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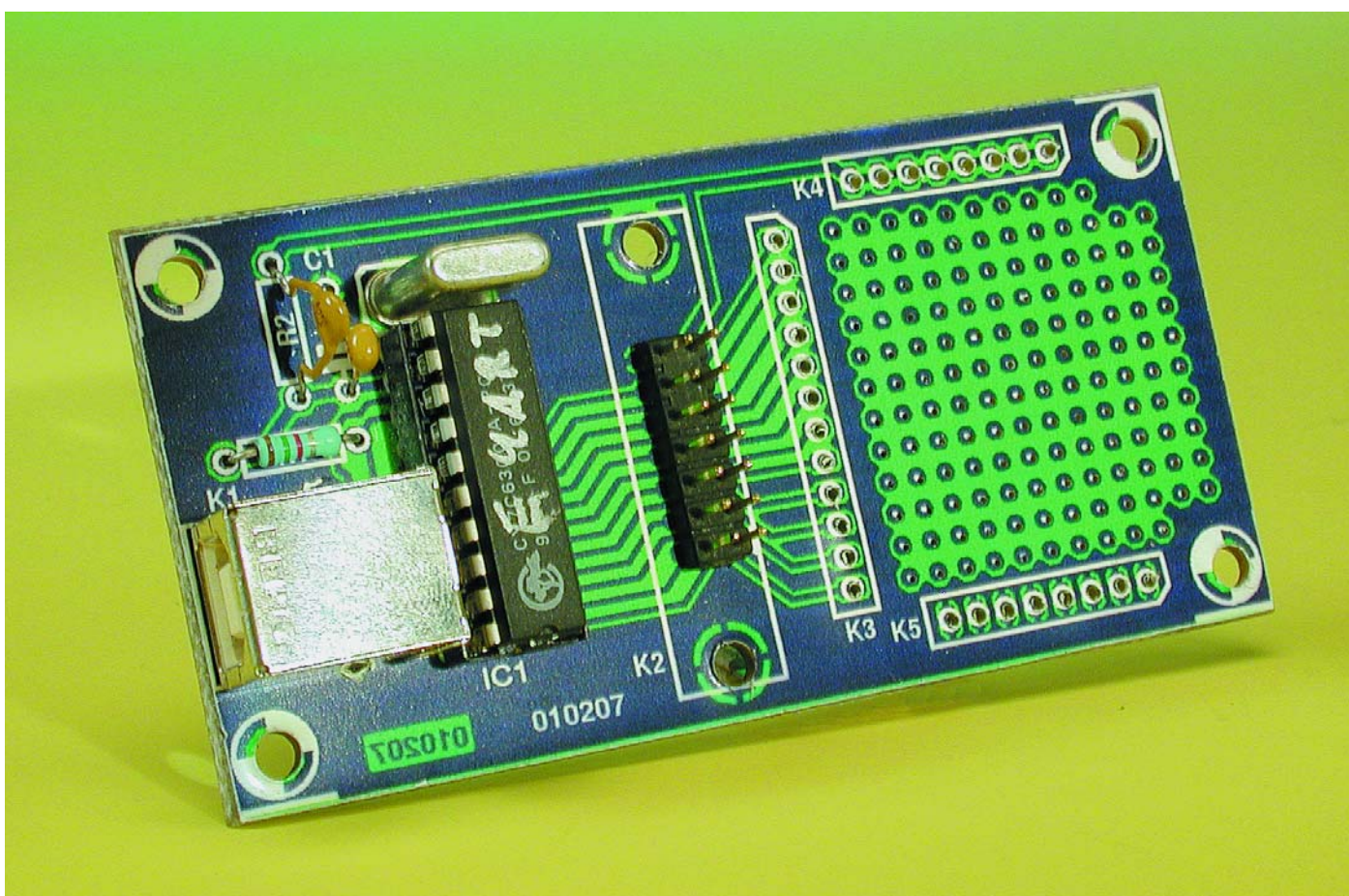
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USB UART (1)

allowing access to all ports

Design by B. Kainka

USB ports can be used in many applications in the field of electronics. However, unlike the RS232 interface, devices have not become available to interconnect USB and parallel ports. This general-purpose USB UART now rectifies that situation.

Just as the legendary AY-3-1015 UART converts between parallel and RS232 interfaces, this *Elektor Electronics* USB chip provides general-purpose ports accessible over USB. The only extra components required to build a complete USB device are a ceramic resonator or quartz crystal and a couple of capacitors. In total twelve port connections are available, which can freely be written and read. Further, the output current can be set for each port connection, which allows, for example, the brightness of a connected LED to be controlled directly.

In the case of the RS232 interface we are accustomed to only having a limited number of ports. Frequently only one COM port will be available.
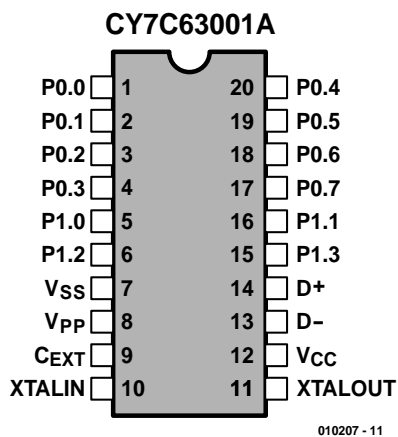
CY7C63001A

P0.0	1	20	P0.4
P0.1	2	19	P0.5
P0.2	3	18	P0.6
P0.3	4	17	P0.7
P1.0	5	16	P1.1
P1.2	6	15	P1.3
V$_{SS}$	7	14	D+
V$_{PP}$	8	13	D–
C$_{EXT}$	9	12	V$_{CC}$
XTALIN	10	11	XTALOUT

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Figure 1. Pinout of the USB port IC.

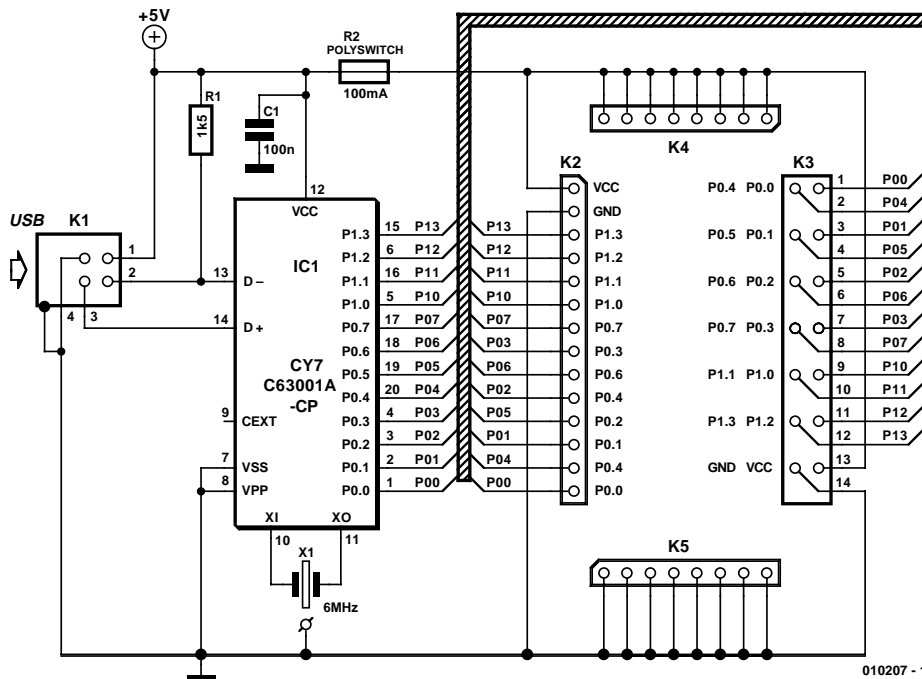|	
Vss, Vpp	Ground
Vcc	+5 V
D+, D-	USB data signals
XTALIN, XTALOUT	6 MHz ceramic resonator or quartz crystal
P0.0-P0.7	port 0 (8 pins)
P1.0-P1.3	port 1 (4 pins)

Figure 2. The prototyping board includes just the basic CY7C63001 application circuit.

If a device uses this port, then it is permanently assigned and further expansion is not a simple matter. In contrast USB is a bus-based system which in principle allows many devices to be connected. Whether multiple devices of the same type can be connected depends on the device driver: the driver for our USB UART does support multiple device instances. It is therefore possible, if desired, to build several devices using this chip and use them together on one PC. In general there will be two USB connectors on the motherboard. If more are required, a bus splitter (or 'hub') must be added.

As in the first *Elektor Electronics* USB interface (described in the September 2000 issue), the device is based on the Cypress CY7C63001A microcontroller, whose pinout is shown in **Figure 1**. Since in this case no special peripheral components are being connected, all port pins are available for use. Further, the sink current can be controlled for all ports, rather than just on one.

The IC is supplied with a special USB driver. For this purpose, *Elektor Electronics* has become a USB developer and has obtained a 'Vendor ID' from the USB organisation. This ensures that the connected devices are correctly enumerated and that the *Elektor Electronics* USB driver is automatically loaded. The advantage is that *Elektor Electronics* readers can develop their own USB devices without having to obtain their own Vendor ID and without getting heavily involved in the complex details of the interface.

Figure 2 shows the standard circuit using the USB UART. Observe the direct connection to the USB D+ and D– signals. In many cases power (+5 V) can be drawn directly from the bus. To provide a clock, a two-pin ceramic resonator or a quartz crystal can be used, although thanks to a third hole in the circuit board the more readily obtainable three-pin parts can be used instead. The internal capacitors should not be connected to ground (as would be usual practice) – they effectively form an extra parallel capacitance. With the -A version of the processor the internal oscillator has become
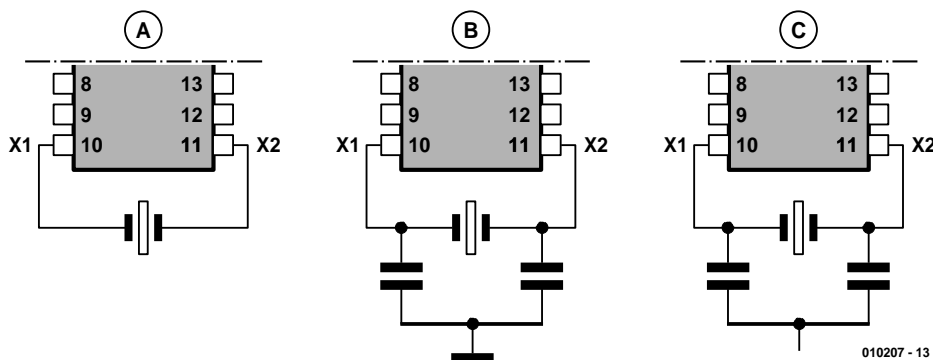

Figure 3. Oscillator options (6 MHz)
A: Crystal or two-pin ceramic resonator
B: Three-pin ceramic resonator with ground connection
C: Three-pin ceramic resonator without ground connection

COMPONENTS LIST

Resistors:
R1 = 1kΩ5
R2 = Polyswitch, 100mA

Capacitors:
C1 = 100nF

Semiconductors:
IC1 = CY7C63001A (Cypress), pro-
    grammed, order code **010207-41**

Miscellaneous:
K1 = USB connector Type B
K2 = 14-way boxheader
K3,K4,K5 = 20 solder pins
X1 = 6MHz quartz crystal or
    ceramic resonator with 2 or 3 pins
PCB, order code **010207-1**
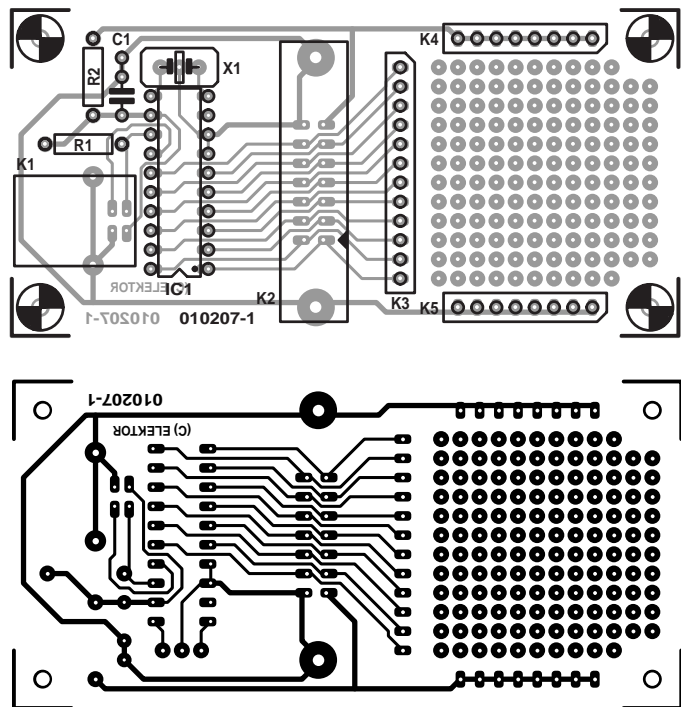Disk, project software,
    order code **010207-11**

Figure 4. Component layout and mounting plan for the prototyping board.

much more reliable, and it is possible to fit a 6 MHz crystal. **Figure 3** shows the three possible oscillator configurations.

All ports have internal pull-up resistors. They are set high on reset and can be used immediately as inputs. Port 0 and port 1 offer different sink currents. Whereas port 0 can switch at most 1.5 mA, port 1 can switch up to 15 mA, enough, for example, to allow LEDs to be connected directly.

The USB UART is an integrated circuit for special applications. Perhaps it could be used to control a coffee machine, or perhaps built into an alarm system. Or a number of chips could be used to control a model railway or a robot. In any of these applications, a little more is required than just the chip and the basic circuit. For our first experiments, then, we present a prototyping board on which all the port connections are brought out to connectors. The tiny circuit board shown in **Figure 4** can also be piggybacked onto a larger assembly and can then function as a universal I/O module.

Installation

Using a USB device under Windows inevitably requires a driver, which allows the USB UART to be seen as a device in its own right. All access to the device by application software takes place via the driver.

The diskette includes the driver USBuart.sys and an information file USBuart.inf, as well as a couple of example programs. Windows reads the device type, copies the required driver and adds it to its database of device drivers. The diskette is only required the first time the device is connected; subsequently the driver is automatically loaded whenever the chip is connected to the USB.

Whenever a new USB device is connected for the first time, the message shown in **Figure 5** appears. That a new device has been connected is detected through the resistor connected between V_{CC} and D–. The D– data signal is pulled high and this informs the PC that a low speed USB device has been connected. Next, Windows requests certain data from the new device. Particularly important are the Vendor ID (*Elektor Electronics* = 0C7D) and the device ID (USB UART = 0001) since they allow the device to be recognised unambiguously. Knowing these two numbers, Windows can now start to look for the appropriate driver. First it looks in its database of known drivers on the PC itself. If no suitable driver can be found here, the user is asked to insert a diskette containing the required driver information.

Installing the driver is simply a matter of following the instructions on the screen. The driver is automatically copied into the
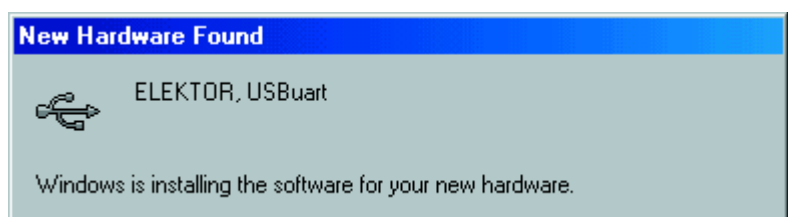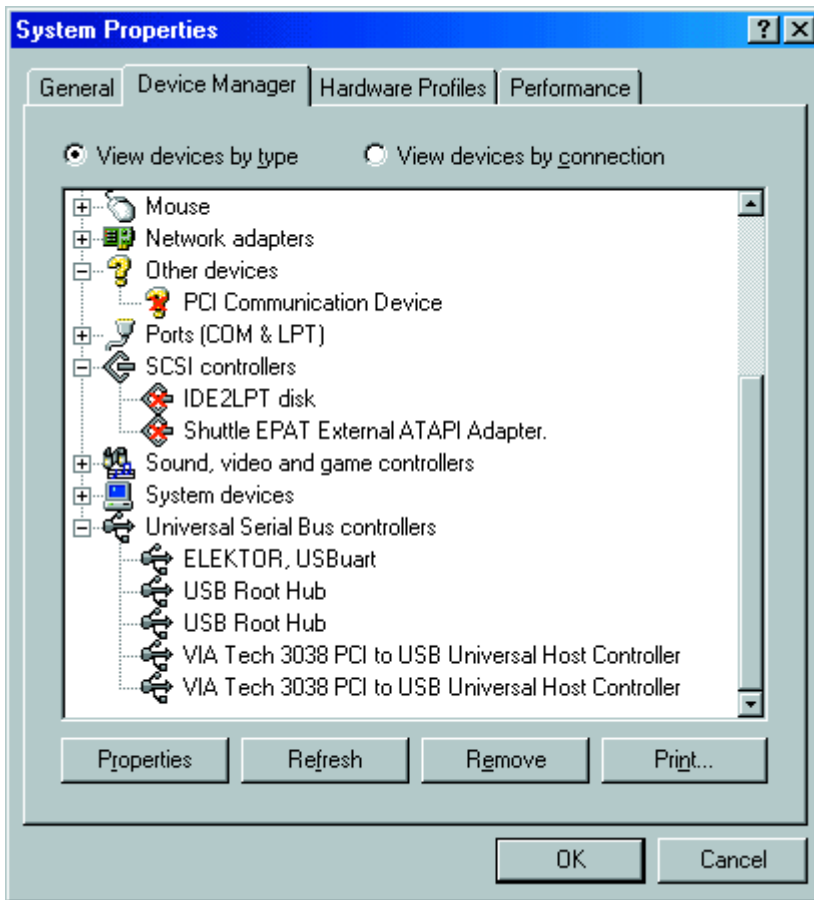
Figure 5. New hardware has been detected.

Figure 6. The Elektor Electronics driver has been loaded.

insisting on searching for the required files on the Windows installation CD (**Figure 7**): then it is necessary to enter the filename USBUART on drive A: and click on OK in order to proceed.

The driver also works under Windows 2000. However, it has no digital signature, which is a form of authorisation of tested software provided to large companies by Microsoft (in exchange for large sums of money). It is therefore necessary to indicate under `System Properties/Hardware/ Device Manager/Driver Signing` that the driver can be installed without a signature. Depending on how the system is set up, it is possible that Windows 2000 will not copy the driver into the proper directory. In such cases the driver should be manually copied into the `System32` directory. The driver used here is based largely on the software developed by Anchor Chips, now part of Cypress. The company provides detailed information on developing for USB on the Internet at www.cypress.com.

Controlling the Driver from Visual Basic

Each USB device requires a driver, which is automatically loaded when the device is connected ('Plug and Play' operation). Individual programs may only communicate with the device via the driver. In order that Windows can determine which driver is to be loaded, the device itself provides certain data during 'Enumeration' (the bus' registration procedure) to allow unambiguous identification. On start-up, Windows can therefore recognise the presence of a new device whose driver must be loaded.

Module **USB1.bas** shows how the driver can be controlled from Visual Basic. It provides the following basic functions:

WrPort0, WrPort1:   Write values to ports
RdPort0, RdPort1:   Read values from ports
WrPullups: Activate pull-up resistors
WrIsink: Set sink current for each port pin

The driver allows several devices to be used simultaneously with identical USB UARTs. The virtual driver name for the first device is:

    sFileName="\\.\usbuart_0"

and for the second device:

    sFileName="\\.\usbuart _1"

and so on.

`Windows/System32` directory, while the information file is copied to `Windows/Inf`. The driver is also loaded into the PC's memory. The result of all this can be seen under `Control Panel/System/Device Manager`: the USB driver is loaded

(**Figure 6**).

Usually installation proceeds without any problems. The number of different versions of Windows makes it difficult, however, to test for every eventuality. In some cases it might happen that Windows keeps
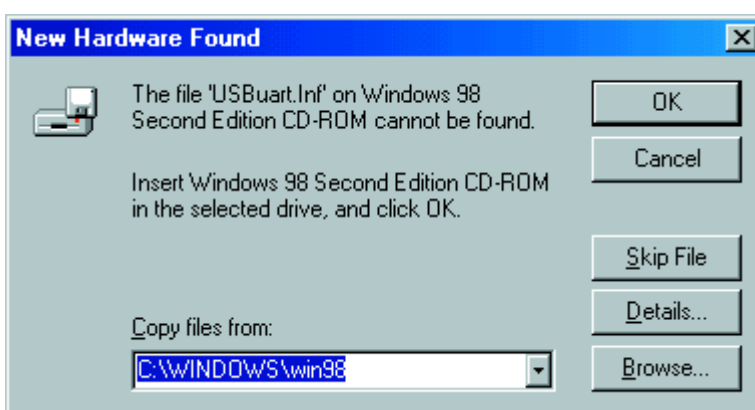

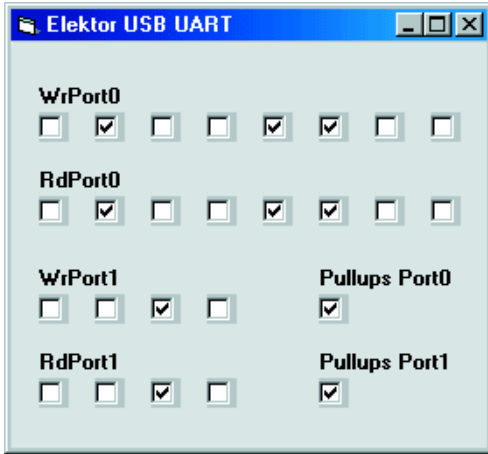Figure 7. Windows fails to find the appropriate driver.

Figure 8. Accessing the ports using Visual Basic.
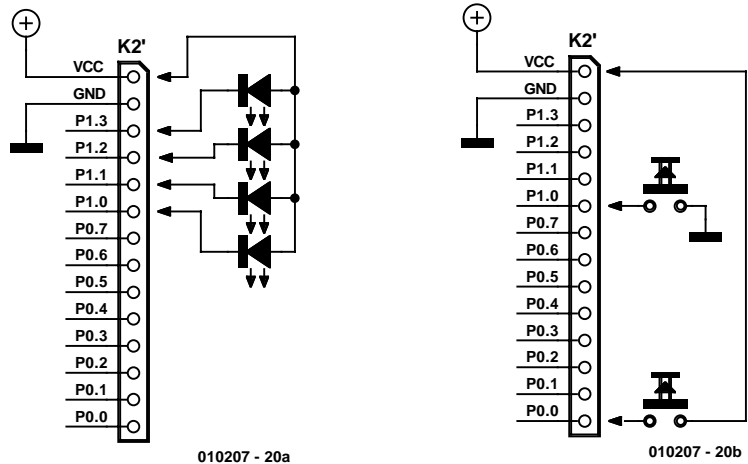
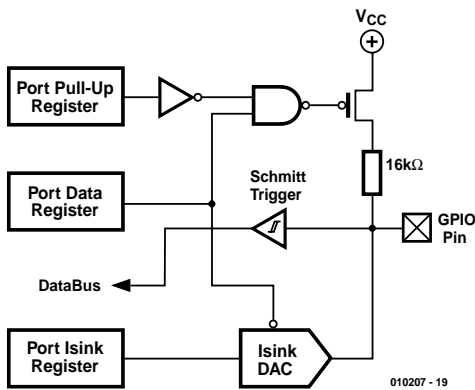

Figure 10. How switches and LEDs can be connected.

Figure 9. Internal structure of the port pins with adjustable current.

Connector pinouts

K1: USB socket

1	+5V
2	D-
3	D+
4	Gnd

K2:

P00	1	2	P04
P01	3	4	P05
P02	5	6	P06
P03	7	10	P11
P12	11	12	P13
Vcc	13	14	Gnd

K3:

1	P13
2	P12
3	P11
4	P10
5	P07
6	P03
7	P06
8	P02
9	P05
10	P01
11	P04
12	P00
K4	8 x Vcc
K5	8 x Gnd

Port Access: Reading and Writing

The first example program, **USBuart1.vbp** allows access to all the ports. With a simple click of the mouse, each signal can be set high, and the pull-up resistors can be enabled or disabled on a port-by-port basis. If no external circuit is connected, the output values are read back verbatim, as long as the pull-ups are enabled. If the pull-ups are disabled, then outputs set high are in a high-impedance state and their level is thus indeterminate. In contrast, a pin that is set low will, even with pull-ups disabled, be low.

