 5.5 V
– Maximum input voltage with respect to ground (all inputs)	–0.5 to Vcc + 0.5 V
– Storage temperature:	–40 to +85 °C
– Peak Optical wavelength:	

	Red R	660 nm typ
	Red O (high efficiency)	635 nm typ
	Green G	565 nm typ
	Yellow Y	585 nm typ

Pin outs:

1 $\overline{WR}$ Write
2 A1 Digit Select
3 A0 Digit Select
4 VCC
5 D0 Data
6 D1 Data
7 D2 Data
8 D3 Data
9 D4 Data
10 D5 Data
11 D6 Data
12 $\overline{BL}$ Display Blank
13 $\overline{CLR}$ Clear
14 GND

Package Dimensions in mm

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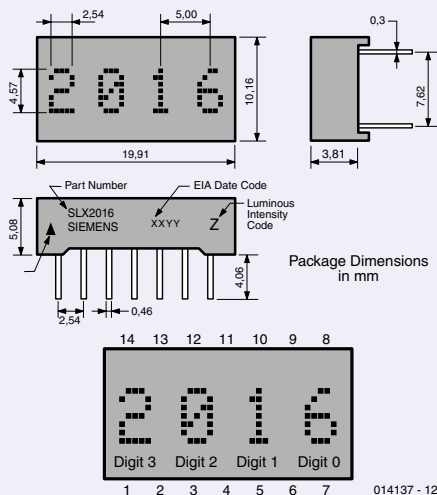
signals A0 and A1 select which of the four positions the character will be displayed in. A short pulse on the $\overline{WR}$ input will load the new values of data and address into LD1 and LD2 where they will remain until they are overwritten.

Data to the displays is sent serially over the COM serial port of a PC. Two shift registers type 74LS164 with a serial input are needed to store the control data for one four-position display and three are used for the two displays used here.

An Example

One worked example can often save a half an hour's head scratching. So let's assume that we need to display a capital B in the fifth character position from the right of the display as shown in **Figure 2**. A capital C is already displayed in the second position from the right and should remain after loading the B. The C is in position 1 of display 1 while the B is in position 0 of display 2. The three shift registers IC1, IC2 and IC3 must be loaded with the bit combination shown at the inputs to the displays. The software looks at the bit value furthest to the right and will correspondingly set or reset the DTR port signal (used here as data output). Next it will generate a shift pulse on the RTS signal to latch the data into the first position of the shift register chain. The next data values will now be treated identically until after 18 shift pulses all of the data will be in the correct position. Now a short pulse on the TXD port signal will cause this new data to be loaded and displayed on LD1 and LD2.

The Software

The software for this project is available as a free download from the *Elektor Electronics* website. The number is **014137-11**. Visual BASIC 5.0 was used to write the software and it has been tested under Windows 98 and NT 4.0. The software comprises four modules:

– A start form to open a serial COM port.

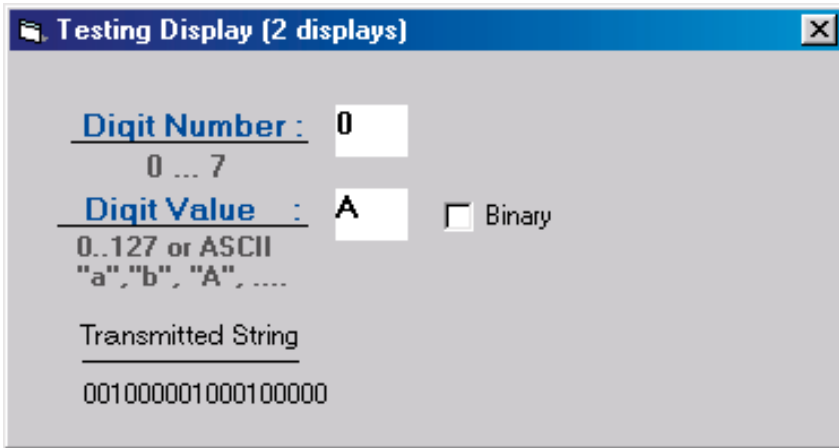– An interface testing form to test the selected port.

Figure 5. Display test module.

– A form to input and control the running text.

– A form to send individual characters to the display hardware.

The start module shown in **Figure 3** enables selection of the serial communication port (Com1 to Com4) and its operating parameters or settings. Ticking 'Save this connection?' will save the interface setup to *c:\comm-port.txt*. Any subsequent re-start of the program will automatically load the last saved configuration. With changes to the menu this module could be adapted for use in other applications that need to configure a serial port.