Listing 1. The required interface procedures in the USB1.bas module.

```
Type SECURITY_ATTRIBUTES
nLength As Long
lpSecurityDescriptor As Long
bInheritHandle As Long
End Type

Type OVERLAPPED
 Internal As Long
 InternalHigh As Long
 offset As Long
 OffsetHigh As Long
 hEvent As Long
End Type
```

```
Declare Function CreateFile Lib "kernel32" Alias "CreateFileA" (ByVal lpFileName As String, ByVal dwDesiredAccess
As Long, ByVal dwShareMode As Long, lpSecurityAttributes As SECURITY_ATTRIBUTES, ByVal dwCreationDisposition As
Long, ByVal dwFlagsAndAttributes As Long, ByVal hTemplateFile As Long) As Long
Declare Function DeviceIoControl Lib "kernel32" (ByVal hDevice As Long, ByVal dwIoControlCode As Long, lpInBuffer
As Any, ByVal nInBufferSize As Long, lpOutBuffer As Any, ByVal nOutBufferSize As Long, lpBytesReturned As Long,
lpOverlapped As OVERLAPPED) As Long
Declare Function CloseHandle Lib "kernel32" (ByVal hObject As Long) As Long

Public Security As SECURITY_ATTRIBUTES
Public gOverlapped As OVERLAPPED
Public hgDrvrHnd As Long
Public Const GENERIC_READ = &H80000000
Public Const GENERIC_WRITE = &H40000000
Public Const FILE_SHARE_WRITE = &H2
Public Const FILE_SHARE_READ = &H1
Public Const OPEN_EXISTING = &H3

Dim sFileName As String
Dim htemp As Long
Dim lIn As Long, lInSize As Long, lOut As Long, lOutSize As Long, lSize As Long
Dim lTemp As Long

Public Sub USB_IO()
  sFileName = "\\.\usbuart_0"
  hgDrvrHnd = CreateFile(sFileName, GENERIC_WRITE Or GENERIC_READ, FILE_SHARE_WRITE Or FILE_SHARE_READ, Security,
OPEN_EXISTING, 0, 0)
  lTemp = DeviceIoControl(hgDrvrHnd, 4&, lIn, lInSize, lOut, lOutSize, lSize, gOverlapped)
  htemp = CloseHandle(hgDrvrHnd)
End Sub

Public Function RdPort0() As Integer
  lIn = 0 * 256 + 20
  lInSize = 2
  lOutSize = 2
  USB_IO
  RdPort0 = (lOut / 256) And 255
End Function

Public Function RdPort1() As Integer
  lIn = 1 * 256 + 20
  lInSize = 2
  lOutSize = 2
  USB_IO
  RdPort1 = (lOut / 256) And 255
End Function

Public Sub WrPort0(Wert)
  lIn = 65536 * Wert + 0 * 256 + 21
  lInSize = 3
  lOutSize = 1
  USB_IO
End Sub

Public Sub WrPort1(Wert)
  lIn = 65536 * Wert + 1 * 256 + 21
  lInSize = 3
  lOutSize = 1
  USB_IO
End Sub

Public Sub WrIsink(Pin, Wert)
  lIn = 65536 * Wert + Pin * 256 + 23
  lInSize = 3
  lOutSize = 1
  USB_IO
End Sub

Public Sub WrPullups(Port, Wert)
  lIn = 65536 * (255 - Wert) + (Port + 16) * 256 + 23
  lInSize = 3
  lOutSize = 1
  USB_IO
End Sub
```

The port connections of the microcontroller are quasi-bidirectional, similar to those of the 8051 microcontroller. A special feature is the adjustable sink current. LEDs can be driven directly and their current adjusted to suit their requirements (although a current of no more than 300 μA can be sourced). To this end, each port connection includes a simple D/A converter with a resolution of 4 bits. The sink current of each pin in port 0 can be adjusted from 0.3 mA to 1.5 mA, while for port 1 the adjustment range is from 4.8 mA to 15 mA. Both ports feature selectable 16 kΩ pull-up resistors. Both the sink current setting and the enabled/disabled state of the pull-up resistors can be controlled for each port over the USB.

The characteristics of the ports permit the following applications:

– High-impedance input port with the characteristics of a COM input

– Input port with 16 kΩ pull-up resistor

– CMOS-compatible output

– Open drain output for direct drive of LEDs etc.

– Adjustable sink current via 4 bit D/A converter

– Simple A/D converter with 4 bit resolution

Program USBuart1 allows more precise experimentation with the characteristics of the ports. Similar to the quasi-bidirectional ports of the 8051 microcontroller, the pins have active pull-downs in the form of FETs (**Figure 9**), which are active when the output value is zero. Normally he pull-down current is very low, only 0.3 mA for port 0 and 4.8 mA for port 1. On port 0 a 10 kΩ resistor to V_{CC} suffices to pull the output high against the will of the output transistor. A logic 1 will be read back, even though the pin is set to output a low level. In the second instalment of this series we will show how the sink current can be adjusted in steps.

These special features of the processor's ports allow switches to be connected to V_{CC}, using positive logic (**Figure 10**): this is the opposite of the usual convention. This is only recommended for use with port 0, as with port 1 the currents involved would be too high. Port 1 is suitable for direct connection of LEDs to V_{CC}, without requiring a series resistor. The current limit function is built into the port. The default current of 4.8 mA is enough to drive a bright LED. With port 0, only high-efficiency LEDs (requiring 1.5 mA) can be connected.

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In the second instalment in this series we will describe how to set the port current and give an example program: a simple A/D converter.

Listing 2.

Accessing the ports with `USBuart1.vbp`.

```
  If Check25.Value = 1 Then
    WrPullups 0, 255
  Else
    WrPullups 0, 0
  End If
End Sub

Private Sub Check26_Click()
  If Check25.Value = 1 Then
    WrPullups 1, 255
  Else
    WrPullups 1, 0
  End If
End Sub

Private Sub Form_Load()
  WrPullups 0, 255
  WrPullups 1, 255
End Sub

Private Sub Timer1_Timer()
  Dat = 0
  Dat = Dat + Check1.Value
  Dat = Dat + Check2.Value * 2
  Dat = Dat + Check3.Value * 4
  Dat = Dat + Check4.Value * 8
  Dat = Dat + Check5.Value * 16
  Dat = Dat + Check6.Value * 32
  Dat = Dat + Check7.Value * 64
  Dat = Dat + Check8.Value * 128
  WrPort0 Dat
  Dat = RdPort0()
  Check9.Value = Dat And 1
  Check10.Value = (Dat And 2) \ 2
  Check11.Value = (Dat And 4) \ 4
  Check12.Value = (Dat And 8) \ 8
  Check13.Value = (Dat And 16) \ 16
  Check14.Value = (Dat And 32) \ 32
  Check15.Value = (Dat And 64) \ 64
  Check16.Value = (Dat And 128) \ 128
  Dat = 0
  Dat = Dat + Check17.Value
  Dat = Dat + Check18.Value * 2
  Dat = Dat + Check19.Value * 4
  Dat = Dat + Check20.Value * 8
  WrPort1 Dat
  Dat = RdPort1()
  Check21.Value = Dat And 1
  Check22.Value = (Dat And 2) \ 2
  Check23.Value = (Dat And 4) \ 4
  Check24.Value = (Dat And 8) \ 8
End Sub
```

Educational hardware and software

89S8252 Flash Microcontroller Board

platform for the Microcontroller Basics course

Design by B. Kainka

A microcontroller board that serves as the foundation for a programming course must be easy to use while still having all the ingredients of a modern microcontroller with its peripherals. This makes such a board interesting for old microcontroller hands as well!
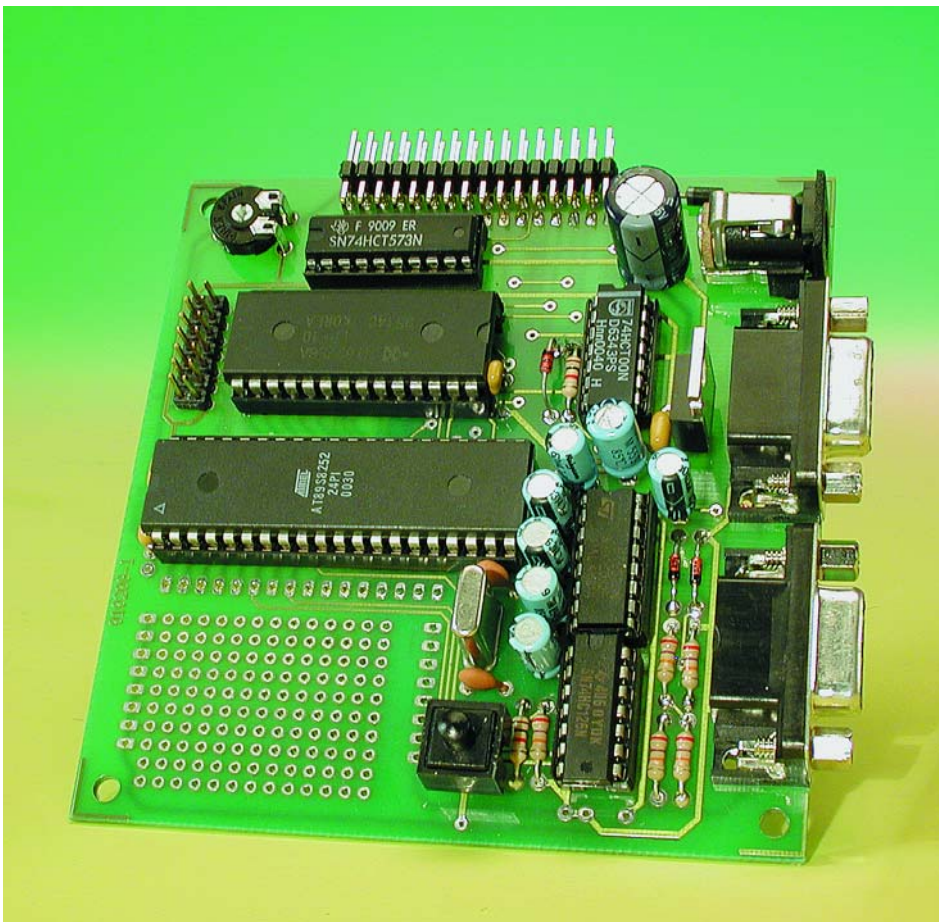
Anyone who wants to convert his own ideas into circuitry will usually achieve the desired result more quickly with a microcontroller than with 'conventional' electronics. However, in many cases the programming is relatively laborious. Consequently, *Elektor Electronics* have developed the new Flash Board. The flash program memory and a well-considered system design ensure easy and fast programming.

Our criteria for a new microcontroller board were based on the following objectives: the circuit to be developed should meet the needs of beginners as well as experienced users; the system should be designed from the start to handle various programming languages, including assembler, BASIC and C; and furthermore, the system should be easily extendible and easy to program. In addition, a program that has been transferred to the board should be retained when power is switched off, in order to avoid the tedious process of (re)programming EPROMs. This means that the board should also serve as a device programmer.

There are many different types of microcontrollers with internal EEP-ROM or flash memories, which in principle promise easy programmability. What should we choose — a PIC, a 68xxx-series microcontroller, an AVR or an extended 8051 device? The difficult question of which type of microcontroller to use was decided in favour of the 8051 family. There were good reasons for this choice. Most other types of microcontroller are only made by a single company, which in the worst case can make them difficult to obtain. The 8051 family, by contrast, can justifiably be regarded as an industry standard, since many different companies produce derivatives of the standard device originally developed by Intel. This means that if we have developed some kind of device and then at some point company A can no longer supply the part, we can easily switch to a microcontroller from company B or company C. Furthermore, there is an abundance of software for the 8051 family and a wealth of available literature. Consequently, if we choose the 8051 standard there is not very much that can go wrong. This is still true, even though new concepts have since been developed.

The Atmel AT89S8252 device that is used here (see **Figure 1**) corresponds to an 8052 in the essential areas. This means, for example, that the well-known BASIC-52 interpreter can be run on this IC without any problems. There are also a few additional features to gladden the developer's heart. For instance, there is an internal watchdog and a data EEP-ROM with a capacity of 2 kB. However, the decisive factor is the 8-kB program memory using flash technology. The programming circuitry for this memory is also contained in the IC. It is not even necessary to use a special programming voltage; the normal 5-V supply voltage is sufficient. Programming takes place serially and synchronously via an SPI interface. Only a few leads are needed to load a program into the internal flash memory area.

The board

The Flash Board adds 32 kB of RAM, an LCD interface, a serial interface and a programming interface to the basic microcontroller. In addition, there is a prototyping area on the board with 130 solder pads. Other extensions, ranging from simple motor drivers or sensors to complete interfaces, can thus be easily fitted onto the board. The full address and data bus and all of the ports are accessible via pin headers. Consequently, the system can be extended in practically any desired manner.

The printed circuit board has two DB9 sockets. One of these is used for communications via the serial interface. Like every other microcontroller in the 8051 family, the 89S8252 has an internal UART that can be connected via a MAX232 interface driver IC to a PC COM port (for example). What the PC does with this link – transmitting control commands to the microcontroller, querying measurement data or communicating with the internal Basic interpreter – depends entirely on the user and the software that is employed.

The second DB9 socket (COM2) is used exclusively for programming the microcontroller. A PC connected to this interface can

89S8252 Flash Micro board specifications

– 32 kB RAM
– 8 kB Flash program memory
– 2 kB EEPROM data memory
– internal watchdog timer
– serial interface
– programming interface
– supply voltage: 9–12V, on-board 5-V voltage regulator
– LCD interface
– all bus lines brought out to pin headers
– all port leads brought out to pin headers
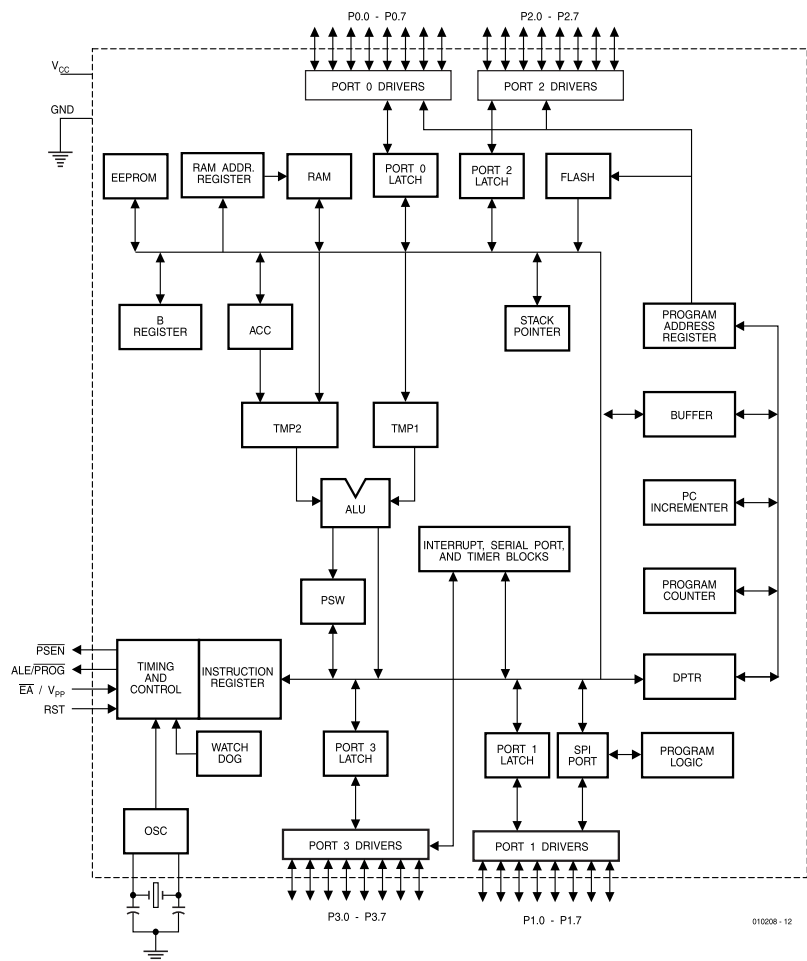– prototyping area for extension circuits

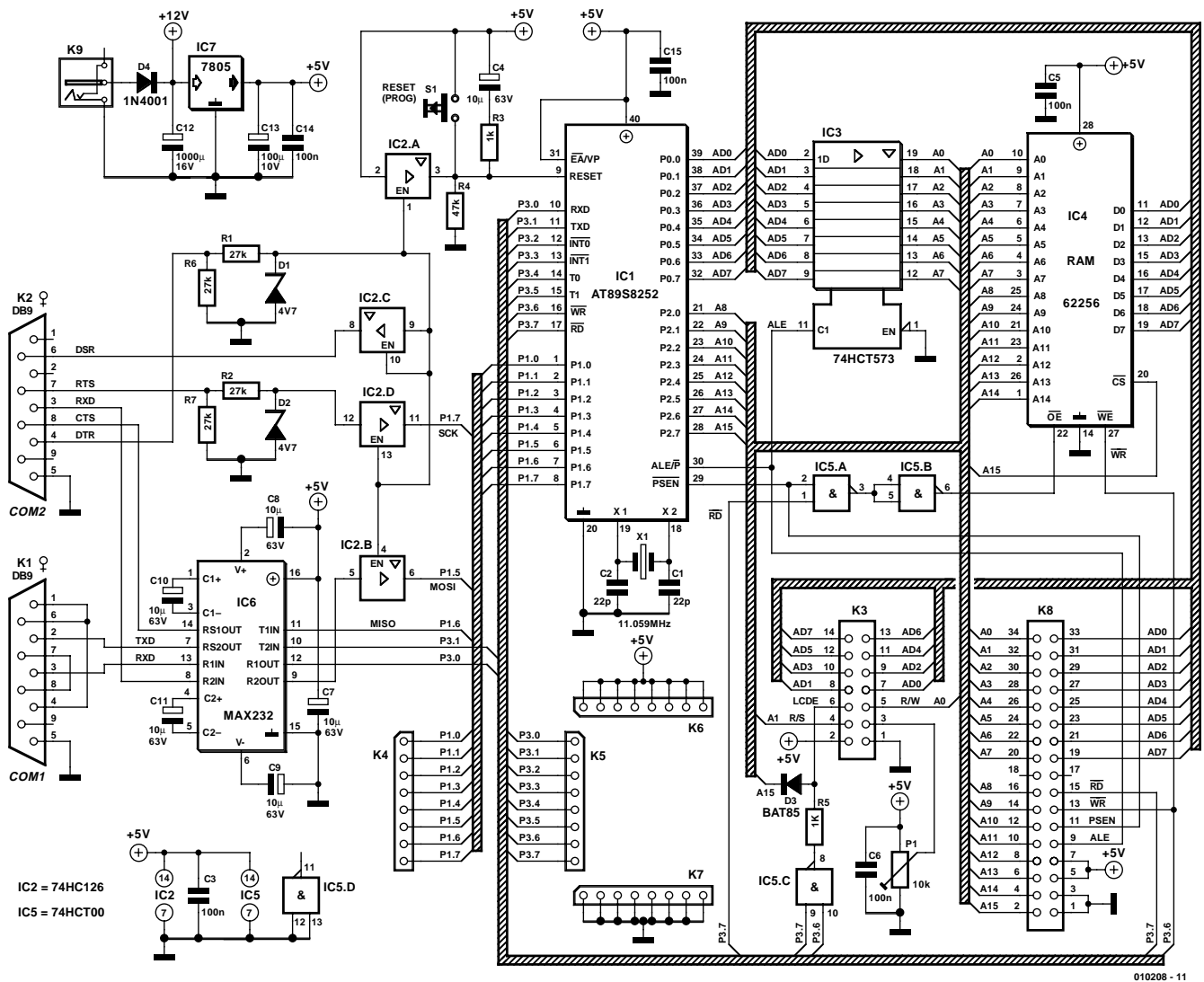Figure 1. Block diagram of the AT89S8252 microcontroller.

Figure 2. A classical, well-configured microcontroller system.

reset the microcontroller, switch it to programming mode, download a program and start the program. The complete board can thus practically be used under remote control. It could be located in an inaccessible place, for example, and still be easily reprogrammed.

The first DB9 socket (COM1, K1) is for connection to a serial interface port of a PC. On the PC, the user writes and compiles his program, transfers it to the microcontroller and tests it on the Flash Board. Connector K1 only has to be used if the transferred program needs to communicate with the PC. Here there are two options: you can either swap the interface cable to the other connector or use two COM ports on the PC. This is possible with many PCs if two COM ports are present and the mouse uses a PS/2 connection or works on the USB. Using two COM interfaces in parallel often proves to be especially practical and convenient. Programming

and testing can be done interactively if the necessary tools can be used in parallel.

The circuit, which is shown in schematic form in **Figure 2,** is largely based on standard designs for 8051 systems. A 74HCT573 address latch (IC3) provides the lower eight address bits for the 32-KB RAM (IC4). Since the /CS line of the RAM is connected to address line A15, this memory occupies only the range 0–7FFFh, leaving the upper range (8000h and above) free for extensions. The $\overline{WR}$ line, which controls write accesses, is driven directly by the processor. By contrast, the signal for the $\overline{OE}$ line (for read accesses) is generated as the logical AND of the PSEN signal (for accessing program memory) and the WR signal (for data

accesses), using two 74HCT00 gates (IC5). 8051 microcontrollers normally use common, parallel address ranges for the program and data memories, but this splitting has been abolished here. Although in most cases the microcontroller will use the internal 8-KB flash PROM as program memory and only store data in the RAM, it is still possible to use program routines located in regions of the RAM above 2000h. Since the same regions can also be accessed as data regions, it is possible to write self-modifying programs, in which the processor writes its own code in the RAM and then executes it.

The internal EEPROM of the microcontroller is actually a pure data memory configured in parallel with the external RAM. The EEP-

ROM must be activated by software. Once this has been done, the EEPROM can be used for non-volatile data storage. In this case, the lower 2 KB of the external RAM are inactive.

The LC display is also connected to the data bus and occupies a region above 8000h. A NAND combination of $\overline{RD}$ and $\overline{WR}$ produces the Enable signal for the display. A simple diode-logic circuit blocks this signal in the address range up to 7FFFh.

The display thus occupies the following addresses:

8000h: write command
8001h: read command
8002h: write data
8003h: read data

These regions are mirrored up to FFFFh, so the region from F000h to F003h can also be used.

As usual, the serial interface (consisting of the TXD and RXD leads) is linked to the PC connector via a MAX232 interface IC. No handshaking is used. The internal interconnections of the handshake lines accommodate the needs of certain terminal emulator programs that expect to see signals indicating that the connected device is ready to receive data.

Assembling the Flash Board is quite simple and should not take longer than an hour. You should use good-quality sockets for all ICs, which means that later you will have to pay attention to the correct orientation of the ICs (as with the polarisation of the electrolytic capacitors and diodes). Either a double-row 34-way boxheader or four 8-way SIL pinheaders are fitted in position K8. The two middle pins are not used and in the case of the boxheader must be clipped off to allow four 8-way single-row cable sockets to be fitted side by side.

Programming

The programming interface of the microcontroller employs an SPI interface using the following leads:
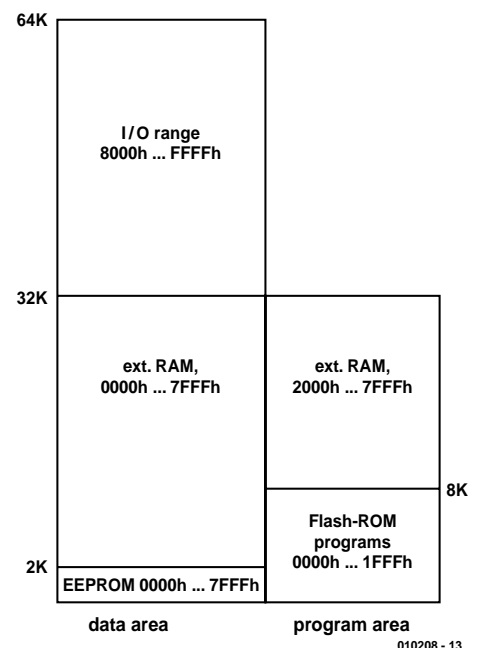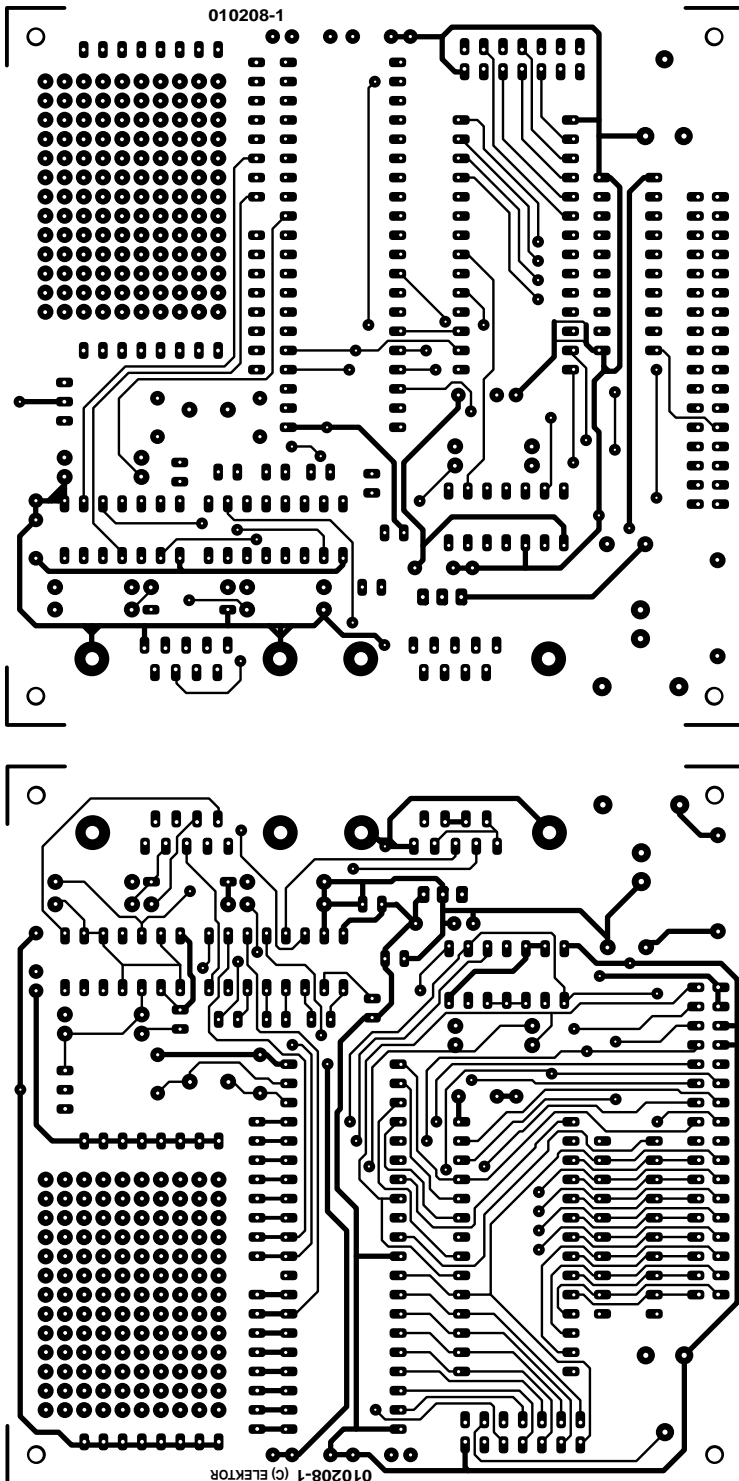

Figure 3a. Printed circuit board layout and …

Figure 4. The internal and external memories of the microcontroller board.

SCK (P1.7)	clock line
MISO (P1.6)	data read
MOSI (P1.5)	data write
RST	reset line

Programming takes place when the Reset line is active. The programming tool thus establishes a Reset state and then writes the data via the MOSI line, with each bit being transferred to a shift register inside the processor by a clock pulse on SCK. In the same manner, the MISO line can be used to verify successful programming or read out a program. All signals are generated directly via RS232 lines that provide voltage levels of ±10 V. This means that an adaptation to the 5-V level of the processor is necessary. The free half of the MAX232 looks after the level conversion for the data lines (MOSI and MOSO). The clock and reset signals, on the other hand, are conditioned using Zener diodes for voltage limiting and tri-state buffers contained in IC2

(74HC126). This takes into account the fact that the port pins in question can naturally be used for other functions in a user-written microcontroller program. The programming interface is therefore completely disabled if it is not needed. In this case, the buffers are in a high-impedance state and are thus effectively not present. These buffers only become active when a processor reset is executed via the DTR line, but they are not enabled when a Reset is triggered by the pushbutton on the circuit board. A buffer stage in the 74HC126 operates in parallel

Figure 3b. … component layout.

Connector K8 pin functions

Pin	Function
1	GROUND
2	A15
3	GROUND
4	A14
5	+5V
6	A13
7	+5V
8	A12
9	ALE
10	A11
11	PSEN
12	A10
13	$\overline{WR}$
14	A9
15	$\overline{RD}$
16	A8
17	NOT CONNECTED
18	NOT CONNECTED
19	AD7
20	A7
21	AD6
22	A6
23	AD5
24	A5
25	AD4
26	A4
27	AD3
28	A3
29	AD2
30	A2
31	AD1
32	A1
33	AD0
34	A0

COMPONENTS LIST

Resistors:
R1,R2,R6,R7 = 27kΩ
R3,R5 = 1kΩ
R4 = 47kΩ
P1 = 10kΩ preset H

Capacitors:
C1,C2 = 22pF
C3,C5,C6,C14,C15 = 100nF ceramic
C4,C7-C11 = 10µF 63V radial
C12 = 1000µF 16V radial
C13 = 100µF 10V radial

Semiconductors:
D1,D2 = zener diode 4V7, 500 mW
D3 = BAT85
D4 = 1N4001
IC1 = AT89S8252 24PC

IC2 = HC126
IC3 = 74HCT573
IC4 = 62256 120 ns
IC5 = 74HCT00
IC6 = MAX232
IC7 = 7805

Miscellaneous:
K1,K2 = 9-way Sub-D socket
   (female), angled pins, PCB mount
K3 = 14-way boxheader
K4-K7 = 8-way SIL pinheader
K8 = 34-way boxheader
K9 = socket for mains adaptor
S1 = pushbutton, make contact
X1 = 11.0592 MHz quartz crystal
PCB, order code **010208-1**
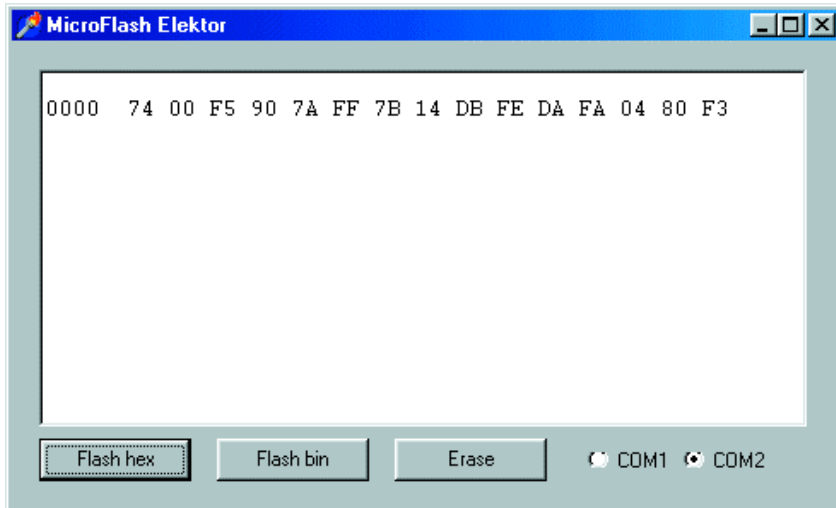Disk, project software, order code
   010208-11
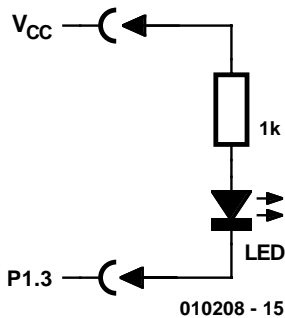
Figure 5. The download program.

Figure 6. Initial testing with a LED connected to a port lead.

with the Reset button. Effectively, an open-drain p-channel FET acting like a second Reset button is driven via DTR. The Reset signal is thus

actively pulled high but never actively pulled to ground. This is possible because the input to the buffer is permanently connected to V$_{CC}$, with the Enable input being driven by the programming interface.

Programming the microcontroller is a relatively complex process, in which certain control bytes must first be transferred. However, the user does not have to worry about this, since a ready-made Windows-based programming tool is available. This program (MicroFlash.exe) can be found on Readers Services diskette **010208-11**, and it can also be downloaded from the *Elektor Electronics* website on the Internet. Using the program is simple. You only have to activate the desired

interface (COM1 or COM2) and then select the file format (Intel hex or binary). Following this, a file selection window opens to allow a suitable program file to be chosen. Programming starts after the file has been selected, with progress being displayed in the text window. When the transfer is finished, the PC program automatically switches the microcontroller to the Run mode and thereby starts the execution of the program.

The first test

The first sample program is located on the same diskette. This program, which is called Flashtest1.hex or Flashtest1.bin, contains a short program loop with incrementing port output values. After it has been transferred to the microcontroller, you will see rectangular signals on all of the pins of Port 1. If you have an oscilloscope available, you can easily see whether everything is working properly, but even a simple LED with a series resistor can be used for this purpose. If you connect this test aid between V$_{CC}$ and the various pins of Port 1, you should see the LED blink at a slow rate on P1.7, with the rate doubling for each of pins P1.6 through P1.0 in turn. We have also written this sample program in assembly language (flash1.asm). The following is the listing of this version of the first sample program:

```
; test1  flash #include 8051.H
.org 0000Hmain    mov   a,#00next
mov   P1,a        mov   r2,#255loop1
mov   r3,#20loop2   djnz  r3,loop2
        djnz  r2,loop1
        inc   a
        sjmp  next
        .end
```

Once the board has been successfully tested, you are ready to start developing your own programs. Here you can make use of already existing development tools. No matter whether your use assembly language, BASIC-52, Pascal or C for program development, the Flash Board will play along.

By the way, if you use BASIC-52, in a certain sense the roles are reversed. This is because the interpreter treats the Basic programs as data. The interpreter itself is an 8-kB program file that is directly loaded into the microcontroller. It is derived from the legendary BASIC-52-AH, and Intel have released it for general use. This software can therefore be distributed via the program diskette or the Internet. An improved version, called Basic-52 V1.3 (see the February 2001 issue of *Elektor Electronics*), is now available and can also be used. A bit of patience is necessary when downloading the program to the microcontroller, since transferring 8 kB serially and
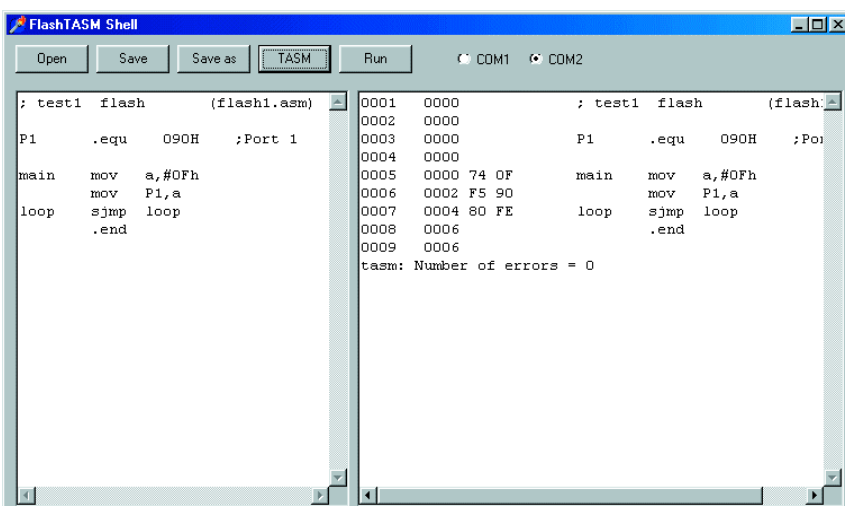
Listing 1. This assembly-language program causes the LED to blink.

loading the data byte by byte into the flash memory takes around a minute. If you wish, you can use the system permanently as a BASIC computer. However, the BASIC programs will not be retained when power is switched off, since they are contained in the RAM. If you wish to develop software for long-term use, you should use assembly language or C.

Not all applications require the use of a RAM. In particular, simple assembly-language programs can frequently manage without RAM. In such cases, the board can be used in a partly populated version with only IC1, IC2 and IC3. For a finished application, the population of the board can be reduced even further, since all that is necessary is the microcontroller (IC1) — here we have a true single-chip application. Of course, you can also go a step further by removing the programmed IC from its socket and fitting it to its own printed circuit board. In this case, the Flash Board serves as both a development system and a device programmer.

A simple example can illustrate this technique. Suppose you want to develop a small robot that is controlled by a microcontroller. You start by building the necessary sensors and drivers on the prototyping section of the Flash Board, following which you develop the control program. As soon as this works to your satisfaction, you can remove the microcontroller from its socket and make a printed circuit board specifically for the robot (as small as possible, naturally). Here the microcontroller does not need much more than a crystal and a few capacitors. While the robot is automatically making its rounds on the carpet, a new microcontroller in Flash Card development board can be awaiting the next assignment. Maybe this time it will be a special piece of measurement equipment for the electronics lab…

(010208-1)

Course preview: Microcontroller Basics

Naturally, there are there always new generations of people interested in technology, but even experienced electronics enthusiasts can always learn something new. Recently, many people have asked *Elektor Electronics* for advice on learning the basics of microcontroller technology. Our answer takes the form of the new Microcontroller Basics course, which will commence with the January 2002 issue and is presently planned to run over six issues.

Although there are already many books on this subject and the Internet is full of concrete applications, in most cases a certain basic knowledge is assumed. For a beginner, it is difficult to know where to start and how to proceed. Which controller should you use, for example, and which software? What are the limitations of particular systems, and which programming language is suitable for a particular application? The Microcontroller Basics course is intended to clarify the murky waters of microcontroller technology.

The course used the Flash Board system described in this issue, which provides many possibilities for utilising a variety of programming languages. Assembly language, BASIC and C will be used in the course, so that everyone can compare the strengths and weaknesses of these languages. However, the course will not just be an introduction to programming languages, but will also concentrate on typical examples of microcontroller applications. Techniques and procedures for measurement systems, controllers and control systems will also be discussed, as well as the special features of the controllers used and the general characteristics of the 8051 family.

What advantages can be gained from participating in this course? Here we attempt to briefly summarise the possible benefits: The user receives a thorough introduction to the general techniques of microcontroller applications, including memory utilisation, using ports and interfaces and driving complex peripheral ICs. A fundamental comparison of various programming languages provides the student with a sound basis for deciding on the choice of appropriate tools. The programs developed during the course can be used with almost any desired 8051-based system. Course participants will be increasingly able to use microcontrollers to implement their own ideas.

The following programming languages will be used:
– assembler (specifically, the well-known TASM shareware assembler with a superimposed Windows interface)
– BASIC-52 (including the new Version 1.3, with Windows-based editor and terminal emulator programs)
– The free Rigel Reads51 C compiler, which also runs under Windows.

If your curiosity has already been aroused, you can directly download the Reads51 software via the Internet from the following site: http://www.rigelcorp.com/. The Rigel Corporation, which is located in Gainesville, Florida (USA), produces microcontroller products for the educational market, among others, and supports these products with software that can be used free of charge for non-commercial purposes. They have been kind enough to grant Elektor Electronics permission to use this software for the Microcontroller Basics course. The basic terminal emulator program (RbHost) and the extensive information to be found on the Rigel home page also deserve recommendation.

The Microcontroller Basics course will use these three programming languages in a comparative manner, which means that the same or similar problems will be solved using all three languages. Course participants can thus compare the special features, speeds, programming styles and other aspects of the various languages. Although the definitive list of the course contents is not yet available, the major subjects have already been outlined. The main headings are:

– Getting started with programming languages; port accesses, timing loops
– Using the serial interface
– Using the 8051 timers, counters, frequency counter and PWM mode
– Driving an LCD; text output module with RS232
– Connecting and driving A/D and D/A converters
– Extensions: the I^2S bus, port expanders, A/D and D/A converters, real-time clock
– Special features of the 89S8252; internal 2-kB EEPROM and watchdog timer

Induction Radio

a nostalgic listening experience

Design by B. Stuurman

This radio is a sight for sore eyes. The magnificent coils, the gleaming valve and the striking wooden chassis suggest that this is a collector's item from the early days of radio. But appearances can be deceptive. This radio can be constructed easily at home and offers good reception across the medium-wave band.
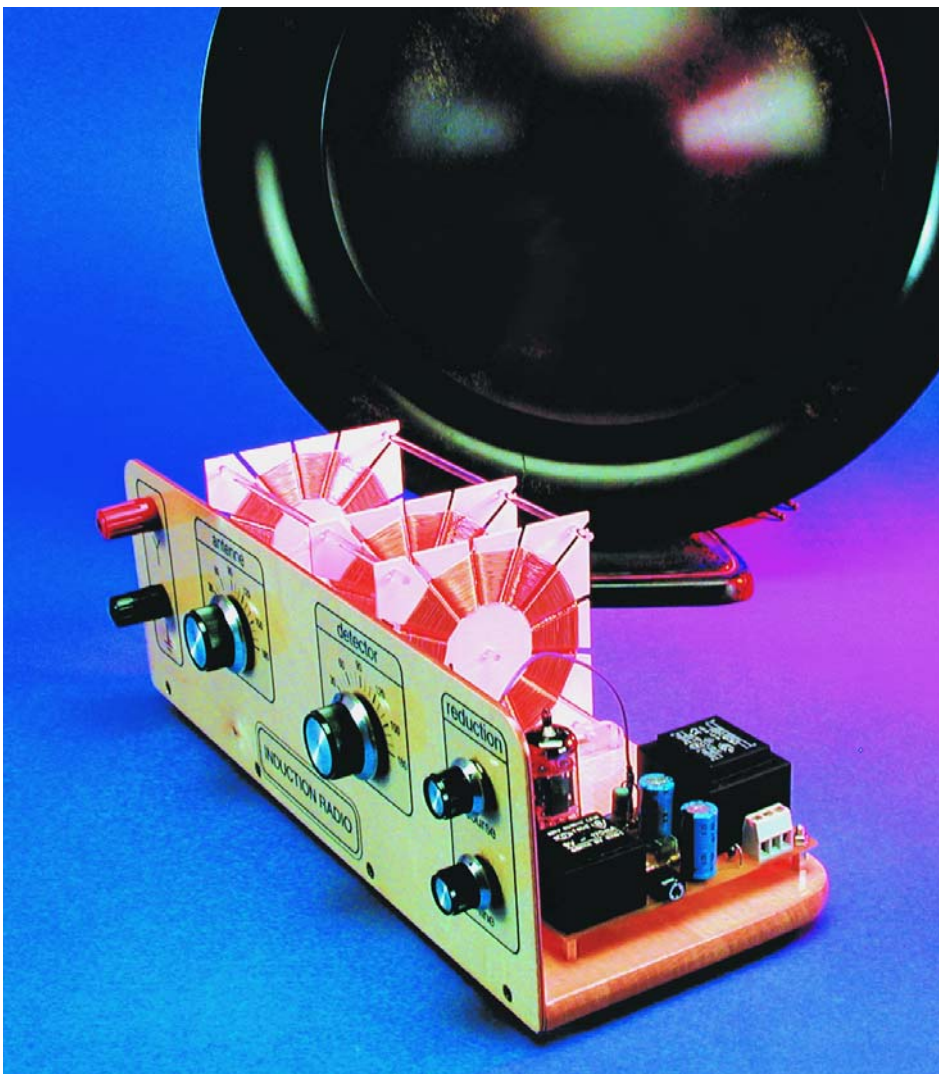
In the period between 1930 and 1960 building your own radio receiver was a very popular pastime. In those early days of radio you had to make nearly everything yourself, but after the increase in broadcasting stations more of the components could be found ready-made. Since then, the construction of a crystal set or single-valve receiver became a piece of cake. You saved your pennies until you had enough money, bought all the bits and constructed the receiver according to one of the many tried and tested designs.

These days, if you try to build a simple valve based medium wave radio you soon hit a brick wall. All those trusted components of the past are hardly available anymore. The supply transformer, output transformer, medium wave coil, tuning capacitor — try finding them. The radio described in this article turns a need into a virtue. It is a combination of old and new. The radio is built along an old design, but using modern components. The components are widely available and the construction really is simple.

The components

As we said, HV transformers for valves are no longer easily obtainable. But operation is still possible with an ordinary low voltage transformer. Likewise, headphones with an impedance of 2000 Ω have become a rarity. But the modern 'walkman' style headphone (32 Ω) is inexpensive and sounds much better. In this design the anode voltage doesn't have to be high and an ordinary low voltage mains transformer is used. Due to the use of the low supply voltage no isolating gap is required in the transformer.

Tuning capacitors with air as their dielectric give the best results, but they are almost impossible to find. Luckily there are low-profile tuning capacitors with a plastic dielectric. It is a pity that these come with circular plates, since this gives them a linear capacitance variation. The kidney shaped plates often found in the past resulted in a linear tuning scale over the range of the band, which was much more pleasing.

The last problem parts are the coils. After experimentation we decided on an old but tried type, the spider's web coil. This type of coil is not difficult to make, has a reasonable Q factor and a low self-capacitance. This capacitance is very

important, because the medium wave band covers 550 kHz to 1600 kHz (545-187 m) and a high self-capacitance would cut off the high end of the scale. Decisive in our choice was that the coils look very impressive. This gave the radio the look that we imagined right from the start.

The circuit

For the receiver we've chosen an old fashioned but simple direct conversion design, using an ECC82 double triode valve (**Figure 1**). This valve has its heating filaments connected in series with a tap for 6.3 V operation. In the series connection a voltage of 12.6 V at a current of 150 mA is required. For the power supply a transformer (T2) with two secondaries of 18 V/133 mA is used. The filament supply is derived from one of the secondaries via series resistors (R7/R8), reducing the voltage to 12.6 V. The current through this secondary is slightly above its rated value, but since the current through the other secondary is only a few mA this doesn't really matter.

Both secondaries of T2 are connected in series and after rectification (D1) and smoothing (C12, R6 and C11) this produces a DC voltage of about 50 V. The electrolytics can therefore be standard low voltage

types rated at 63 V. Capacitor C10 is added for high-frequency suppression.

Triode V1a functions as a standard grid detector circuit. The detector circuit (LD + C3) is connected to the grid via a small capacitor and the grid is connected to ground via grid bias resistor R1. The cathode is connected directly to ground.

During reception the tuned circuit connected to the aerial (LA + C1) induces an RF signal in the detector circuit. Due to the space charge in the triode the grid potential will be about 0 V when no signal is received. With an RF signal present, capacitor C5 will be charged up slightly during each positive half-cycle, because the grid functions as a rectifier. After several cycles the voltage across C5 will be equal to the peak voltage of the RF signal and the grid potential follows that of the RF signal, with a maximum of 0 V. As is well known, the RF signals in the medium wave band are amplitude modulated. C5 discharges via the grid bias resistor (R1), causing the grid potential to follow the envelope of the RF signal. Hence the anode current changes in step with the modulation. The result is a strongly amplified LF signal across R2, along with the remnants of the RF signal.

This RF component, which is inverted compared to the RF signal in the detector circuit, is fed via C4 and P1/P2 to a third coil (LR). This coil is connected with the windings opposite to that of the detector circuit, putting the signals back in phase. This positive feedback gives rise to amplification, increasing the Q factor of the detector circuit.

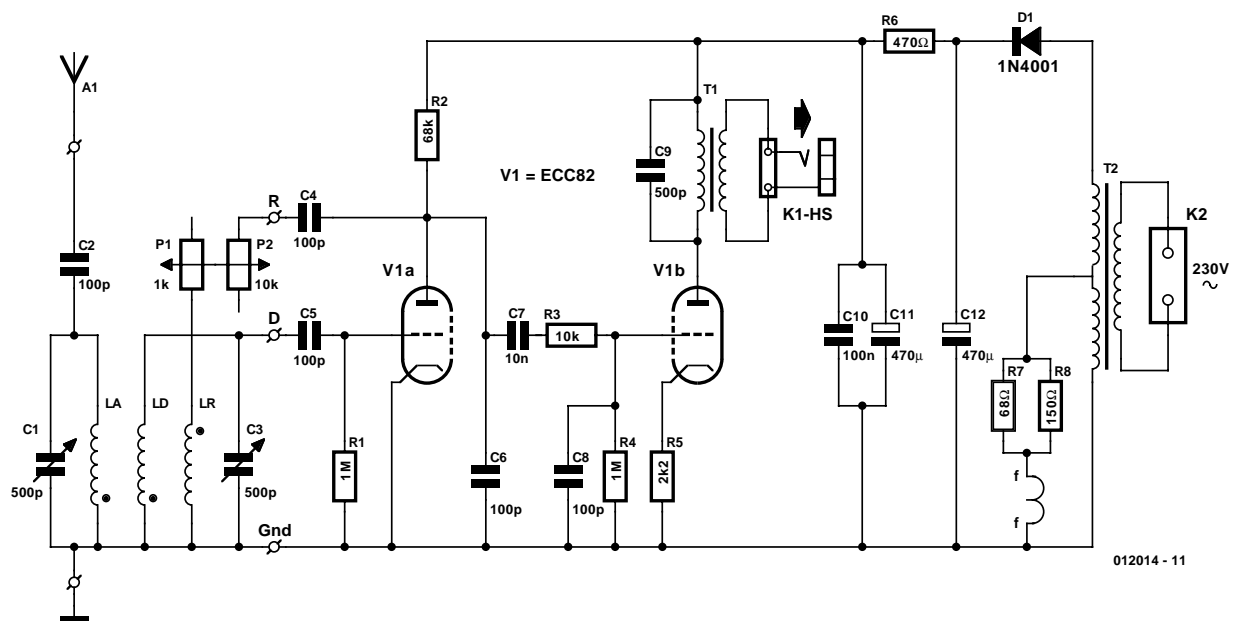If the damping of the circuit is reduced too

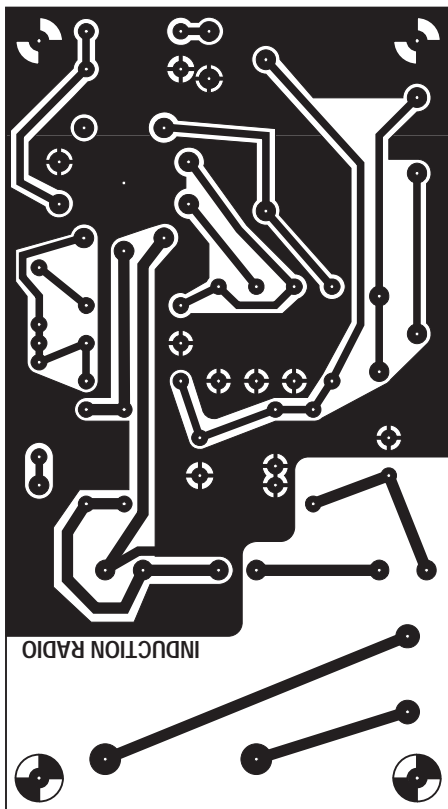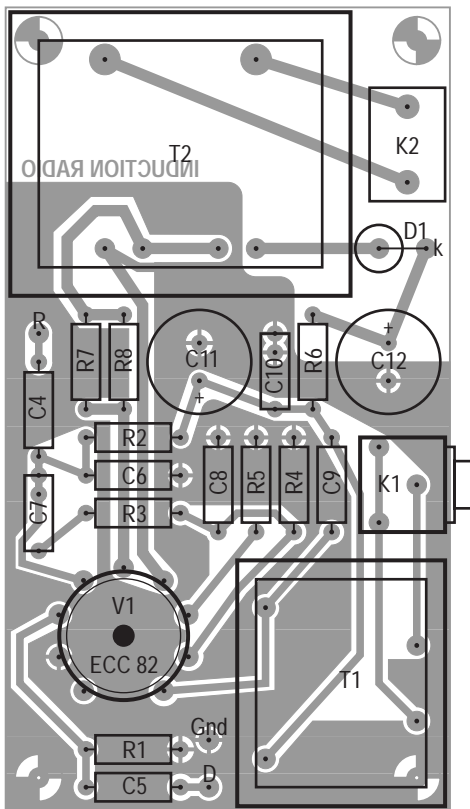Figure 1. The ECC82 double triode (V1) is at the heart of the circuit.