From the start module a 'Comtest' option can be selected (**Figure 4**). This module displays the actual port configuration set up in the previous module and also allows the signals of the serial port to be tested. The TXD line can be pulsed and the DTR and RTS line can be set high or low. This module needs the 'mod_test-comm.bas' BASIC module in order to function correctly.

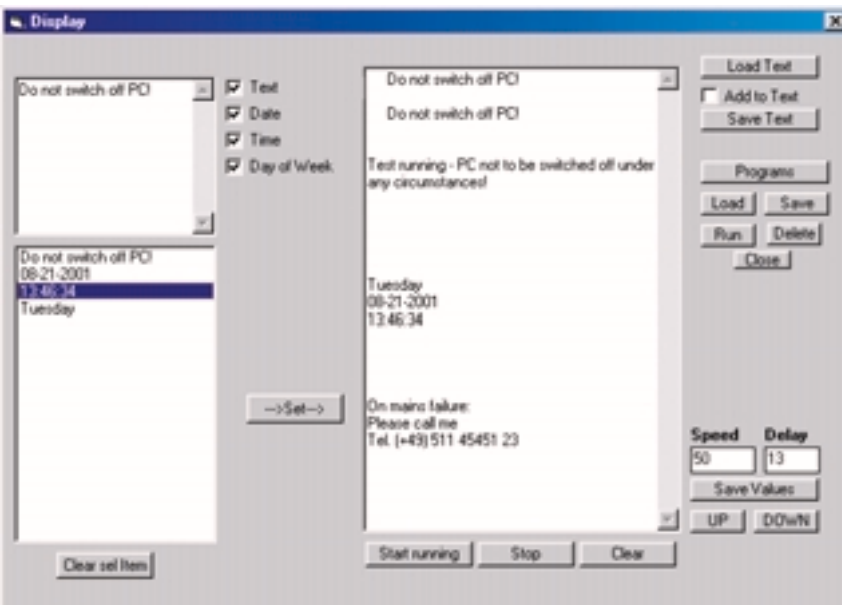Another option from the start module is to check the display with the 'Display test' option (**Figure 5**). This module allows you to position any character or symbol directly on the display. The digit number defines the position while the digit value selects a symbol from the character generator in the display. Entering a value from 0 to 127 will display the corresponding ASCII character. The Basic modules 'mod_testcomm.bas' and 'displ2.bas' are required for this module.

Lastly the start module option 'Display' (**Figure 6**) enables running text messages to be entered. 'Display' comprises three windows. At top left is a small text box, below it is a list box and to the right a large text box showing the message that will be sent to the display. The small text box allows messages to be entered while the list box lists the message together with the standard texts selected by the check boxes. These check boxes have been implemented as an array so it should be relatively easy to modify the source code for your own applications. The Set button transfers the message into the large text box. Along the right hand side of the screen are a series of buttons that perform the following functions:

– Loading, storing and adding text to messages.

– Loading and saving programs in another list box.

– Running the selected program (e.g. to output information for the text box).

– Adjustment of the running text speed and delay before repeating.

– Saving the speed and delay values.

– And finally starting and stopping the running text.

Electromail (*www.rswww.com*) stock the red and green versions of the dot matrix display (SLR2016 and SLG2016 respectively). The quoted price of almost £20 per display seems a tad expensive and might make you think that a cheaper version could be built using simpler single dot matrix displays together with a little additional hardware. Think again! a comparable dot matrix display costs in the region of £2 to £3 per character, multiplying this by four and adding the necessary LED drivers and multiplex circuitry together with the data latches and character generator the final design would not work out any cheaper. The finished product would certainly not be as neat as the design presented here.

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Figure 6. The running text window.

DMX 512

protocol, software and interfaces

By Harry Baggen

In recent issues we have regularly devoted attention to the DMX-512 system. Several construction projects have already been published, and more are sure to follow. An enormous number of companies that make or sell commercial DMX products can be found on the Internet. For the DIYer, though, there are not all that many DMX projects. However, there are still a few interesting designs and informative sites to be found.

The DMX standard was originally intended to be used for theatre lighting systems. In the meantime, the possibilities of the system and the available equipment have been extended to the point that it can be used for much more than just controlling lights at a distance. Of course, this is not news to regular readers of *Elektor Electronics*, since we already published an article about the protocol in the May issue of this year. Naturally, there is a lot more that can be said about the DMX protocol than what we presented in a few pages in that issue.