Figure 2. PCB and component layout of the induction Radio (board not available ready-made).

much the circuit will begin to oscillate. The receiver then becomes a transmitter and nearby receivers tuned to the same station will be subjected to very irritating whistles. So you have to take care that this doesn't happen. With the correct adjustment of P1 and P2 the sensitivity increases enormously, but at the same time the bandwidth of the signal is reduced. The high frequencies disappear and the signal begins to sound muffled.

The audio signal is fed via C7 and R3 to the grid of triode V1b, which is configured as an LF amplifier. C6, R3 and C8 attenuate the RF components considerably, leaving only the audio signal for the triode to amplify. The transformed impedance at the anode is about 10 kΩ $[(220/9)^2 \times 36/2]$. C9 gives a slight boost at 5 kHz, making the sound clearer and the cathode bypass capacitor has been left out to keep distortion down.

Construction

A simple PCB has been designed for this radio (**Figure 2**), which contains nearly all components. When you use the recommended components you'll find that everything fits perfectly and it is just a matter of careful soldering to complete the board. To keep the PCB to a reasonable size, two of the mounting holes — diagonally opposite each other — are underneath the transformers. On the component side of the PCB, these holes have to be countersunk such that the heads of the M3 mounting screws (5mm long) are flush with the PCB. Then all components can be mounted, apart from the transformers.

The holes for Gnd, D and R have 1.3 mm PCB terminal pins inserted. Headphone connector K1 is a standard 3.5 mm stereo jack socket; the left and right channels are connected in series giving an impedance of 16 Ω. K2 is a PCB terminal block with the pins 10 mm apart. Resistors R7 (vertical!) and R8 are mounted about 5 mm above the board because they become fairly hot.

After all the components have been mounted two standoffs (M3 × 10 mm) are screwed to the solder side of the board with countersunk screws. It's only then that the

COMPONENTS LIST

Resistors:
R1,R4 = 1MΩ
R2 = 68kΩ
R3 = 10kΩ
R5 = 2kΩ2
R6 = 470Ω
R7 = 68Ω 1W
R8 = 150Ω 0.5W
P1 = 1kΩ linear potentiometer
P2 = 10kΩ linear potentiometer

Capacitors:
C1,C3 = tuning capacitor, flat models, 500pF, (e.g., Conrad Electronics # 482323, Display Electronics (Holland) # 02.84.500p
C2,C4,C5,C6,C8 = 100pF polystyrene or polypropylene (e.g., Conrad Electronics # 458686)
C7 = 10nF, MKT (Siemens), lead pitch 7.5 or 10mm
C9 = 500pF (470pF) polystyrene or polypropylene (e.g., Conrad Electronics # 458767)
C10 = 100nF, MKT (Siemens), lead pitch 7.5 or 10mm
C11,C12 = 470µF 63V

Inductors:
LA,LD,LR = see inset

Miscellaneous:
D1 = 1N4001
V1 = ECC82
T1 = mains transformer, secondary 9V 1.5VA, e.g., Gerth # 3109-1, Display Electronics (Holland) # 02.10.159.091
T2 = mains transformer, secondary 2x18V 4.8 VA, e.g., Gerth # 421.36-2, Display Electronics (Holland) # 02.10.459.362
K1 = stereo headphones socket, 3.5 mm, PCB mount
K2 = PCB terminal block, lead pitch 10mm
Socket, noval, 9-pin, for ECC82
Binding post (red) for antenna wire
Binding post (black) for earth connection
2 pointer knobs, 15 x 33 mm, for 6mm spindle
2 pointer knobs, 13 x 20 mm, for 6mm spindle
Mans cord
Headphones, 32Ω

The spider's web coils
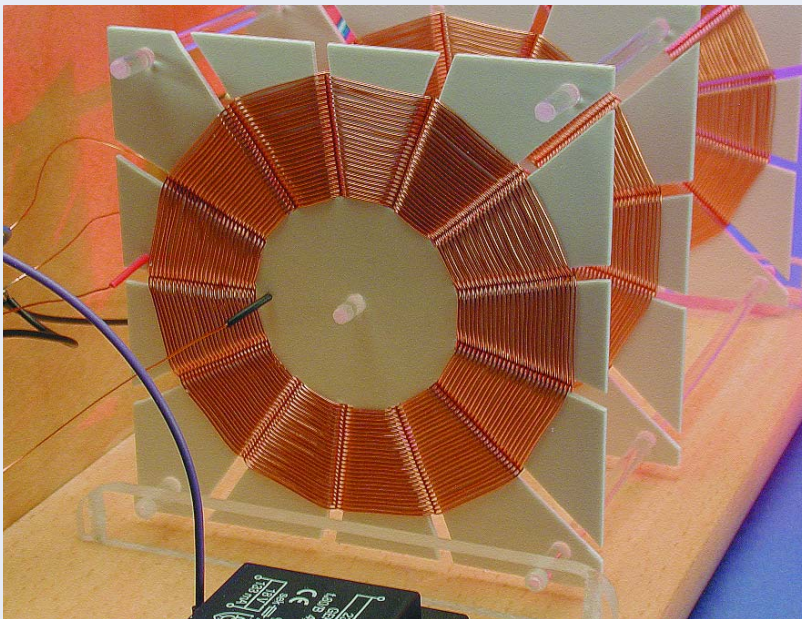
To obtain a reasonable Q (quality) factor it is important that air-cored coils are large and that a thick gauge of wire is used. Since the medium wave frequencies are relatively low there is no need to use Litz wire.

To keep the self-capacitance low in an air-cored coil it has to 'contain as much air as possible', which is one of the properties of spider's web coils (as with honeycomb coils, but these are much more difficult to wind).

We can use three identical coils for our radio. This is made possible by varying the separation (and hence the coupling) between the coils.

For the coils you'll need a reel of enamelled copper wire (0.4 mm diameter) and a board of ABS with a thickness of 1.5 mm. These ABS boards are available in many model shops.

Construction of the coil formers becomes easy when you use the template shown here. You'll need to make three copies of the template onto tracing paper. The copies are stuck to the ABS board with double sided sticky tape or paper glue. In the last case the glue has to be put onto the paper. The three rectangular coil formers are then cut out of the board using a fretsaw. Then we make cuts along the 26 lines from the sides to the central circle. Using a screwdriver with a 2 mm head we remove the resulting strips along the circle, leaving a coil former with 13 segments. The paper (and glue or sticky tape) is then removed and all sawn edges are deburred and smoothed by sliding a knife along them.

After drilling four holes at the corners and one in the middle (using a 3 mm drill) and cleaning with water and soap, the coil formers are ready for use. Two holes have to be made at positions A and B for the wires to go through. The wire is pushed through the hole at A from the rear of the board, leaving a length of about 15 cm sticking out at the front. This is rolled up and pressed flat against the centre, keeping it out of the way. The wire at the rear of the board is then brought forward through the slit below segment 1 and then back to the rear through the slit below segment 2. At each slit the wire

changes side. In this way 53 complete turns should be made. Since the number of segments is uneven this 'changing sides' works through the whole winding. If you keep the wire at a reasonable tension it will almost slide into place by itself. After 53 turns the wire should be cut, leaving a length of 16 cm, and fed through the hole at B from the rear of the board. The wire from A is unwound and is given a slight kink such that it can't slide back through the hole; the same is done for the wire from B. The 'A-wire' is the start of the coil; the 'B-wire' is the end. The start and end wires should be on the same side of the board, otherwise there probably was a mistake with the number of turns.

We now have three identical coils, each with an inductance of 200 µH, a low self-capacitance and (in conjunction with the tuning capacitor) a Q factor of about 60, which isn't bad.

The coils are mounted such that they are inductively coupled. At the left side is the aerial coil (LA), 10 cm to the right is the detector coil (LD) and 5 cm to the right of that is the reduction coil (LR). To simplify the construction of the coil assembly a wooden coil holder can be made. Three pairs of slats (0.5 x 0.5 x 10 cm) are glued to a wooden base, with the resulting slots 10 and 5 cm apart. Each slot should hold a coil firmly in place. The coils should have the B-wire at the front and facing to the right. Three connecting rods are put through the central and top holes, and are held in place with a drop of glue. We've used transparent plastic rods because they look so good (they are available in shops for model train accessories). Once the glue has dried, the coil assembly can be turned round and the two rods in the bottom can be put in place. The coil assembly is mounted to the chassis using two clear Perspex strips (110 x 5 x 10 mm, l x w x h). The photo shows the construction method very clearly.
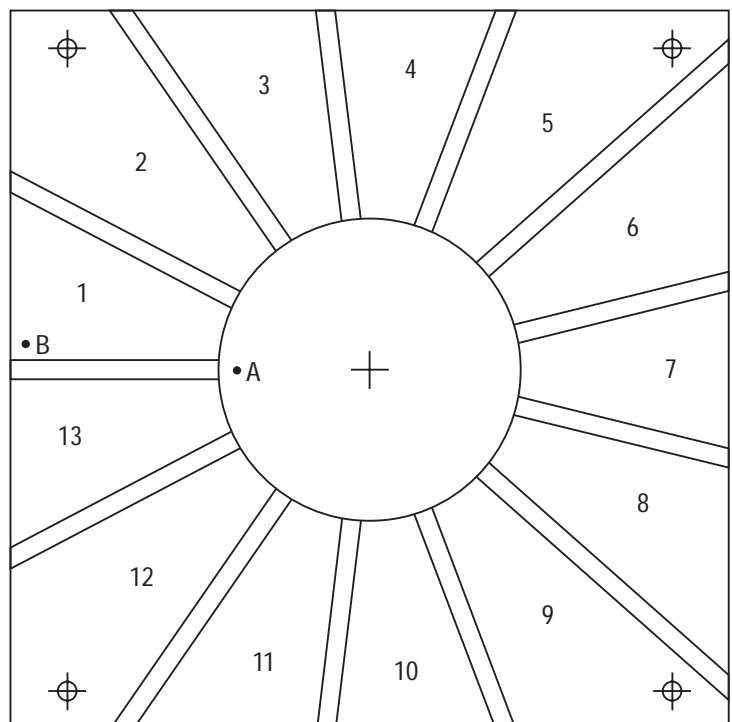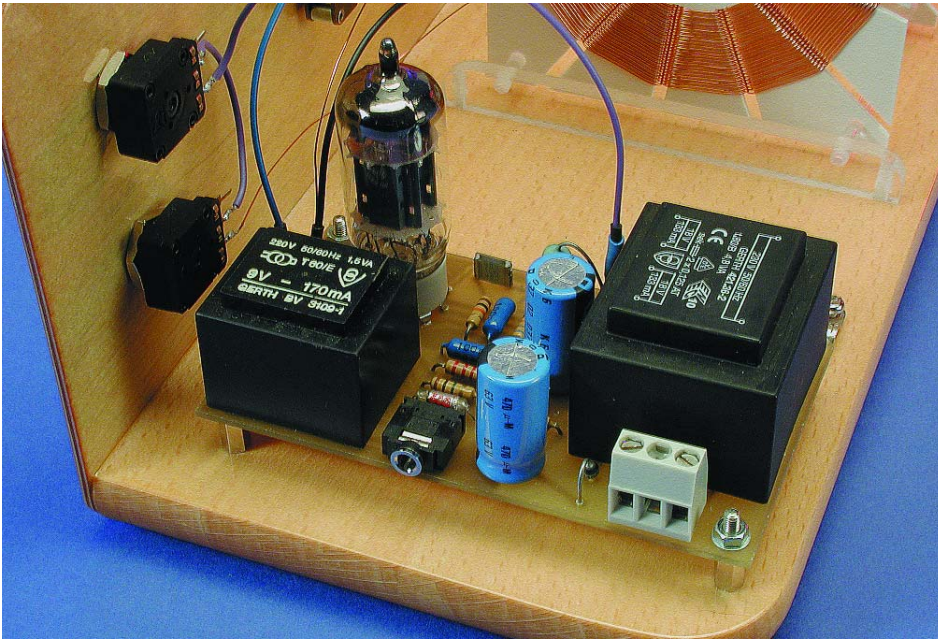

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Figure 3. Populating the PCB is easy.

transformers can be soldered into place. Two standoffs (M3 × 10 mm) are then bolted through the other holes onto the solder side of the board with nuts and washers. The board is then supported at all four corners. **Figure 3** shows a photo of the completed PCB.

Now for the rest of the receiver. The coil assembly is mounted on the chassis and the tuning capacitors, reduction potentiometers (P1: fine, P2: coarse) and the sockets for the aerial and earth are on the front panel.

A good starting point for the chassis is a beech wood breadboard of about 33 × 20 × 1.2 cm. You need to cut off a 7 cm piece along its length, leaving 33 × 13 cm. A laminated beech wood front panel is screwed against the cut side of the chassis. The top corners of the front panel should be sanded down to give a rounded appearance. All of the wood should then be sanded down thoroughly and given a coating of clear yacht varnish.

The coil assembly is mounted on the left-hand side of the chassis,

with the PCB on the right. The front panel contains the tuning capacitors, potentiometers and the aerial and earth connectors.

The aerial coil (LA) and detector coil (LD) are connected directly to C1 and C3 respectively (A-wires to the wipers). The wipers are connected together and to the common ground. A wire is connected to the wiper of the detector tuning capacitor, for connection to the 'Gnd' terminal on the PCB. This wire is soldered with the B-wire from the reduction coil (LR) to a terminal socket, which plugs onto the 'Gnd' pin. The connection between the 'hot' side of C3 and pin D on the PCB is also made using a terminal socket. Then the A-wire from coil LR is connected to P1, the wipers of P1 and P2 are connected together, and P2 is connected to pin R on the PCB again using a terminal socket. And finally the aerial socket is connected via a 100 pF capacitor to the 'hot' side of C1. **Figure 4** gives a rear view of the completed receiver.

For the professional look and for ease of use we've stuck transfers to the front panel, with a scale for the tuning capacitors.

Performance

During the day the author received (using a washing line on the balcony as aerial and a radiator as earth) about six stations at his flat in Weesp (near Amsterdam in The Netherlands). The BBC came through very clear and a station from Brussels less so. All the Dutch medium-wave stations came through loud and clear. Using a moderate damping reduction the resulting sound quality is surprisingly good.

Using the two tuning capacitors, the volume can be adjusted and the bandwidth can be adjusted such that a weaker station becomes perfectly audible next to a stronger local station. In the evening and at night the number of stations that can be received increases tremendously.

You will find that it is a special experience to listen to this receiver. Twiddling with those knobs brings back a nostalgic feeling that no modern radio can provide!
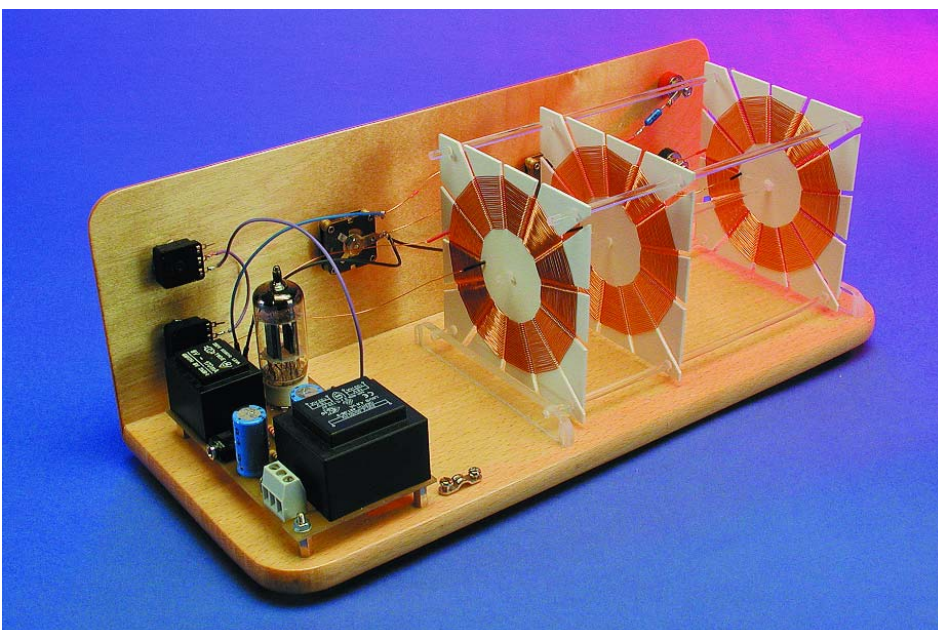
(012014-1)

Figure 4. Rear view of the completed receiver.

Memory Modules

CompactFlash, MemoryStick, SmartMedia, MMC, SDC and others

By Guy Raedersdorf

These days, solid-state-memories are available in all shapes and sizes. It is becoming more and more difficult to keep up-to-date with all the different properties, advantages and disadvantages of the many types of memory modules. Reason enough, therefore, to devote an article to these.

In the last few years, the appearance of new electronic products on the market has been ever increasing. The movie camera has already lost the battle with the electronic version, still cameras are being replaced with digital models and even the humble diary is being threatened by the pen-computer. All these products have to store their information (photos, appointments) somewhere, preferably on a media without moving parts or batteries. For this purpose, manufacturers have designed memory modules with a large quantity of non-volatile memory elements. Just as has happened with many other products in the past, manufacturers have not been able to limit themselves to a single world-wide standard. Therefore, we now encounter various types that are (solely on different dimensions alone) not mutually interchangeable.

The most common memory modules are the CompactFlash (38%), SmartMedia (35%) and MemoryStick (approximately 24% market share). The rest (SD, MMC and others) account for the remaining 3%. Not less than 7 different families of memory modules fight for their position in the marketplace, and make desperate attempts to gain the favour of the potential customer.

You only need to look at a few advertisements for photographic equipment to obtain an overview of the state of affairs: one makes use of CompactFlash, another uses Smart-Media and the third uses Memory-Stick.

There are several manufacturers of memory modules around the world. SanDisk, the inventor of CompactFlash, is one of the more important and most active of manufacturers. This company possesses 31.3% of the market share, Toshiba 20.5, Sony 13.8, Hitachi 8.7, Samsung 7.9 and the others 17.8%.

The various types

We will now examine the different types of memory modules up close.

CompactFlash
The CompactFlash (CF) with its dimensions of 42.8 x 36.4 x 3.3 mm is quite large, nearly twice as large as the MemoryStick. It was developed at the SanDisk laboratories and exists in various capacities from 4 to 512 MB (**Figure 1**). The CF has a controller on board, so that it may be used in non-intelligent adapters. Note that two types of CF-module exist, type 1 and type 2, which only

differ in thickness. The first is 3.2 mm thick and the second is 5 mm thick. The CF, together with the SMC, are the only ones with a parallel interface.

SmartMedia Card
The SmartMedia Card (SMC) is about the same size as the CF and is mostly known from the first portable MP3-players. It was developed in 1995 at the Toshiba laboratories and exists in capacities from 4 to 128 MB (**Figure 2**). The very thin SMC occupies about 1/3 the dimensions of a credit card. This module does not have any intelligence of its own and therefore has to be placed in a suitable reader.

MemoryStick
The MemoryStick from Sony, (MS to the connoisseur, see **Figure 3**) appeared relatively late on the market, compared to the other well-known memory modules (such as CompactFlash and the SmartMedia Card). Sony makes use of the MS in many new devices, such as the astonishingly small player of audio files in the ATRAC3-format, a competitor to MP3. Initially it appeared that the MemoryStick was going to be a proprietary solution for the Sony-world, but in recent times other manufacturers have also developed an interest.

The MS is currently available in capacities of up to 128 MB, but models with 512 MB or even 1 GB are planned for release towards the end of 2003.

The internal construction of the MS consists of a flash-memory and a controller. The transfer of data is achieved over a three-wire (Data, Clock and Bus) serial interface in blocks of 512 bytes at a maximum frequency of 20 MHz.

A small notch at the bottom of the MS is used to protect the data from being inadvertently overwritten, a feature that it shares with the SD-module.

There is also an MS, the Magic-Gate, which is white in colour. This version is specifically intended for the reproduction of digital data files (audio and text) that are subject to copyright. Every MagicGate possesses a unique serial number.

Another variation is the MSD

(Memory Stick Duo), especially developed for equipment that requires ultra compact modules. This version measures $31 \times 20 \times 1.6$ mm and weights 2 g! With the aid of an adapter the MSD re-acquires the dimensions of the original MS.

MultiMedia Card
The MultiMedia Card, abbreviated MMC, was introduced in 1997 by SanDisk and Siemens (**Figure 4**). This device is a flash memory with serial interface; reading occurs at a respectable 13.7 to 20 Mb/s, writing varies from 3.2 to 20 Mb/s. Note that two different types of MMC exists: the MMC 1 and the MMC 2, which is slightly thicker.

The MMC has 7 contacts and is available in capacities from 4 to 64 MB.

SD (Security Digital) Card
This card appeared in 2000 and traces its origins back to SanDisk, Toshiba, and Matsushita. Except for the thickness, which is 2.1 mm, its dimensions are the same is for the MMC. The SDC exists in capacities from 8 to 64 MB and has 9 contacts.

PC Card
The PC Card (**Figure 5**), its shape is analogous to the normal PCMCIA-module and its thickness corresponds to either a type 2 or type 3, has a capacity from 8 MB to 1 GB. Work is already in progress on a 2 GB version; this is not all that amazing considering the difference in dimensions between the CD and the PCMCIA module (which in addition to the memory also has to find room for a controller).

And the others?

There are a number of other, lesser known, memory modules, such as:
– The ATA Flash Card, a kind of PC card with higher specifications. The ATA Flash Card makes use of a flash-memory and NAND-gates. The maximum reading speed is 1.5 MB/s and the write speed is 3 MB/s. These modules are available in sizes ranging from 8 MB to 2 GB (type 3).
– The Linear Flash Memory Card, which is used, among other things, in the Alesis synthesiser; maxi-

mum 32 MB.
– The Miniature Card; the dimensions are a quarter those of a standard PC card.
– The SRAM module, fitted with a lithium battery to preserve the data; currently the maximum capacity is 6 MB and the device is very expensive.
– The ATA FlashDisk from SanDisk.
– The MicroFlashDisk
– The MicroDrive from IBM. A miniature hard disk in CF2-format with a capacity of up to 1 GB
– The Click Drive from Iomega, a mini-floppy with a capacity of 40 MB.

The technical aspects

Table 1 lists the most important differences between the various types of memory modules.

But this doesn't say anything about the technical aspects of these cards, something

Figure 1. The Compact Flash is one of the most universal memory modules.

Figure 2. The SmartMedia Card is commonly used in MP3 players and digital cameras.
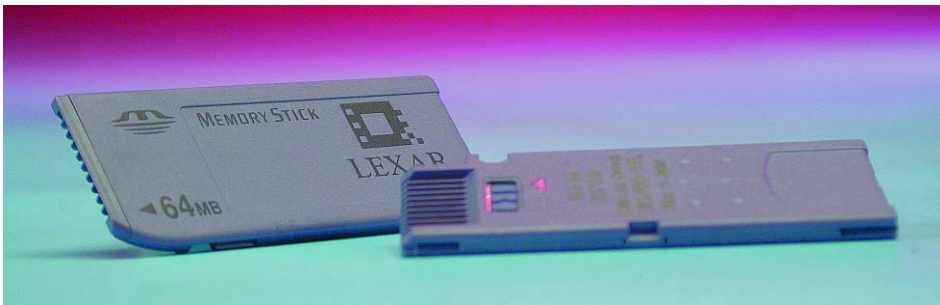
Figure 3. The standard model Memory Stick is always blue in colour.

that will be of particular interest to readers of *Elektor Electronics*.

We have taken a memory card from Lexar Media as an example. Lexar is one of the few manufacturers of memory modules who develop and manufacture their own controllers. This way, they can incorporate interesting features.

The writing speed of a memory module is an important specification. This is of particular concern to the professional photographic industry. This speed is labelled on a Lexar memory module: 4× for normal use, 8× for amateur photographers and 12× for the professional. Every '×' stands for 150 kB/s so that data storage occurs at a rate of 600 kB/s to 1.8 MB/s. Because modern digital cameras generate very large files, these differences are clearly noticeable.

A unique aspect of the CF-modules from Lexar is the integrated USB (refer to the diagram in **Figure 6**) in the module itself, hence the name CF+. This way it is possible for the user to use a cheap cable, named Jumpshot (in the photo at the start of this article in the middle at the top), to connect the module

Figure 4. The MultiMedia Card has the dimensions of a postage stamp.

directly to a USB-port on a PC or MAC. The USB-port on board of the CompactFlash+ is then automatically activated and appears to the PC as a normal drive.

Another feature of the Lexar products is the presence of a Space Manager function in the controller, to optimally utilise the flash-memory. In contrast with magnetic mass-storage devices where a write command overwrites the previous data, a flash-memory has to be erased first before new data can be written. The Space Manager technology is based on the indirect exchange between physical and logical addresses, in such a way that it is possible to fill sectors with data without having to erase them first. At a later time, when the system is idle, unused data blocks are erased.

The last remarkable technical feature of the CF+ is the 'programmable firmware'. The controller program resides in the flash-memory. At run time, the software is copied to the internal RAM. This way it is easy

to keep up with the current version of the program. It is also possible to optimise the controller for different applications or circumstances.

Reading the modules

Because there are so many different types of memory modules, a similarly large number of readers have been developed in order to be able to connect them all to a computer.

The PC Card, as we mentioned earlier, is not a problem, since it fits in a PCMCIA slot. All other types need some sort of provision to read them back.

One very simple solution is the:

PC Card adapter
This is a type of adapter (**Figure 7**) that allows a memory module to be plugged into a PCMCIA-slot, that is already built into the vast majority of laptops.

This type of adapter is available from various manufacturers and for several different types of modules, such as the MemoryStick, the CF-card and the SmartMedia Card. They are very easy to use. After the adapter, fitted with a memory module, is plugged into a PCMCIA-slot, the computer will automatically recognise the PCMCIA-card. The first time, Windows will install the necessary driver. Thereafter the memory is available is if it were an additional hard disk.

Because there aren't very many desktop computers with a PCMCIA slot, another solution has been developed:

Diskette-adapter
The diskette-adapted is, as the name implies, an adapter shaped like a 3.5"-diskette (**Figure 8**). This adapter is usually supplied with an appropriate driver. They are also easy to use. The adapter (with the memory module fitted inside) is placed into the floppy-drive. The data transfer is faster than with a diskette.

Diskette adapters are available for different types of modules, such as for the MemoryStick, the Smart-Media and the MultiMedia Card.

External readers
Just about every memory manufacturer also has an external reader,

Figure 5. The PC Card module has currently the largest memory capacity.

Table 1. Physical properties of the current memory modules.						(source : Sony)
	CompactFlash	**Memory Stick**	**Memory Stick Duo**	**MultiMediaCard**	**SD Card**	**SmartMedia**
Dimensions (mm)	42,8 x 36,4 x 3.3	50 x 21,5 x 2.8	31 x 20 x 1.6	32 x 24 x 1.4	32 x 24 x 2.1	45 x 37 x 0.76
Mass (g)	8 to 15	4	2	1.5	2	2
Volume (cm3)	5.141	3.010	0.992	1.075	1.612	1.265
Origin	SanDisk (1994)	Sony (1998)	Sony (2000)	SanDisk (1997)	SanDisk (2000)	Toshiba (1995)
Number of contacts	50	10	10	7	9	22
Current capacity (MB)	16, 32, 64, 96, 128, 192, 256, 384, 512	8, 16, 32, 64, 128	8, 16, 32, 64, 128	8, 16, 24, 32,64, 128	4 … 64	8, 16, 32, 64, 128
Maximum data speed (MB/s)	1.8 (E) – 2.45 (L)	1.8 (E) – 2.45 (L)		0.375 E) 1.75 (L)		
Copyright protection	ID-number	SDMI-norm	SDMI-norm	ID-number	SDMI-norm	ID-number
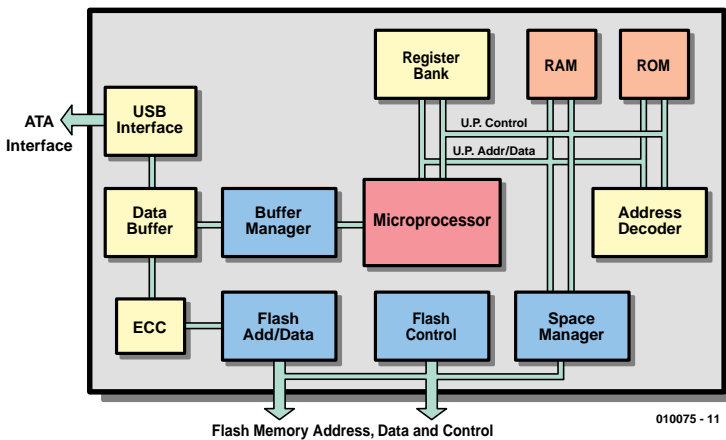
Figure 6. Schematic overview of a CF+-module from Lexar Media (source: Lexar).

mainly USB models, to connect a memory module to a computer. San-Disk has the Imagemate, in versions for CompactFlash, MultiMedia and SmartMedia. The SecureMate is specifically intended for Secure Digital modules.

Currently there also exist readers that can read both CD as well as SMC-modules and have two different connectors.

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A number of interesting websites:

www.memorystick.org
A lot of information can be found here regarding the MemoryStick. This site is intended for developers, but is definitely also of interest to readers who would like to know more about this memory module from Sony.

www.sandisk.com
All information about SanDisk products can be found here.

www.lexarmedia.com
Lexar Media, just like SanDisk, has a considerable offering of various types of memory modules (even the MemoryStick).

www.sdmi.org
Here you can find out about the protection of copyright sensitive material (SDMI = Secure Digital Music Initiative).

Figure 7. A PCMCIA-adapter from Lexar for CF and CF+-modules.

Figure 8. This diskette-adapter has been designed for MMC modules.

ISAC (3)

part 3: the software development environment

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

In this third instalment in the series on the intelligent sensor/actuator controller (or ISAC) we look at the software development environment for the Analog Devices MicroConverter. Following on from the description of the device in part 1 and the construction of a prototyping system in part 2 we are now in a position to write our first program for the ISAC cube.

The Analog Devices MicroConverter can, in principle, be programmed using any of the familiar programming languages, including Assembler51, Basic52, Pascal51, C51 and so on. The result of the translation carried out by the assembler or compiler is simply an Intel Hex file, which must be downloaded, either serially or in parallel, into the MicroConverter's Flash memory.

However, Analog Devices offers a complete software development environment optimised for use with the MicroConverter family, freely downloadable from the Internet: the 'MicroConverter QuickStart Development System V3.0' [1]. This allows programs to be developed in assembler or in C.

Also, a complete 'QuickStart Development Kit' can be ordered from Analog Devices: this contains, in addition to the development software, an ADuC812 evaluation board (in Eurocard format) with mains power supply, data transfer cable and two ADuC812 chips. If you plan to use the hardware described in the last instalment of this series (ISAC cube plus prototyping board), then alongside the software development environment you can find much other information (data sheets, application notes and so on), all freely downloadable from the Internet. **Table 1** and **Table 2** give an overview of the available software tools.

When developing programs for the MicroConverter there are two fundamentally different ways to proceed:
– Develop and test programs using the low-level Assembler51 programming language.
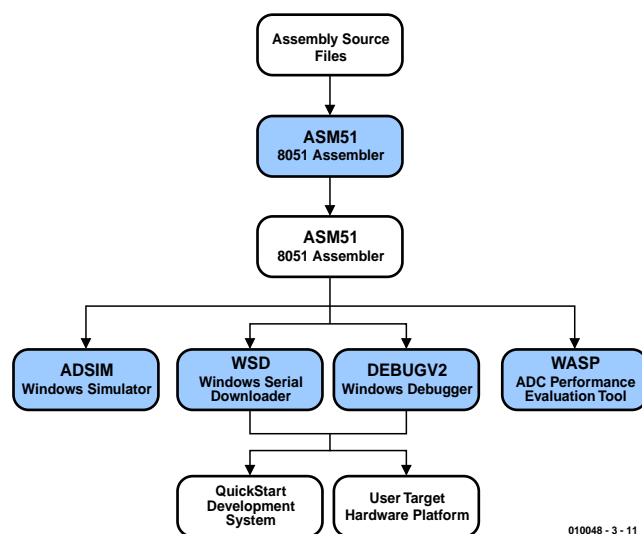
Figure 1. Developing MicroConverter programs in assembler.

– Develop and test programs in a high-level language, i.e. in BASIC52, Pascal51 or C51, of which the last is now regarded as the professionals' choice in industry.

Assembler51

The Assembler51 route is illustrated in **Figure 1**. Using an ordinary text editor the assembler source file is prepared in 8051 assembler code.

The Intel Hex file generated with the aid of the 8051 assembler can now be loaded into a simulator (adsim812) running under Windows. This allows the complete behaviour of the MicroConverter to be simulated on the PC at assembler level, including all the on-chip peripherals (A/D, D/A converters and so on), without the need to connect the actual target hardware. Powerful debugging facilities, such as setting breakpoints, single-step execution,
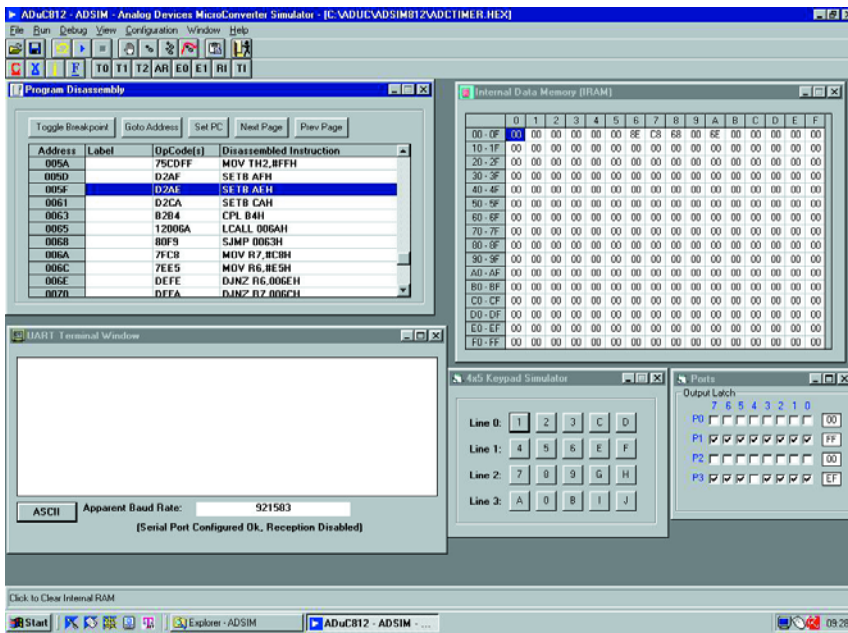
Figure 2. The software-based ADuC812 simulator.

register modification, preloading of data memory and so on are all included in the set of commands. This tool is a purely software-based simulator and debugger, with the whole of the ADuC812 laid out on the PC's screen (**Figure 2**).

If, while simulating or debugging, it is necessary to include the actual target hardware, for example to check the exact behaviour of externally-connected peripheral units (sensors, an LC display, keyboard etc.), then the ADuC Debugger can be used. This connects directly to the development PC using the ADuC812's serial interface. The debug results are taken directly from the actual hardware, and the debugging commands are sent directly to, and carried out by, the actual hardware. Again, all the various test facilities are of course available here: single-step execution, breakpoints, register loading and so on. This tool is thus a hardware-based debugger (**Figure 3**).

In very many cases using the simulator and the debugger will uncover all bugs and problems in a program.

In summary, Assembler51, the software-based simulator, and the hardware-based debugger offer the user an ideal introduction to assembler programming for the MicroConverter family from both a hardware and software point of view.

C51

To develop MicroConverter programs in the C51 high-level language Analog Devices have made available a 'trial' version of the μVision integrated development environment (IDE) produced by Keil, limited to a maximum program size of 2 kbyte. Keil is one of the world's leading producers of IDEs for all derivatives of the 8051 microcontroller family [3]. The μVision user has the great benefit of gaining familiarity with a very powerful professional development tool, with, however, the small concomitant disadvantage that gaining this familiarity takes a little effort (**Figure 4**).

To make the first steps easier, you can download application note uC002 'Writing an ADuC812 Application in C' from the MicroConverter homepage, and application note apnt_151 'Using the Keil Monitor51 /μVision 2 Debugger with the Analog Devices ADuC812 Evaluation Board' from the Keil Homepage (*www.keil.com*). There

Table 1

The software development environment for the MicroConverter

Programming in a low-level language: Assembler51
MetaLink DOS-based 8051 cross assembler: asm51 (V1.2h).
Windows-based simulator for the ADuC812: adsim812.
Windows-based debugger for the ADuC812: ADuC (V2).

Programming in a high-level language: C51
Keil μVision Integrated Development Environment (IDE) (limited to 2 kbyte maximum program size).

Program downloader
Windows-based serial downloader for programming the on-chip Flash EEPROM program memory from an Intel Hex file and for programming the Flash EEPROM data memory on the device.

Analysis Tools
Windows-based tool for analysis of data values obtained from the A/D converter (including FFT analysis).

Documentation
Getting Started — Introduction
User guides for the MicroConverter
Tool tutorials
Application notes / example code
Data sheets
Broad support via third-party tools

Table 2

Additional C tools for the MicroConverter

Commercial tools (trial versions):
Raisonance Rkit-51 (*www.raisonance.com*)
IAR Embedded Workbench™ ICC8051 (*www.iar.com*)

Free tools:
Reads51 (*www.rigelcorp.com*)
Small Device C Compiler – SDCC (sdcc.sourceforge.net) for Windows and Linux

you will find a very clear step-by-step explanation of how to organise and compile your first project in C51 under μVision, arriving at a downloadable Intel Hex file as the final result. This IDE also allows convenient simulation of your C program. Another reason for downloading and working through these application notes and installing μVision as described is that we will be using C51 exclusively in the following experiments in the world of ADuC812 software.

As already indicated at the start, in addition to the tools described above any other 8051-family programming tools can be used with the MicroConverter. A further selection of tools for programming in the C language can be found in **Table 2**.

Serial Downloader

Now that you have created the final Intel Hex file (containing machine code for the ADuC812), using either Assembler51 or C51 (or some other 8051 language), you must transfer this program code file to the ADuC812.

This can be done with the ADuC debugger, or alternatively you can use the Windows-based Serial Downloader from Analog Devices, designed for the full range of Micro-Converter products (**Figure 5**).

This very important process of downloading the program is carried out in three key steps (**Figure 6**).

Step 1: The ADuC812 must first be switched into Download/Debug mode (Figure 6a). To do this, the $\overline{PSEN}$ pin of the ADuC812 is taken to ground via a 1 kW resistor (resulting in a low level on $\overline{PSEN}$) and then the reset button is pressed. On the ISAC cube, hold down T2 ('Boot') and then press T1 ('Reset'). Then release T1 and then T2.

Explanation for 8051 experts:
a. *On a 'normal' 8051 the PSEN pin is always an output (read enable for program memory). On the MicroConverter, however, PSEN becomes an input on reset (i.e., as the reset button is released) and the level on the pin is read. If PSEN is at a low logic level, the ADuC812 switches immediately into Download/Debug mode, which means that a program to be downloaded can be received over its serial port and the on-chip Flash program memory can be programmed.*
b. *Each MicroConverter contains a 'secret' program memory in which the manufacturer has provided routines for serial program download, for programming of the Flash EEPROM, and to implement the debugging functions as described above.*

Figure 3. The hardware-based ADuC812 debugger.

On normal initialisation (when power is applied or the reset button is pressed with PSEN not being held low), this special memory area is disabled and invisible: the ADuC812 ignores its contents and runs the application program from Flash EEPROM (normal operation). If, however, the ADuC812 detects a low level on PSEN when the reset button is pressed or released, it ignores the application program in the Flash EEPROM *and switches instead to the secret program memory and runs the program stored there — the Download or Debug routine — thereby entering Download/Debug mode.*

Step 2. Now you can start the Serial Downloader (**Figure 5**). This program automatically looks for a Micro-Converter connected (in the first instance) to COM1, and establishes a connection with it. If the ADuC812
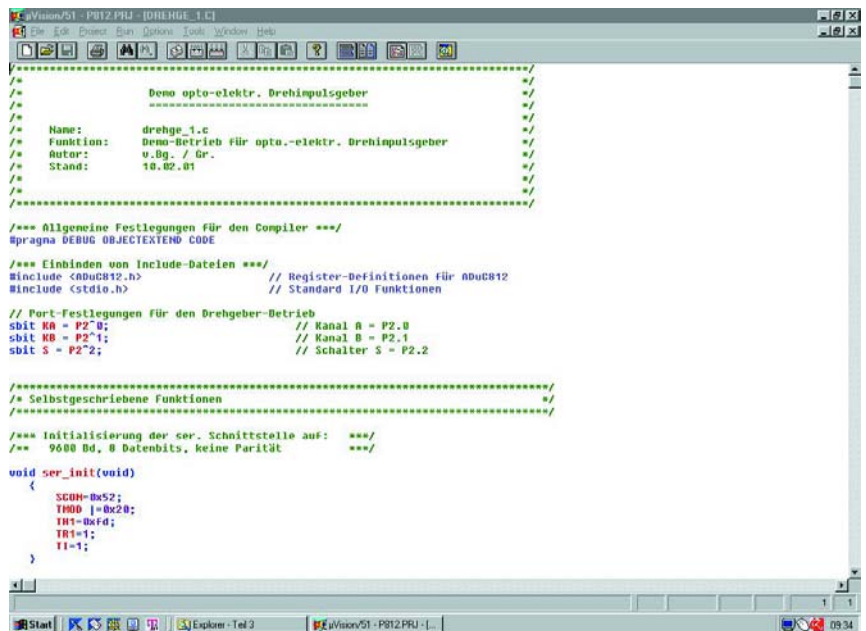
Figure 4. The μVision IDE.

is connected to a different COM interface, the appropriate interface can be chosen using the 'Configuration' menu. Here also you can set other parameters for the download. Initially, leave the settings at their default values. Next click on 'Download' and select, in the usual Windows way, the Intel Hex file to be downloaded from the appropriate directory. Downloading should then proceed automatically and without problems.

Step 3. After the download procedure is complete the Serial Downloader can be dismissed to the task bar. Press the reset button (T1) on the cube, and start your program running on the ADuC812 (**Figure 6b**). Recall that, since you were not holding down T2, PSEN will not be held low and the ADuC812 does not execute from its hidden internal program memory.

Each fresh download proceeds always from step 1 again: hold down T2, press T1, release T1, release T1, start the Serial Downloader, and so on.

Best before date

The Flash EEPROM on the ADuC812 is a non-volatile memory, which means that it retains its contents even in the absence of a power supply — but not forever. Also, there is a limit to how many times fresh programs can be downloaded.

Analog Devices provides the following information on this point in the ADuC812 data sheet:

– Data are retained in the Flash memory (with or without power supply) for at least 10 years; after that there may be 'drop-outs' which manifest themselves as errors in the stored data.
– The maximum number of reprogramming cycles (erase and rewrite of memory locations before errors occur in the memory) is given as 10,000.

It is worth noting that in each ADuC812 there are two separate regions of Flash memory available.

For the program memory the 10,000 reprogramming cycles are

certainly enough: if you rewrite your program 20 times a day, you can carry on for a full 500 days! Things are different, however, with the 640-byte Flash EEPROM data memory, where any desired data can be written as often as required. In some cases it is possible to reach or even overstep the critical limit of 10,000 erase/write cycles very quickly, especially when, for example, you store frequently changing measured values in these memory locations. In such cases it is better to opt for external expansion data memory in the form of a RAM (how this can be done will of course be explained later). But even here Analog Devices is developing its MicroConverter product line further: later derivatives (see Table 2 in the first instalment of this series) have a data retention of up to 100 years(!) and are specified for at least 100,000 erase/write cycles.

Emulators

Finally we should note that there are emulators available for the Micro-Converter. MetaLink (*www.metaice.com*) produces a classical emulator for the ADuC812: that is, one which replaces the Micro-Converter in its socket in the target system.

Accutron (*www.accutron.com*) produces the ACE 'single pin emulator', which supports all derivatives in the MicroConverter family and which includes C source-level debugging. The emulator is connected to the target system via the EA pin. Like the PSEN pin, this pin has many uses, which are described in the data sheet and in the Micro-Converter 'User's Manual'. In regard to MicroConverter derivatives with 16- and 24-bit analogue-to-digital converters in particular, this type of connection with the target system is of course very simple and has many advantages. This puts a powerful development tool at the disposal of the professional user.

Once you have learnt how to use the full range of tools to turn your ISAC cube programming ideas into reality, we can proceed in the next instalment to a few suggestions for interesting applications written in C51. Meanwhile, Analog Devices is

Figure 5. The Serial Downloader.

developing an enhanced version of the development tools for the MicroConverter, and so it is worth keeping an eye on the MicroConverter homepage (*www.analog.com/microconverter*), to obtain the most up-to-date information.

(010048-3)

Literature and websites:
[1] MicroConverter Internet homepage:
    www.analog.com/microconverter
[2] Analog Devices on the Internet:
    www.analog.com
[3] Keil μVision IDE: *www.keil.com*
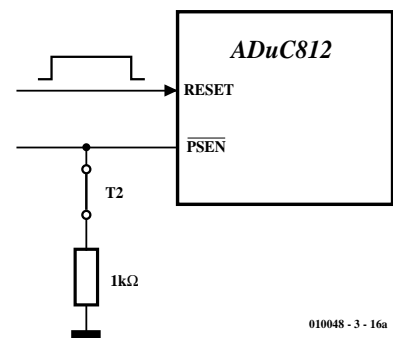
Figure 6a. Activation of debug/program download mode.
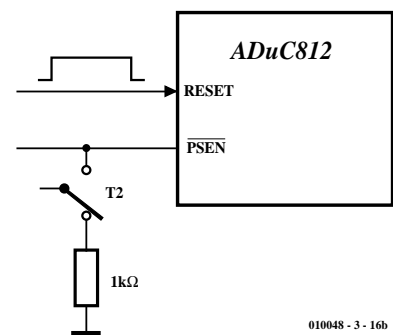
Figure 6b. Normal operating mode.

CUMULATIVE INDEX 2001

Application Notes

Audio, Video, Music

Computers, Microprocessors, Software, Internet

General Interest

Power Supplies & Battery Chargers

Radio, TV & Communications

Test & Measurement

Corrections & Updates, Letters (Readers Corner)

Battery Discharger/Capacity Meter (2)

Part 2: keyboard, discharger and assembly

Design by B. Stuurman

To enable the control module, described in Part 1, to function as a battery discharger, a number of additional hardware components are required. First, of course, is the keyboard for the entry of data and second, a printed circuit board with the actual discharger itself. A nice design aspect of this project is that the hardware can be tested with the aid of a few diagnostic programs.

Keyboard

A small keyboard is required to enable the entry of user information. Our approach has been a ready-made keyboard with 12 buttons. Each key has an individual as well as a common connection. Because the control module can measure analogue voltages, it suffices to fit a voltage divider for each key. The schematic of this is shown in **Figure 5**. The table below the figure lists the key symbols. The second line indicates the resistor value for each key and the third line shows the resulting hex value that will be obtained when the key is pressed.
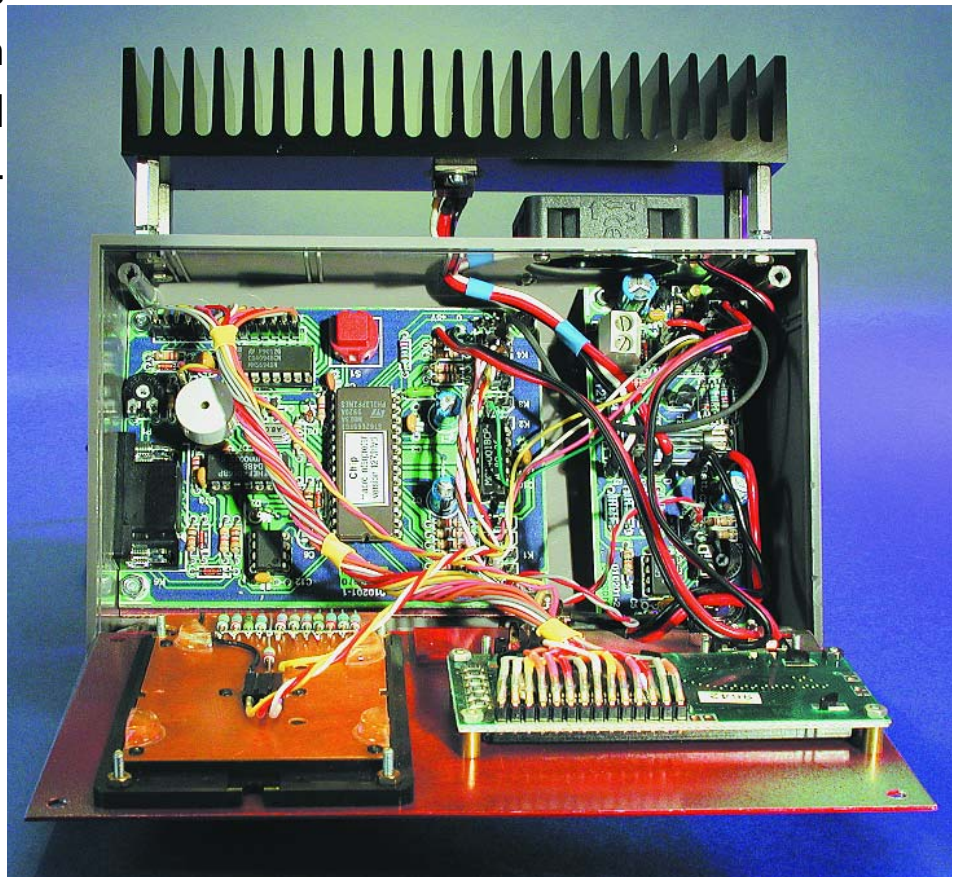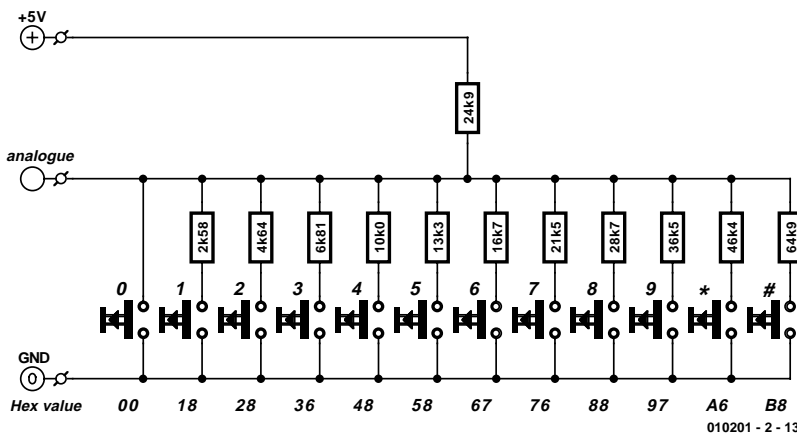
Figure 5. The keyboard with the necessary voltage dividers.