The full DMX standard is published by the **USITT** (United States Institute for Theatre Technology). The complete version of the standard is available in printed form, but only portions are available on the Internet. However, information and news of the latest developments are provided by the USITT web site [1]. To order the DMX standard in Europe, contact the **PLASA** (Professional Lighting and Sound Association) [2].

Besides these official sources, there are various sites maintained by DMX users and fans that provide useful information about the protocol. Although this information is never complete, most users probably do not need to know everything. We have searched out a few interesting sites in several different languages. At **DMX512.COM** [3] and **The anatomy of DMX512** [4] the language is English, at **Soundlight** [5] it's German and at **Ressources Techniques** [6] it's French.

A site that addresses all aspects of DMX is **Ujjal's DMX512 Website** [7]. This extensive

site is very practically arranged and also deals with DMX problems. In addition, there is a large collection of links related to DMX, including all known manufacturers of DMX equipment. Furthermore, there is a download section for DMX software and hardware.

There are also several DMX FAQs available on the Internet. Most of these are obviously not particularly current. For example, we found three

addresses having the same FAQ list, with only the revision date being different — and all around five years old! One FAQ site we should mention is **DMX512 mini-FAQ** [8], since the contents are still quite useful in spite of their age (they deal primarily with basic issues).

If you want to start working with DMX hardware and software, you will need to know not only the organisation the protocol, but also the

and the schematic diagram and hex code file for a 12-button DMX flasher.

The **Electronic Projects** pages of Christian Mohr [13] contain various attractive electronics projects. Two DMX projects that are currently under development are a PC/DMX interface and a DMX receiver.

At the site of another DMX-512 fan, Adam Davis, you can find a description of a small DMX controller implemented using a PC [14]. This is also still in the experimental stage, but it should be interesting to keep an eye on how it develops.

LPR2DMX [15] is a very small printer interface for the PC that supports DMX-512 communications. This interface can be controlled using a Linux driver that can be found under the name of **DMX4Linux** at the Cubic site [16]. This driver supports several other (commercial) DMX interfaces in addition to the LPR2DMX.

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codes to which the equipment from various manufacturers responds. Information on this subject is certainly available. There are two important summaries: the ESTA has a page with **DMX Usage Data** [9], and a **DMX Protocol Library** [10] is available from Interactive Technologies.

Hardware and software developments can be found only sporadically on the Internet, but they will probably become more frequent with the increasing popularity of DMX for hobby applications.

In particular, linking a PC with a DMX-512 system appears to interest many designers. For example, there is an **AVR DMX-512 dongle** for PCs [11]. This is a small interface build around an AVR microcontroller and an RS-485 transceiver IC. The circuit is connected to the printer port of the PC. The associated software is written in C. The author makes both the hardware and the software available for download from his site.

Another printer port interface is available at **Kristof's Webpage** [12]. The schematic diagrams and hex code files can be downloaded free of charge. Here you will also find the schematic diagram of a DMX booster

Internet addresses

[1] USITT:
www.usitt.org/DMX/DMX512.htm
[2] PLASA:
www.plasa.org
[3] DMX512.COM:
www.dmx512.com/web/light/dmx512/index.htm
[4] The anatomy of DMX512:
www.euro-pa.be/dmx.html
[5] Soundlight:
www.soundlight.de/techtips/dmx512/dmx512.htm
[6] Ressources Techniques:
http://ogloton.free.fr/dmx_512/presentation.html
[7] Ujjal's DMX512 Website:
www.geocities.com/dmxpage/
[8] DMX512 mini-FAQ:
www.lightresource.com/dmx512fq.html
[9] DMX Usage Data:
www.esta.org/tsc_dmx_data/dmx-cat.htm
[10] DMX Protocol Library:
www.interactive-online.com/library/
[11] AVR DMX-512 dongle for PC's:
www.ele.tut.fi/~viikari
[12] Kristof's Webpage:
http://users.skynet.be/kristofnys/
[13] Electronic Projects:
www.hb.se/cmo/projekt/default.htm
[14] Adam Davis:
www.ubasics.com/adam/electronics/dmx512.shtml
[15] LPR2DMX:
www.lighting-solutions.de/products/LPR2DMX/index.html
[16] DMX4Linux:
http://llg.cubic.org/dmx4linux/