The resistors may be mounted directly on the back of the keyboard. The common connection for the buttons is connected to Gnd. The +5 V supply is connected to the common divider resistor, which has value of 24k7. The other end is connected to the individual key resistors. To the keyboard we fit a 3-core cable with a length of 20 cm, the end of which has a 3-way PCB socket. This socket is connected to Input 0 of the control module.

The proper functionality of the keyboard can be tested with the aid of the program 'KEYTEST.HEX', which can be found on one of the diskettes that belong with this project (see the Parts List). After that program has been loaded, it can be started by typing 'chip'. When no key is held down, the display will show the value 'FF$_h$' or 'FE$_h$'; when a key is held down, the displayed value should be the same as the one listed in the table. The actual value may deviate a little, because only the high nibble is used, the low nibble should be between 5$_h$ and A$_h$.

Discharger

The discharger, the schematic if which can be seen in **Figure 6**, comprises three parts. The upper part serves as the power supply and for the on and off control of the cooling fan. An unregulated mains adapter (6-12 V/300 mA) may be used for the power supply. The regulator (IC1) is a 'low drop-out' type, which will provide 5 volts even when the input voltage is as low as 6 volts. If you use a mains adapter with an adjustable output voltage then you can use this to set the speed of the 12-V fan. The mains adapter is connected to K3, the cooling fan to K2, while K1 is used for the power supply connector from the control module.

The battery voltage is measured at connector K6 (+aV and –aV). A short length of wire links this connector directly to the terminals for the battery, so that the voltage drop across the fuse and current carrying wires does not affect the measurements. The signal at K6 is filtered by R4 and C3 and is subsequently fed to an adjustable attenuator with three ranges: 10.2 V, 20.4 V and 40.8 V. The high value of each range results in FF$_h$ (255$_d$). The attenuator is controlled with Out 0 and Out 1. A reduction in (unnecessary) calculations was obtained by selecting appropriate values for the attenuator resistors. The program 'DIVITEST.HEX' on the diskettes is used to test the attenuator.
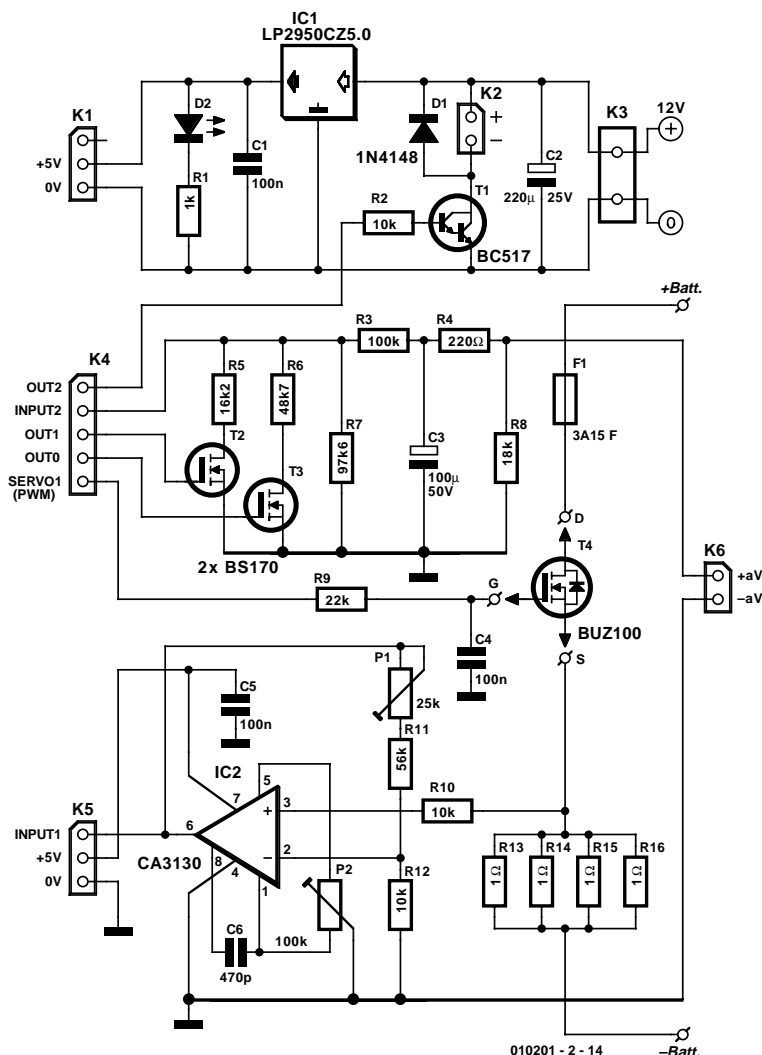

Figure 6. Schematic of the actual discharger. Power-MOSFET T4 does the 'heavy work'.
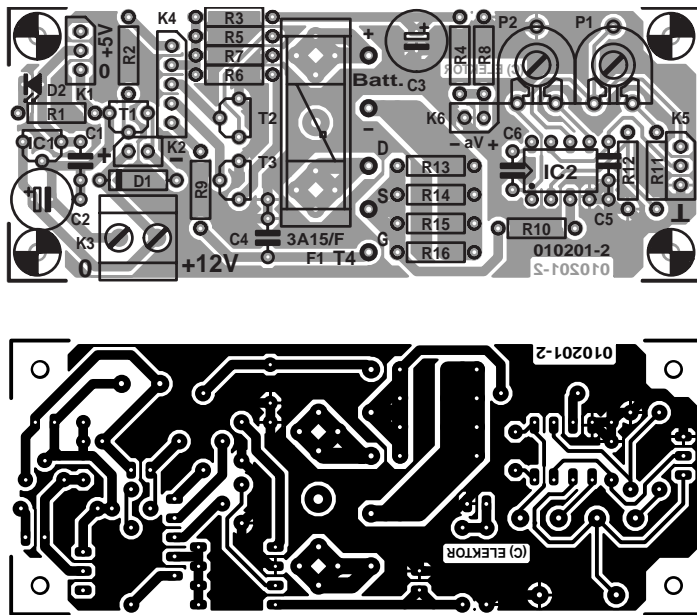
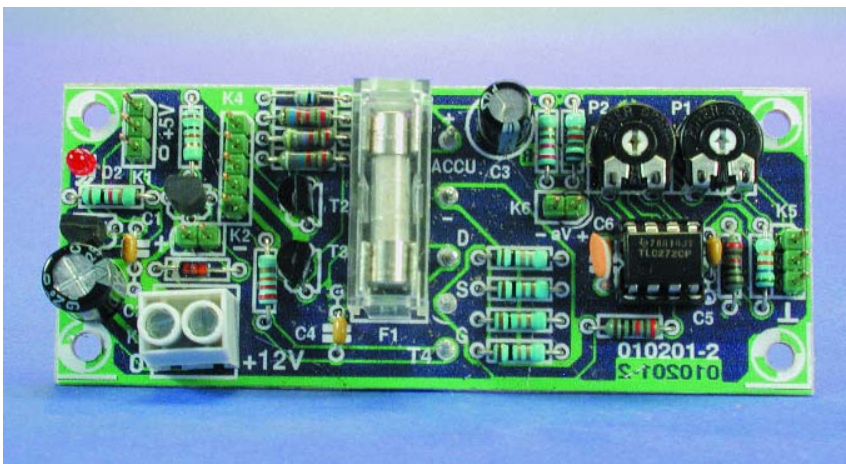Figure 7. Copper-layout and component overlay for the discharger PCB.

Figure 8. This is what the completed discharger PCB looks like.

COMPONENTS LIST
(Discharger board)

Resistors:
R1 = 1kΩ
R2,R10,R12 = 10kΩ
R3 = 100kΩ
R4 = 220Ù
R5 = 16kΩ2
R6 = 48kΩ7
R7 = 97kΩ6
R8 = 18kΩ
R9 = 22kΩ
R11 = 56kΩ
R13-R16 = 1O, 0.5W
P1 = 25kΩ preset
P2 = 100kΩ preset

Capacitors:
C1,C4,C5 = 100nF ceramic
C2 = 220µF 25V radial
C3 = 100µF 50V radial
C6 = 470pF

Semiconductors:
D1 = 1N4148
D2 = LED, red, high efficiency
T1 = BC517
T2,T3 = BS170 (or BSN10A)
T4 = BUZ100
IC1 = LP2950CZ5.0
IC2 = CA3130

Miscellaneous:
K1,K5 = 3-way SIL pinheader
K2,K6 = 2-way pinheader
K3 = 2-way PCB terminal block,
  lead pitch 5mm
K4 = 5-way pinheader
F1 = fuse 3.15 A (fast) in PCB mount holder
PCB, order code **010201-2** (supplied
  together with control board 010201-1)
Diskettes, project software, order code
  010201-11

The remainder of the circuit is for the adjustment and regulation of the discharge current. The Servo 1 output has a PWM signal that is filtered by R9 and C4 and is then applied to the gate of the power-MOSFET (T4). The source connection contains the current-measuring resistors R13-R16. The voltage drop across these is amplified by opamp IC2 and routed, via Input 1 on K5, to the control module. P1 adjusts the gain and P2 is used to compensate for the offset voltage. A variable is used to set the operating range of the PWM. It also shows if the current is stable. It is possible that the MOSFET is unable

to provide the desired current when the voltage is lower than 1 V. In this event, the current variable 'goes through zero' and this is then indicated.

There is an anti-parallel body diode between the drain and source of the power-MOSFET. If, by accident, a battery is connected the wrong way around, fuse F1 will blow and limit the damage. It is important to use a fast fuse here.

The printed circuit board layout and component overlay for the discharger are shown in **Figure 7**. The assembly of the board is self-explanatory. All the connectors are,

again, male PCB headers, with the exception of K3 (screw terminals) and those for the current carrying connections, for which PCB pins are used. Resistors R13-R16 are mounted 4 mm above the board to improve their power dissipation.

With the prototype, the printed circuit board traces that go to the battery terminals were tinned with extra solder in order to reduce their resistance. **Figure 8** shows a correctly assembled example of the discharger PCB.

Assembly

The prototype was successfully housed in a Teko sloping enclosure type 362, but many

other kinds of enclosures are also suitable, of course. The title photograph gives a good indication of how the various components have been fitted inside the enclosure.

The rear panel has a large opening for the airflow from the cooling fan and in the front there are 8 holes, dia. 14 mm, for the air inlet. Both printed circuit boards are mounted to the bottom of the enclosure with the aid of stand-offs. Suitably sized apertures need to be cut in the front panel for the keyboard and the LCD. Additional holes are required for the two slide switches and binding posts (wander sockets). The RS232 connector was mounted on the left-hand side of the prototype enclosure.

The battery discharger is now nearly ready. All that remains are a few interconnections. In order to prevent mistakes, the complete schematic of the necessary wiring is given in **Figure 9**. The lead from the mains adapter is connected to K3 (check the polarity!). Solder three wires to the power MOSFET (use heavy wire for the source and drain connections) with push-on terminals at the other end; these are connected to the terminals for T4. Use the same heavy wire to make the connection between the battery connections on the PCB and the terminals on the front panel. All other interconnects employ connectors, which are cut from a strip of turned pins for PCB mounting. The cable for K6 has two ring terminals at the other end, which (together with the other ring terminals) are bolted to the binding posts. The cooling fan is connected to K2 and the plug from the control module power supply lead goes to K1. A 3-core cable, with a 3-way female header at both ends, is used for the connection between K5 and Input 1 of the control module. This cable also carries the +5-V and 0-V lines. A 5-way female header with 5 individual wires, each with a 1-way female connector at the other end, is connected to K4. These are connected to Out 2, Input 2, Out 1, Out 0 and PWM (Servo 1) respectively. This prevents ground loops.

The final wire that is required, connects K5 on the control module to the slide switch 'Chip-Auto' on the control panel.

Software

The battery discharger has two modes of operation: the command processor can be active or a program can be running. To communicate with the device, or to upload a program, 'CHIPTERM' or 'VBTERM' (Windows version) has to run on a PC and the discharger connected to the serial port. The switch 'Chip-Auto' on the discharger has to be set to the Chip position before it is

switched on.

A program can now be up-loaded by pressing Alt+l. At the bottom of the screen you are prompted for the name of the program. The extension is always 'HEX'. The program is loaded after confirming with enter. By loading the program 'KEYTEST' the keyboard can be tested. The program can be executed with the command 'chip' or by setting the switch 'Chip-Auto' to the 'Auto' position and switching the discharger on.

The voltage divider has to be tested as well. For this purpose we load the program 'DIVITEST' and run it. We connect a voltage of 5 Vdc to the battery terminals. The value on

the display should be 125 (5/10.2 ? 255) with an attenuation of 2. At an input voltage of 15 Vdc the value should be 188 and the attenuation 4. And finally 25 Vdc; the value should be 156 and the attenuation 8. The measured values may deviate by about 2 or 3 units, but if it is more, and the resistor divider values are correct, then it is possible that either T2 or T3 is leaky.

Once all the tests have been completed successfully, the program 'NICADIS' may be loaded. The discharger is now ready for use, with the exception of calibrating the current. Connect a battery pack to the discharger, with an ammeter in

Analysis
of a discharge voltage curve

The curve shown below is the discharge voltage of a 7-cell NiCad battery with a nominal capacity of 1900 mAh. The discharge current was set to 190 mA (0.1 C) and the discharge voltage to 1 V/cell. The battery was fully discharged after 8 hours and 4 minutes. The measured capacity was 1532 mAh. A little bit low perhaps, but then the battery wasn't new any more either.

The curve is as expected, but there is still something strange. At a voltage of 8.4 V the battery pack is empty, the voltage declines rapidly – this much is normal. At 7.1V however, the voltage flattens out. Because the voltage drop has been about 1.3 V it appears that 1 cell has reversed polarity and is accepting a charging current in the wrong direction. Shortly afterwards the end voltage has been reached. Because the discharge current was 0.1 C, it would have been better if the switch-off voltage was set to 1.1 V/cell. In this case no polarity reversal would have taken place.

Lead-acid batteries are more sensitive to polarity reversal than NiCad or NiMH-cells. It is usual to select a switch-off voltage of around 70% to 80% of the nominal voltage, but this is also dependent on the discharge current, of course.

010201 - 16
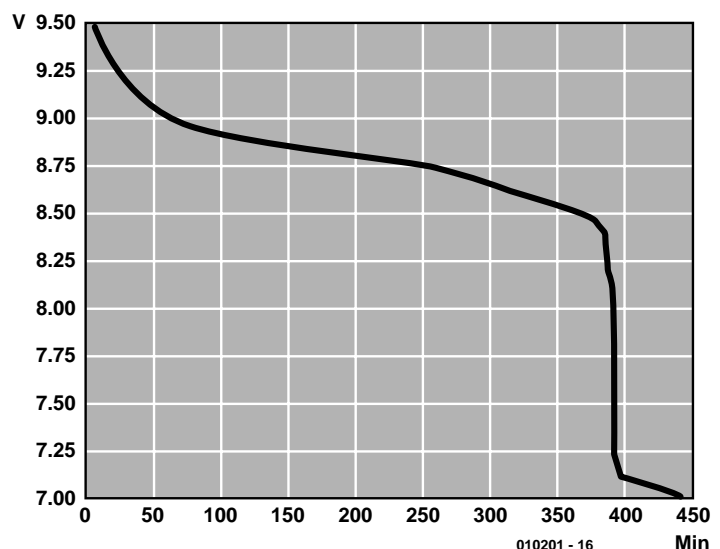
Discharge curve for a 7-cell NiCd-battery pack.

series. Set the number of cells and the voltage per cell as appropriate. Set the current to 2500 mA. Using P1, calibrate the actual current to be 2500 mA. Now set a current of 100 mA, and use P2 to set the actual current to this value. Because of the control loop the readout may fluctuate a little; therefore adjust to a best possible average.

Generating discharge voltage curves

While discharging, a voltage sample is stored in memory every minute. Memory locations 600_h-$7FF_h$ in the EEPROM are used for this. Address 600h contains the attenuator value and 601_h the current value. Once the discharge cycle is completed, these values can be retrieved and stored in a file. To do this, go the command processor and open a .LOG file using Alt+o. By giving the command 'prog 600' the address 600h is displayed on the screen followed by two data bytes. By pressing the '+'-key successive values will appear. Continue until the data byte is equal to 00_h. This indicates that the end of the sample log has been reached and the .LOG file can now be closed with Alt+c. Using the program 'LOGDAT.EXE' the sample values are converted to voltages and numbered. In addition, interpolation is
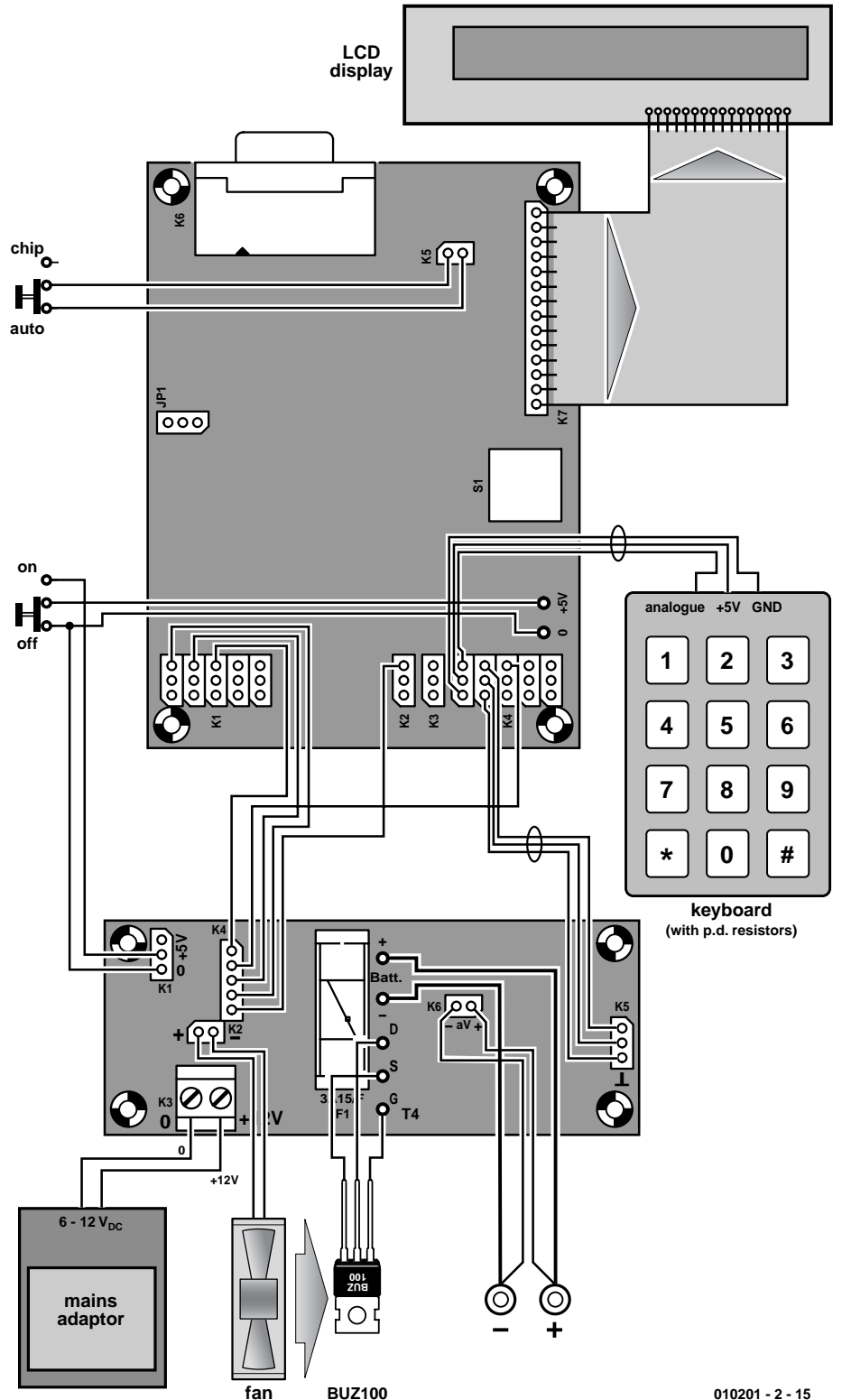
carried out to smooth the curve. At the same time, the average voltage and discharged energy are calculated. The generated .DAT file can

be read by the plot program and be drawn as a discharge curve. The file PLOTR.ZIP contains all the necessary information.

(010201-2)

Figure 9. Wiring diagram for the battery discharger. There are quite a few connections!

COMPONENT LIST
(mechanical)

– enclosure, e.g., Teko desk type 362
– heatsink for T4: Fischer SK132/37.5/SA
– fan, 40 x 40 mm, 12 Vdc
– mains adaptor, 300 mA, 6-12 Vdc,
– binding post, red
– binding post, black
– keyboard, 12 keys, 1 common connection, 12 individual connections, e.g., Display Electronics # 03.52.1252 or Conrad Electronics # 19-55-61
– miniature slide switch, 2 x changeover
– turned pin socket strip, lead pitch 2.54mm

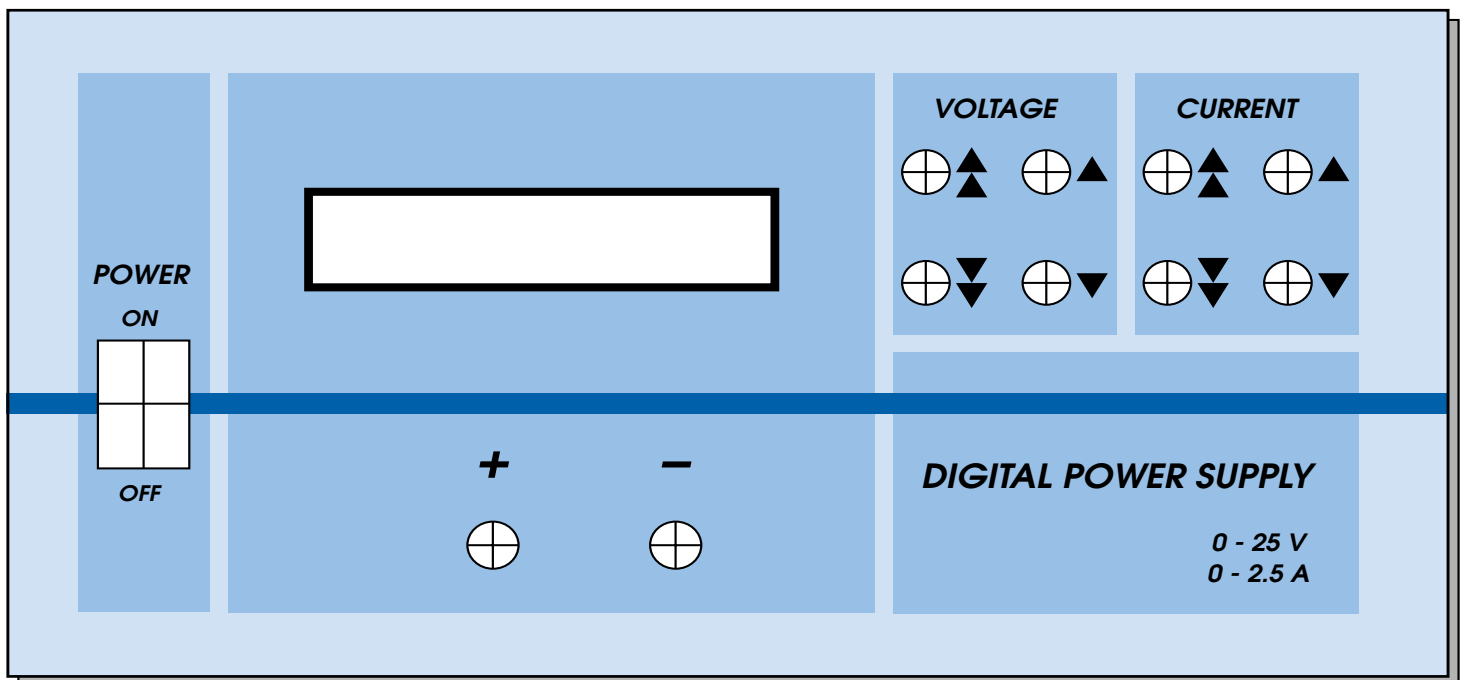# Digital Bechtop Power Supply (2)

Part 2: soldering, sawing and drilling

Design by R. Pagel

The construction of the Digital PSU requires extra care and precision. Just like the electronics inside, the mechanical construction and overall finish of the instrument should meet professional requirements.

000166 - F

Figure 1. Front panel layout for an elegant final appearance.

As indicated at the outset, there are two versions of the power supply that you can build. However, we have decided not to produce special circuit board and front panel layouts for the smaller power supply and concentrated on the larger 2.5 A unit.

For the 2.5 A power supply a metal enclosure 200 mm (width) by 180 mm (depth) by 100 mm (height) and a 24 V 80 VA toroidal transformer are used, with all the parts of the enclosure securely connected to earth. A mains filter must also be fitted, or else the microcontroller may reset in the event of mains interference. The circuit board is fixed to the front panel with bolts, while the base simply carries the toroidal transformer (and possibly also, as shown in the photograph, the mains filter). The heatsink, RS232 connector and next

to that the mains cable with strain relief are fitted to the rear panel. Alternatively, a 'cold condition' IEC mains inlet with fuse carrier can be fitted. Ideally a mains inlet with built-in filter can be used. The specification of the filter we used was 2L=2.4 mH, Y=2200 pF, X2=0.1 µF and R=1.0 MΩ, and the filter must of course have a suitable maximum load specification.

Next we get our hands dirty with the construction of the enclosure. Preparing the front panel in particular demands a lot of work and high accuracy since it constitutes an advertisement for home-built test equipment.

The unpopulated circuit board can be used as a drilling template for the front panel. **Take care to allow an adequate gap (at least 6 mm) between the mains switch connections and the circuit board!** The rectangular hole for the LCD can be carefully cut out using an electric jigsaw or a fretsaw and the
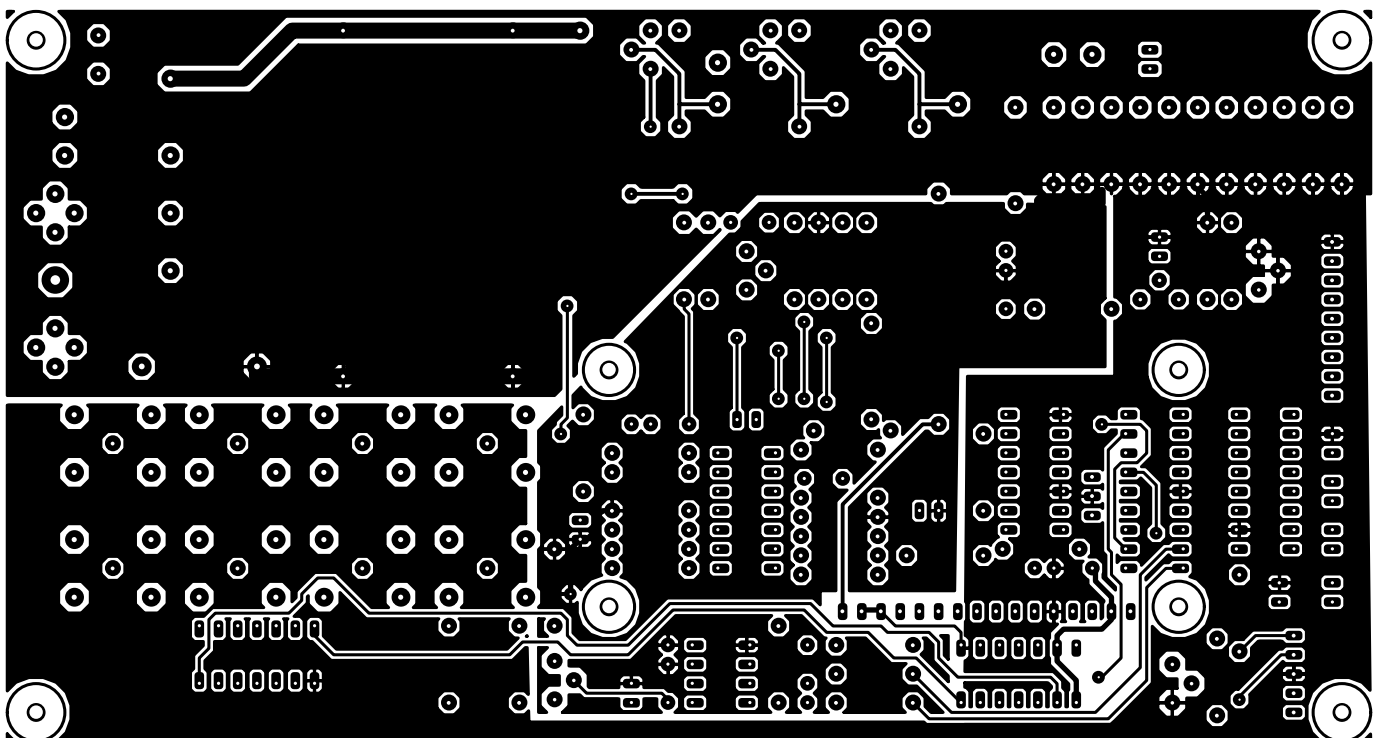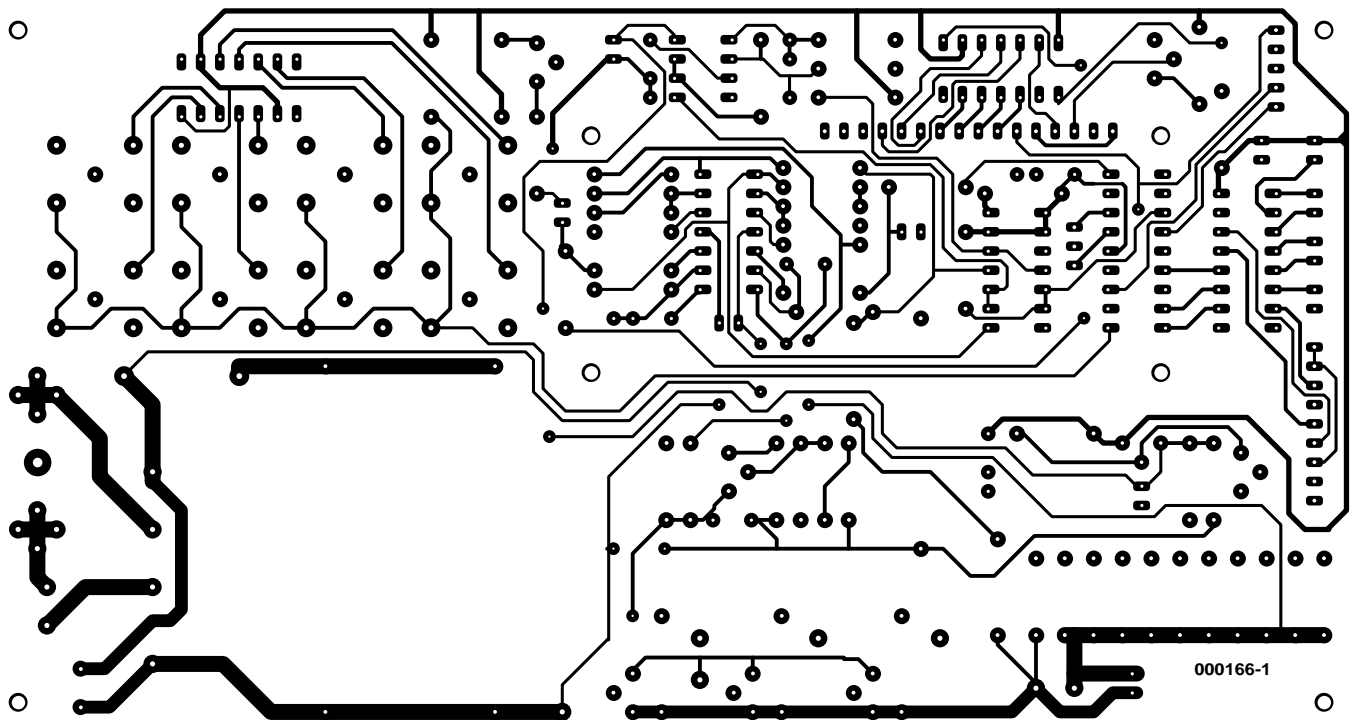

000166-1

Figure 2a. Layout of the double sided circuit board for the power supply.
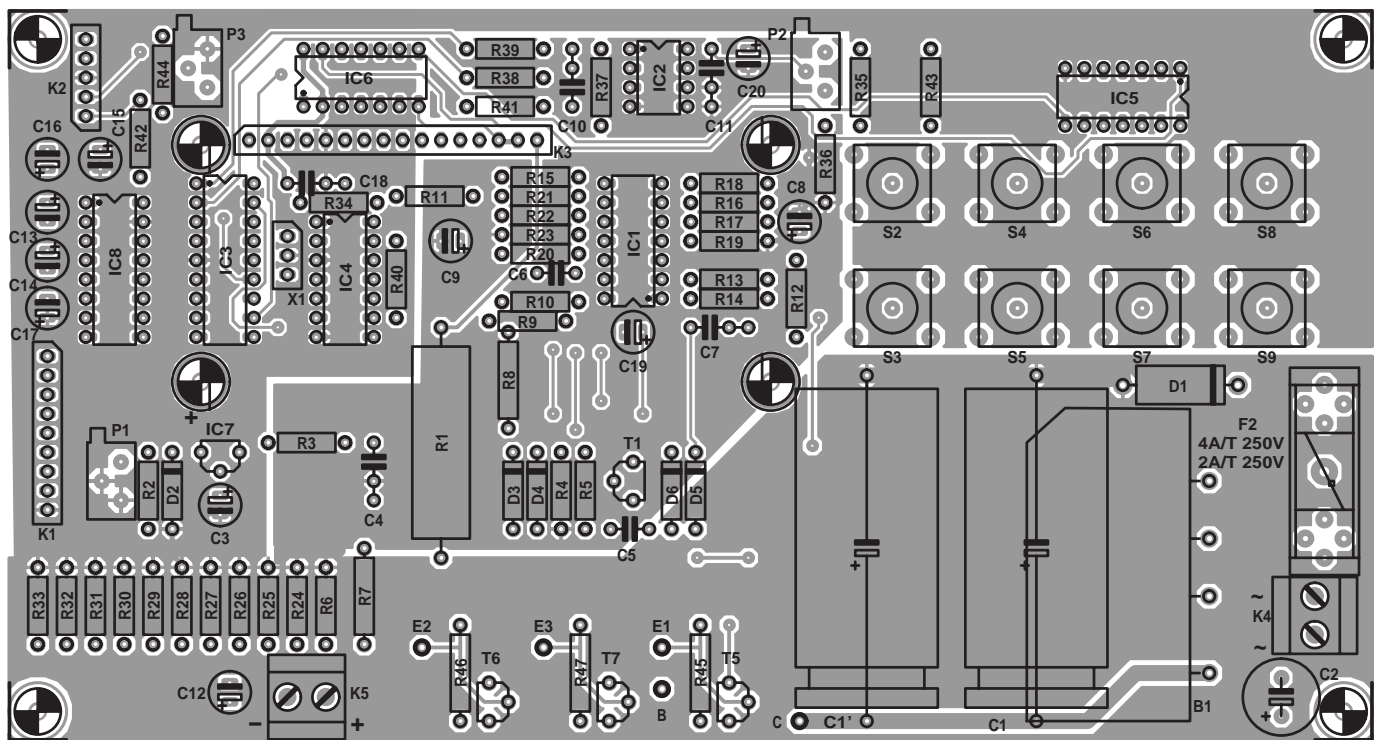
Figure 2b. Component mounting plan of the double sided circuit board for the power supply.

cuts can then be filed straight. If you are not confident of doing a professional job, you can use a display with a bezel to cover the rough edges. Cutting the hole for the mains switch proceeds similarly. Use a taper drill for a circular mains switch. The holes for the push buttons can be drilled out in stages using various twist drills until they have a diameter 0.5 mm bigger than the buttons, and then filed smooth. Then four more holes are required for the mounting screws, which should be countersunk so that the heads of the 3 mm countersunk screws are perfectly flush with the panel. On the rear side fit nuts to the screws as tightly as possible. Since the nuts should not (and indeed, without damaging the front panel, cannot) be undone again it is a good idea to fix the nuts with superglue. The thread should protrude a few millimetres to ensure that the screws have adequate grip. The fixing holes for the two terminal posts must also be suitably drilled.

If the anodised or brushed front panel is presentable (free of scratches and other faults) it can be annotated using rub-down lettering followed with a few coats of protective spray. Alternatively you can make a front panel using the suggested layout in **Figure 2**. Photocopy the layout onto paper at 1:1 scale and apply a few coats of protective spray. Spray from a distance of at least 40 cm to ensure that the toner does not run. When completely dry apply general-purpose glue to the back of the paper and glue it to a sheet of white self-adhesive labels. Thus we have a robust front panel foil which is easy to work with and which, thanks to the self-adhesive labels, will stick firmly to almost any surface.

The foil should not be attached to the front panel until after the power supply has been fully tested. In order to avoid bubbles when attaching the foil, it should always be smoothed out from the centre to the edge. Finally, go over the foil with a rubber roller or a round pencil. The cutouts and holes can now be carefully cut through using a knife. Work only from the front of the foil making many small cuts, especially when making the holes for the push buttons. An alternative way of making front panel foils using a PC and a printer was described in the July/August 2000 issue of *Elektor Electronics*.

Component mounting

After the double-sided printed circuit board has served its purpose as a drilling template, the components can be fitted according to the plan in **Figure 3**. This should proceed without difficulty since there are no surface-mount components, wire links, hairline tracks or tightly spaced solder pads to worry about. The board should be populated in the usual fashion. Before starting to solder,
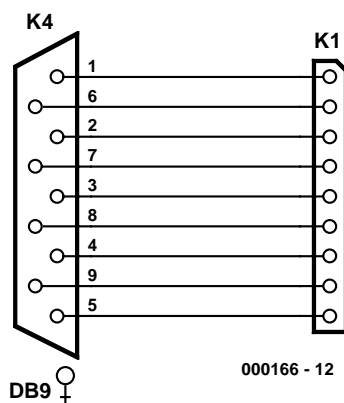

Figure 3. Connections between K1 and the sub-D socket.

COMPONENTS LIST
2.5 A version
(1 A version in brackets)

Resistors:
(* Metal film, 1% tolerance)
R1 = 220Ω, 5W
R2 = 330Ω, 0.5W
R3 = 150Ω
R4 = 100kΩ
R5 = 330Ω (1kΩ8)
R6 = 1kΩ, 0.5 W
R7,R18,R23 = 1kΩ *
R8,R17 = 39kΩ *
R9,R10,R13,R14,R40,R41,R43 = 10kΩ
R11,R12 = 47kΩ
R15,R16 = 10kΩ *
R19 = 8kΩ2
R20,R39 = 1kΩ
R21 = 1kΩ * (0Ω)
R22 = 18kΩ * (39kΩ *)
R24-R34 = 1Ω * 0.6W
R35-R38 = 100kΩ *
R42 = 47kΩ
R44 = 3kΩ3
R45,R46,R47 = 0Ω51, 0.5 W (not fitted)
P1 = 10Ω multiturn preset
P2 = 500Ω preset H
P3 = 2kΩ5 preset H

Capacitors:
C1 = 10,000µF 50V (4,700µF 35V), axial
C2 = 470µF 50V, radial
C3,C13,C14,C15,C16,C17 = 10µF 25V, radial
C4,C7,C11 = 100nF, ceramic, 5mm lead pitch
C5 = 10nF, ceramic, 5mm lead pitch
C6 = 1nF, ceramic, 2.5mm lead pitch
C8,C9 = 10µF, tantalum bead
C10 = 4nF7, FKS-2
C12 = 4µF7 63V, MKS-4

Semiconductors:
D1 = P600D (1N4007)
D2 = zener diode 12V 1.3W

D3,D4,D5,D6 = 1N4148
B1 = B80C5000 (B80C1500)
T1 = BC557B
T2,T3,T4 = TIP142 (1 only)
T5,T6,T7 = BC547B (not fitted)
IC1 = LT1491
IC2 = TLC272
IC3 = PIC16F84A-04P, programmed, order code **000166-42**
IC4 = 4066
IC5, IC6 = 74HC164
IC7 = 78L05
IC8 = MAX232

Miscellaneous:
F1 = Fuse, 2A, time lag
F2 = Fuse, 4A, time lag (2A, time lag)
S1-S8 = pushbutton, C&K 3FTL6 + 1S09 22.5, or general-purpose 10×10×20mm, lead pitch 5mm
TR1 = mains transformer, toroid, 24V, 80VA, e.g. UI 39/1721 V, 2571 mA
X1 = ceramic resonator, 4MHz, 3 pins
LCD module 16×1, with backlight
Fuse holder, PCB mount
Fuse holder, chassis mount, (alternatively IEC mains appliance socket with integral fuse)
Two wander sockets (red, black)
F11 = mains filter, 2A (not fitted)
K1 = 9-way SIL pinheader, with 9-way sub-D socket (female), chassis mount
K2 = 5-way pinheader
K4,K5 = 2-way PCB terminal block, lead pitch 5mm
14-way IC socket with turned pins
18- way IC socket with turned pins
12 solder pins
Heatsink, size 180×75×48 mm, spec 0.6 K/W (100×50×31mm, spec 2.4 K/W)
Enclosure (w×d×h) 200×180×100 mm, e.g. Telet type LC950
Mains switch, mains cord
PCB, order code **000166-1**

make sure that the push buttons stand a good 10 mm higher than the electrolytic capacitors. A few components are soldered to the rear of the board: the bridge rectifier (for reasons of space), the trim potentiometers, the connectors, the solder tags for the transistors and the fuse (so that it can be changed easily). The circuit board connector for the banana sockets is mounted on the component side. The components

under the display, such as C19, must, where possible, be mounted flat.

If you know that you will never want to reprogram the microcontroller on the board, you can of course dispense with the programming connector K2. High-quality sockets should be used, at least for the two expensive ICs, IC1 and IC3. R1, R2 and R6 can get hot and should be fitted raised slightly above

the board. Ensure that any solder flux is removed from the area around IC1, IC2 and IC4 after soldering, to avoid the effect of parasitic resistance.

After checking all the soldered connections the display can be suitably fixed using long bolts. The electrical connections are made using bare wire. Now the whole assembly can be fixed to the front panel, and the transformer and PC interface wired up as shown in **Figure 4**.

The power transistors are fitted with an insulating mica washer and fixed to the heatsink, the module being connected to the main circuit board using three 10 cm long 0.75 mm^2 wires.

Initial operation

Once everything has been assembled and wired together, you will not want to wait a month for the description of the software and operation of the unit; you will want to try your power supply out immediately. With IC1 and the microcontroller not fitted, the mains can be switched on for the first test. As long as no smoke signals are emitted, the unit can be left switched on.

Between pins 4 and 11 of IC1 a voltage of 27 V (for the 1 A power supply) or 32 V (for the 2.5 A power supply) should be measured. There should be a voltage of 12 V across Zener diode D2 and a voltage of 5.1 V between pins 5 and 14 of the microcontroller. If all is well, turn off the power supply and fit the remaining ICs. Turn P2 fully to the left. When the unit is turned on again the display should read:

00.0V   0.00A

When a push button is pressed (or held down) the display should switch to 'set mode' and show the values as they are adjusted either in milliamps or millivolts. To adjust the offset voltage, turn P2 gradually to the right, checking whether the display changes. When the display stops changing, you have gone too far and you should back the potentiometer off a little.

Alternatively, connect a PC to the interface and start up HyperTerminal with the following interface settings

9600, 8, N, 1, hardware handshake

Now adjust the trimmer so that the value represented by the first five digits after the **D** is as small as possible, but not zero. A value of 2 is ideal, since the unit will then continue to operate correctly even if the value should change slightly as a result of ageing, mechan-
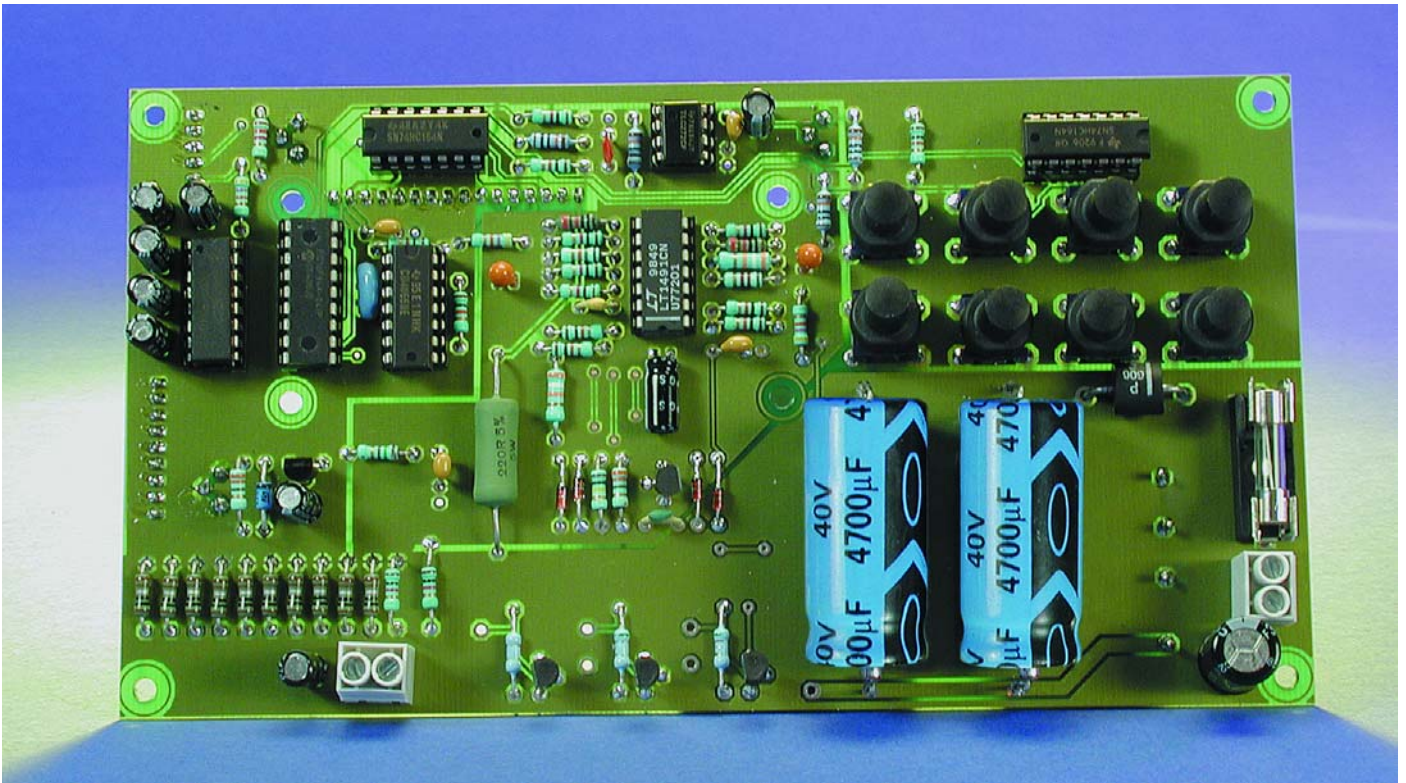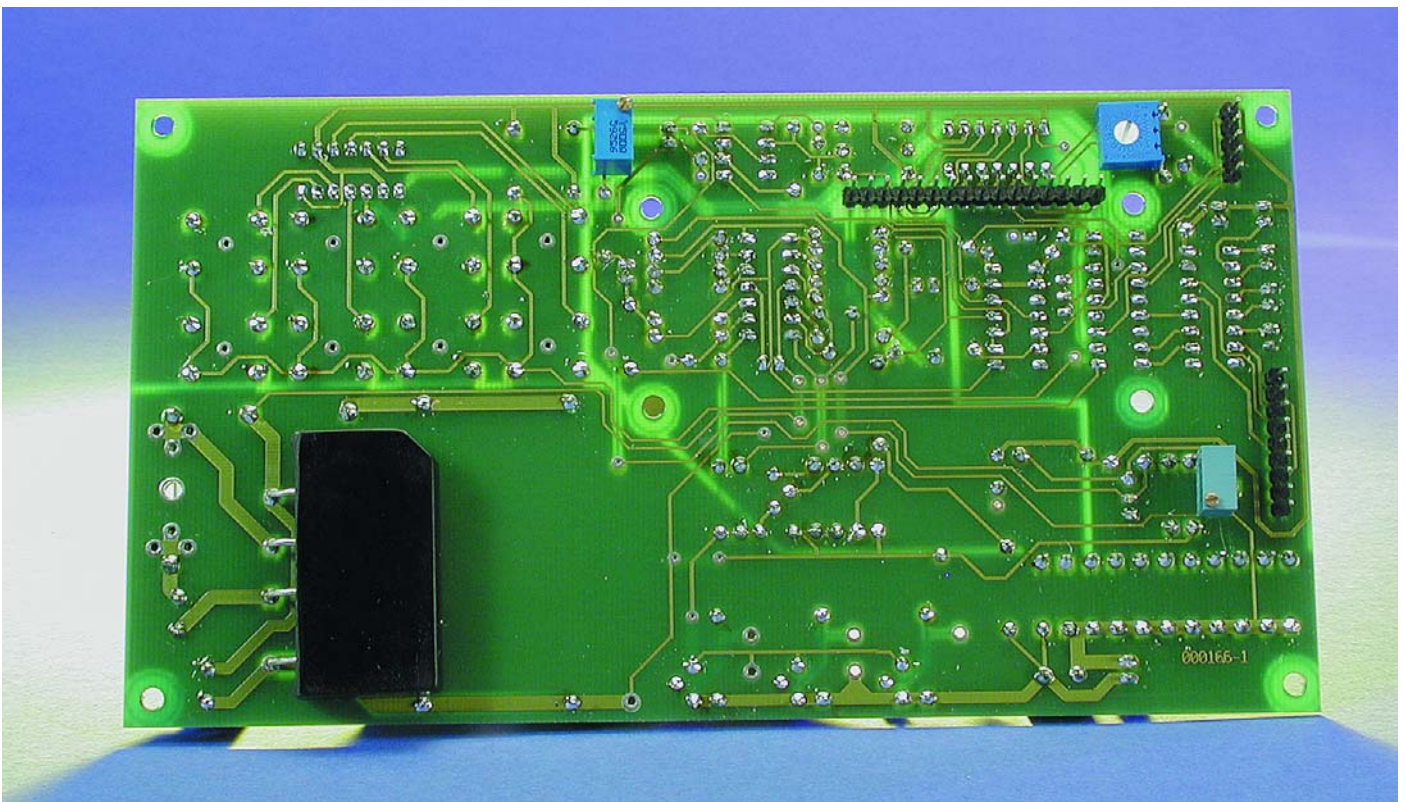
Figure 4. The main circuit board.

ical shock or temperature drift.

After this adjustment the output voltage should be measured with the voltage setting at 0.00 V. It should be 30 mV (±15 mV). Next set the voltage to 19.0 V and adjust P1 for an actual output voltage of 19.03 V. The output current adjustment and its displayed values will then automatically be correct. If the values are awry, or the above values cannot be achieved, the first thing to check is that all the components are correctly fitted and that there is no solder residue between the tracks.

(000166-2)

Digitising Video Imagery

everything together on a single site

By Harry Baggen

Making your own video CDs is a popular subject among computer users. Regardless of whether you're dealing with your own recordings or converting videotapes or DVDs to CD format, a considerable amount of expertise and software is always necessary to achieve good results.

Digitising video recordings and converting digital imagery from one medium to another are currently very popular, partly due to the fact that these days (almost) everyone has a fast computer and a CD burner. But even with a super-fast computer, digitising analogue video imagery or converting one format to another one can take hours or even days, so you can hardly consider it to be truly fast. On top of this, there are so many different formats that you need a fairly hefty collection of programs to obtain the proper result, not to mention all the settings, which can sometimes be difficult to understand.

The Internet is flooded with sites dealing with this issue, and computer magazines regularly dedicate long articles to the subject. That is not what we want to do here; instead, this time we limit ourselves to a single site that actually provides everything that a novice or experienced image manipulator needs: VCDHelp.com.

As the name suggests, this site provides information and help, in the broadest sense of the words, for making video CDs. There are sepa-

rate sections for video CD (VCD), Super Video CD (SVCD), eXtended Video CD (XVCD) and DVD RW. Detailed manuals provide step-by-step instructions for making a VCD, SVCD or SCVD from a video recording and identify the necessary programs. The conversion of a DVD to a to a VCD, SVCD or XVCD is also dealt with in detail (we naturally assume that your are making a copy for your own use, as is legally allowed).

We have already mentioned that the digitising and conversion of video recordings is extremely compute-intensive. A very handy feature is the comparative tables that list the quality and conversion speed of the best-known conversion programs, for instance from AVI to MPEG1 or MPEG2.

There list of programs for video editing is very long. VCDHelp does not deal with all of them, but the most important programs are described and there are links to sites where they can be found.

There is even more to be found on this site. For example, if you are in the market for a video capture card, you will find a summary of a number of cards with their most important features. There are even test reports for a number of cards!

There is also a compatibility list of stand-alone DVD players, which indicates which ones are suitable for playing back various types of video CDs.

In addition, there is an overview of modification possibilities for DVD players to make them suitable for playing back more than one region code.

Fans can make use of a forum and an extensive FAQ section to exchange information or search for information on particular subjects.

Perhaps you're not particularly interest in all of this? Then you should at least read the latest news on the home page in order to keep abreast of what's happening in the (digital) video area.

(015108-1)

Internet address:

www.vcdhelp.com

Voltage Tester for Model Batteries **001**

014071-1

014071 - 11
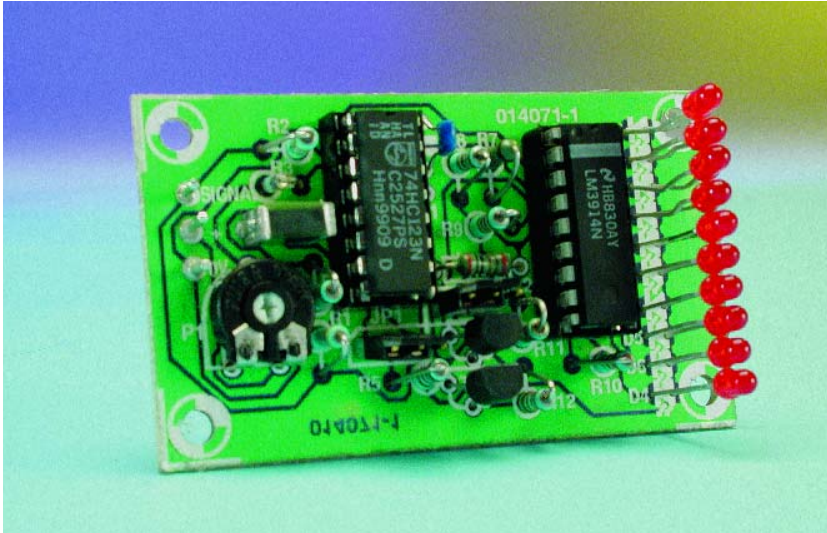
With a suitable load, the terminal voltage of a NiCd or lithium-ion battery is proportional to the amount of stored energy. This relationship, which is linear over a wide range, can be used to build a simple battery capacity meter.

This model battery tester has two functions: it provides a load for the battery, and at the same time it measures the terminal voltage. In addition, both functions can be switched on or off via a model remote-control receiver, to avoid draining the battery when it is not necessary to make a measurement.

The load network, which consists of a BC517 Darlington transistor (T2) and load resistor R11 (15 Ω / 5 W), is readily evident. When the load is active, the base of T1 lies practically at ground level. Consequently, T1 conducts and allows one of the LEDs to be illuminated.

The thoroughly familiar voltmeter circuit, which is based on the LM3914 LED driver, determines which LED is lit. The values of R6 and R7 depend on the type and number of cells in the battery. The objective here is not to measure the entire voltage range from 0 V, but rather to display the portion of the range between the fully charged voltage and the fully discharged voltage. Since a total of ten LEDs are used, the display is very precise. For a NiCd battery with four cells, the scale runs from 4.8 V to 5.5 V when R6 = R7 = 2 kΩ. The measurement scale for a lithium-ion battery with two cells ranges from 7.2 V to 8.0 V if R6 = 2 kΩ and R7 = 1 kΩ.

For remote-control operation, both jumpers should be placed in the upper position (between pin 1 and the middle pin). In this configuration, either a positive or negative signal edge will start the measurement process. A positive edge triggers IC1a, whose output goes High and triggers IC1b. A negative edge has no effect on IC1a, but it triggers IC1b directly. In any case, the load will be activated for the duration of the pulse from monostable IC1b. Use P12 to set the pulse width of IC1a to an adequate value, taking care that it is shorter than the pulse width of IC1b.

If the voltage tester is fitted into a remote-controlled model, you can replace the jumpers with simple wire bridges. However, if you want to use it for other purposes, such as measuring the amount of charge left in a video camera

014071-1

014071-1 (C) ELEKTOR
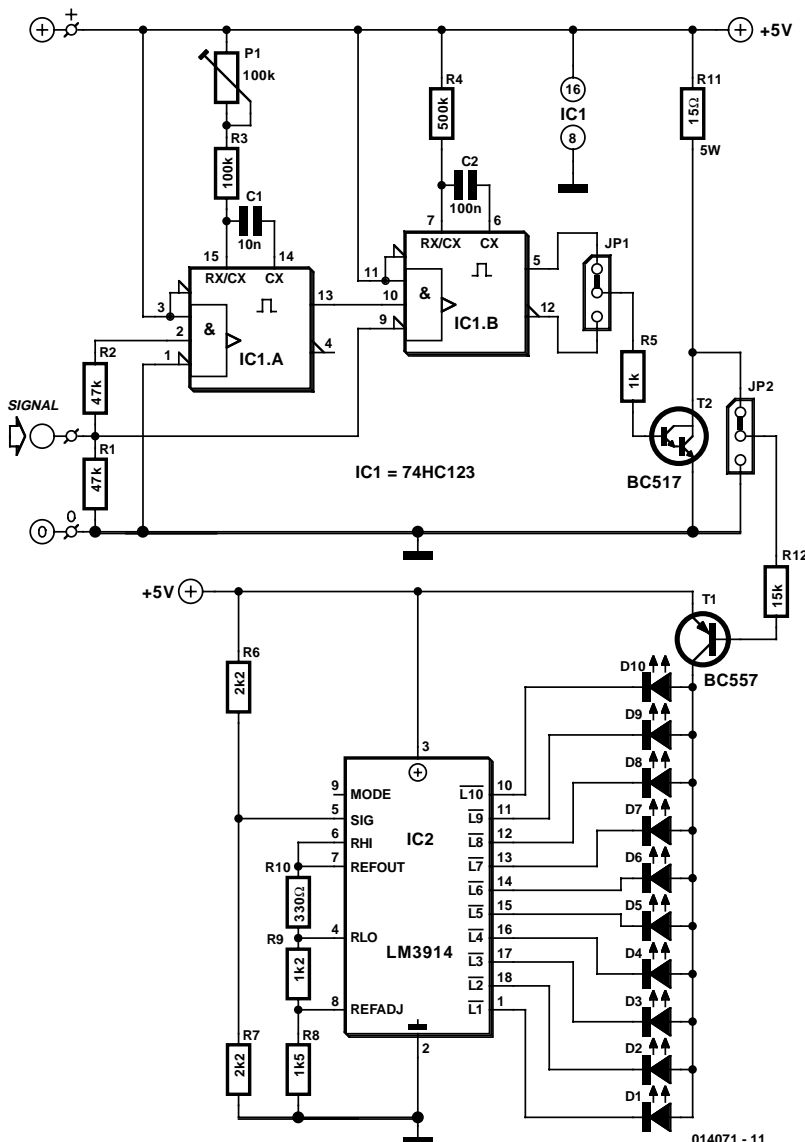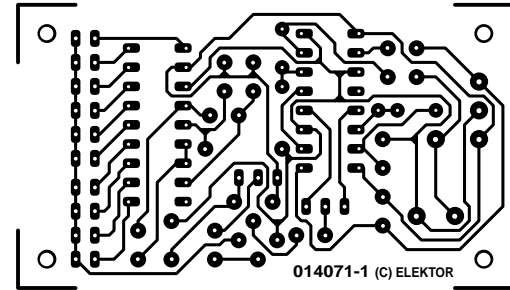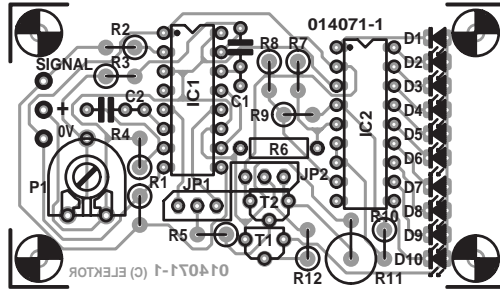
COMPONENTS LIST

Resistors:
R1,R2 = 47kΩ
R3 = 100kΩ
R4 = 500kΩ
R5 = 1kΩ
R6,R7 = see text (1% resis-
tors!)
R8 = 1kΩ5
R9 = 1kΩ2
R10 = 330Ω
R11 = 15Ω 5W
R12 = 15kΩ
P1 = 100kΩ preset

Capacitors:
C1 = 10nF
C2 = 100nF

Semiconductors:
D1-D10 = LED, red, high effi-
ciency
T1 = BC557

T2 = BC517
IC1 = 74HC123
IC2 = LM3914AN

Miscellaneous:
PC1,PC2,PC3 = solder pin
JP1,JP2 = jumper or pushbut-
ton

battery, it is recommended to connect double-throw push-button switches in place of JP1 and JP2. The normally closed contact corresponds to the upper jumper position, while the normally open contact corresponds to the lower position.

(014071-1)

Twilight Switch

002

Nowadays, you do not actually need to build twilight switches yourself, since they can be purchased quite inexpensively. However, if you enjoy doing so and you perhaps already have the parts on hand (cannibalised from a ready-made unit?), then who's to stop you? In addition, if you do it yourself you have the unique opportunity to make some-

thing that exactly matches your own taste and wishes. Building a twilight switch is certainly not difficult, as is illustrated by the design presented here. It uses the well-known 555 IC (here in the economical CMOS version), which has a trigger input with hysteresis ('on' at 2/3 of the supply voltage, 'off' at 1/3) and an internal flip-flop as a memory element. The 555 output can switch up to 100 mA, which is adequate for driving a relay. When it becomes dark, the resistance of the LDR (R1) increases and the voltage on pins 2 and 6 of the 555 rises. When it reaches 2/3 of the supply voltage level (which depends on the setting of P1), the relay is engaged and the load is switched on.

Since relay contacts are used for switching, the load can also be inductive (which means that you can also connect an energy-saving (PL) lamp or a halogen-lamp trans-

COMPONENTS LIST

Resistors:
R1 = LDR
R2 = S10K250 varistor
R3,R4 = 470Ω
R5 = 10Ω 1W
P1 = 100 k preset H

Capacitors:
C1 = 100nF
C2 = 100µF 16 V radial
C3 = 470nF 250VAC,
  class X2
C4 = 470µF 16V radial

Semiconductors:
D1,D3 = zener diode 12V
  1W
D2,D4 = 1N4004
D5 = 1N4001
IC1 = 555C

Miscellaneous:
Re1 = 12-V-relay, e.g.,
  Siemens V23057-A2-A101
K1,K2 = 2-way PCB
  terminal block, lead pitch
  7.5 mm

former). Although the relay can switch up to 4 A, it is a good idea to keep the load current under 1 A, since the tracks on the circuit board cannot handle more than this. The circuit board layout shown here is anyway intended primarily as an example. Space for the lamp fitting has intentionally been left in the middle of the circuit board.

Since the circuit is connected to the mains network, you naturally have to give suitable regard to safety when fitting it into a fixture. With an earthed fixture, ensure that the insulation clearance is at least 3 mm; for non-earthed fixtures it must be at least 6 mm. Also fit a cover plate, to prevent accidental electrocution when replacing the bulb. Always switch off the mains voltage before using P1 to adjust the light sensitivity!

In many cases it will be necessary to provide a small (watertight!) window for the LDR, such that daylight can fall on it but it is screened from the light of the lamp. The shell of a pilot lamp can often be used for this purpose. Use a medium-sized, encased LDR (approximately 1 cm diameter). Without a case, the LDR would not be able to achieve

014040 - 11

high enough resistance in damp weather.

The relay is a Eurocard type with a coil voltage of 12 V. It draws around 37 mA. A 230-VAC VDR is connected across the contacts. This is a voltage-dependent resistor that acts somewhat like a bi-directional Zener diode and suppresses voltage spikes when the load is switched off. Larger or smaller types can also be used, as long as they are suitable for 230-V operation. An S5K250 or S20K250 could thus be used instead.

(014040-1)

Fundamental/Overtone Crystal Oscillator

The schematics show two crystal oscillator circuits constructed using the high-speed LT1394 comparator from Linear Technology (www.linear-tech.com). In each case the crystal is in the positive feedback path, while in the negative feedback path an RC network provides the necessary phase lag.

Circuit (a) is designed to use AT-cut crystal oscillating at its fundamental frequency and is suitable for operation over a frequency range from 1 MHz to 10 MHz.

Circuit (b) includes the RC network consisting of R4 and C3, which reduces the gain as the frequency rises by increasing the loading on the positive feedback path correspondingly. In this way oscillations at higher multiples of the fundamental frequency are suppressed, although the wanted third harmonic must not be unduly damped. This circuit is designed to use AT-cut crystals between 10 MHz and 25 MHz.

(014110-1)
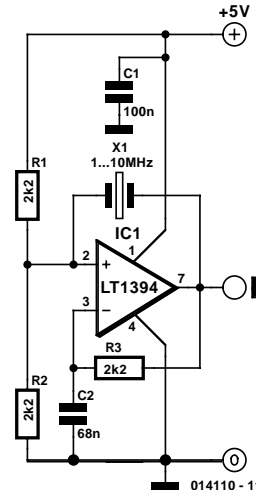
(a) Q1 = AT-cut crystal for operation at a fundamental frequency in the range 1-10 MHz
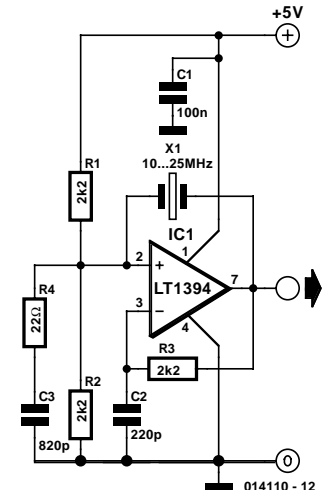
(b) Q1 = AT-cut third-overtone crystal for operation in the range 10-25 MHz

PC-to-PC
with Two Printer Cables

004

1a

2a

014117 - 11
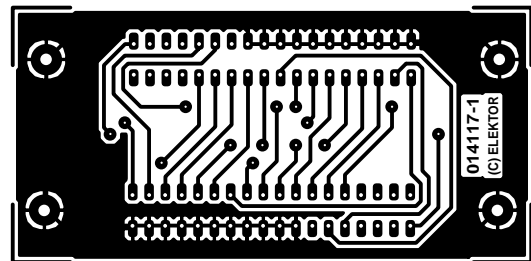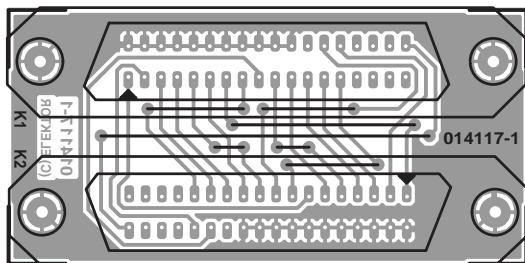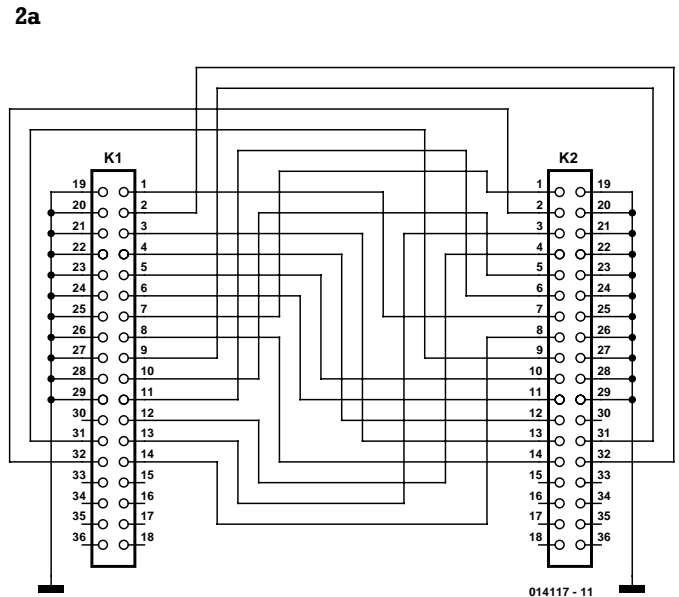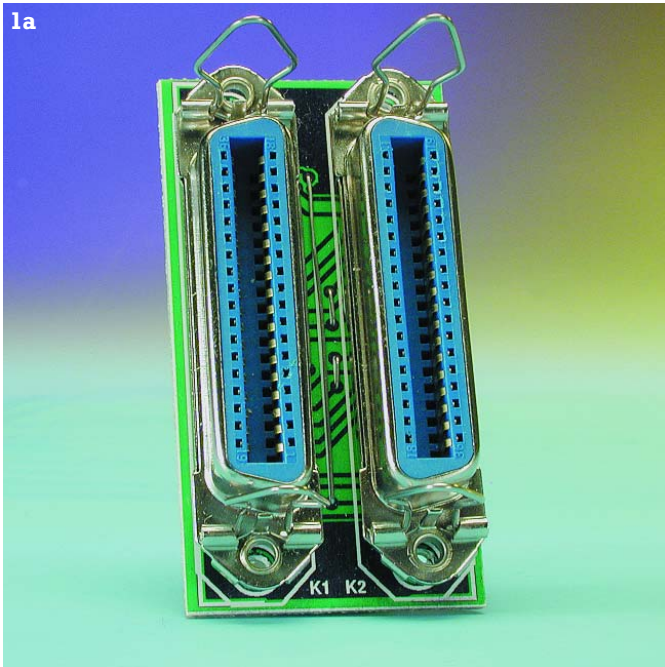
A special cable known as Interlink or Laplink is usually necessary for a 4-bit direct cable connection between two computers. Using a small adapter between two printer cables or a different adapter between computer and printer cable can also accomplish this type of connection.

The first adapter (**Figures 1a** and **2a**) contains two 36-way Centronics connectors with crossed connections and is intended to connect two printer cables together. In order to make a compact assembly, vertical connectors have been used, but right-angle connectors may be used as well. The second (**Figures 1b** and **2b**) is fitted with right-angle connectors because it is intended to be plugged into the back of a PC. Both layouts also contain additional crossed connections for 8-bit communications (Norton Commander, for example). Only one connection is missing from each connector: 'Initialise printer' (pin 16 of 25-way Sub-D, 'Input prime' pin 31 of Centronics) to 'Data7' (pin 9 on both connectors). Normally these are joined within each

connector, in this case however this line has been cross connected to the opposite connector, because some cables were found to have this. It may take some trial and error to

Table 1 Adapter 1 (2 x Centronics)

Conn.1	Conn.2	Conn.1	Conn.2
1	7	11	6
2	32	12	4
3	13	13	3
4	12	14	8
5	10	31	9
6	11	32	2
7	1	36	36
8	14	19 - 29	19 - 29 (GND)
9	31	*Other pins not connected*	
10	5	*(15/16/17/18/33/34/35)*	

1b

2b

014117 - 12

014117-2

014117-2 (C) ELEKTOR
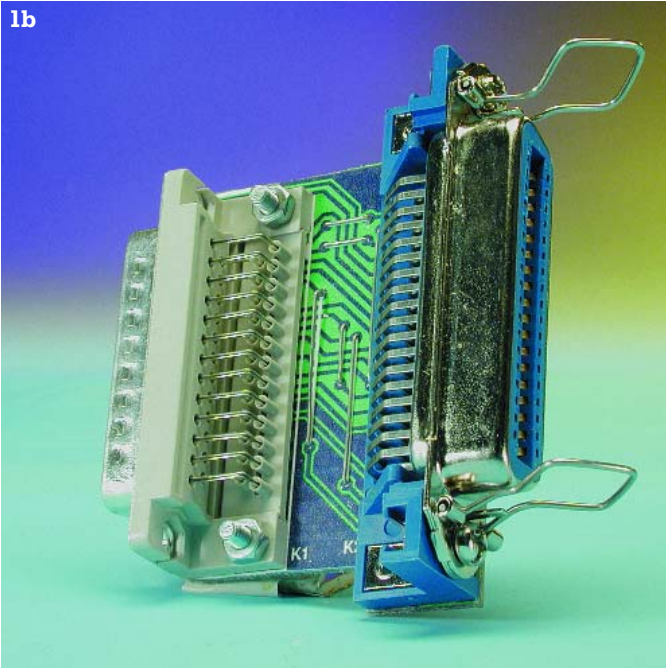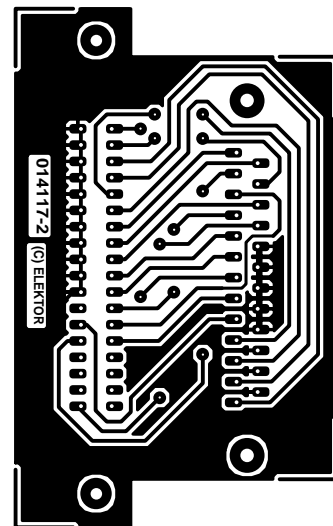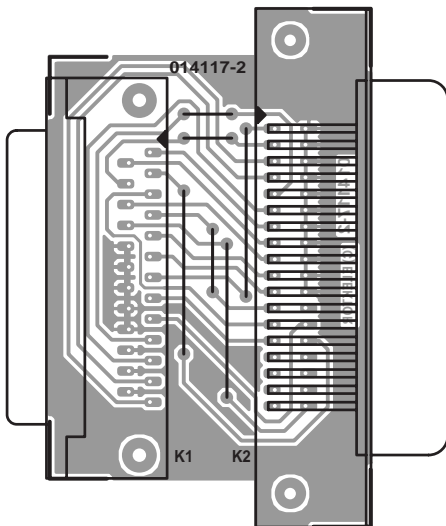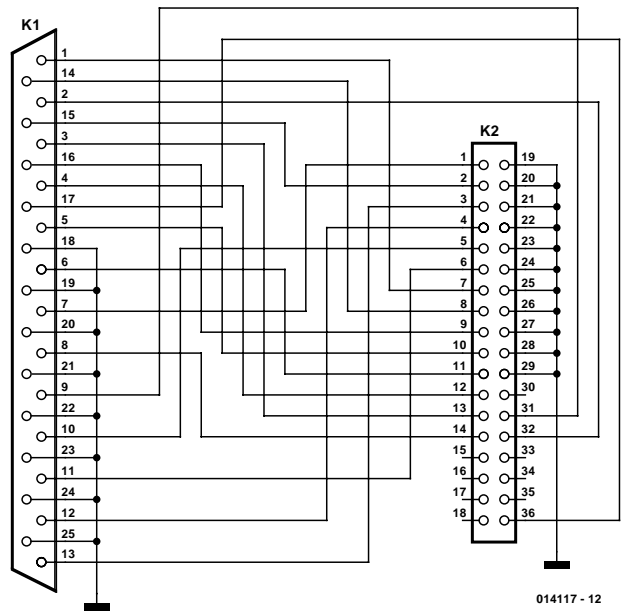
establish if this connection is really necessary for 8-bit communications.

Both adapters have been tested between a 40 MHz 486 with Windows 95 and a standard printer port, and a 166 MHz Pentium with Windows 98 and an EPP/ECP-compatible printer port. A warning: the installation of a direct cable connection with either operating system is anything but easy. The Internet contains various information sources and FAQs, also have a look at www.lpt.com. We also refer you to two articles in previous *Elektor Electronics* issues: 'a cable for all occasions' in the PC Topics section of the November 1999 issue and 'a simple PC network' in the PC Topics section of February 1998. Two tables with the necessary interconnections may be easier to understand than the schematics.

(014117-1)

Table 2 Adapter 2 (25-way Sub-D to Centronics)

D25	Centronics	D25	Centronics
1	7	12	4
2	32	13	3
3	13	14	8
4	12	15	2
5	10	16	9
6	11	17	36
7	1	18 to 25	19 to 29 (GND)
8	14		
9	31	*At the Centronics -connec-*	
10	5	*tor end pins 15 to 18/30/33/*	
11	6	*34/35 are not connected.*	

Electronic Code Lock

005
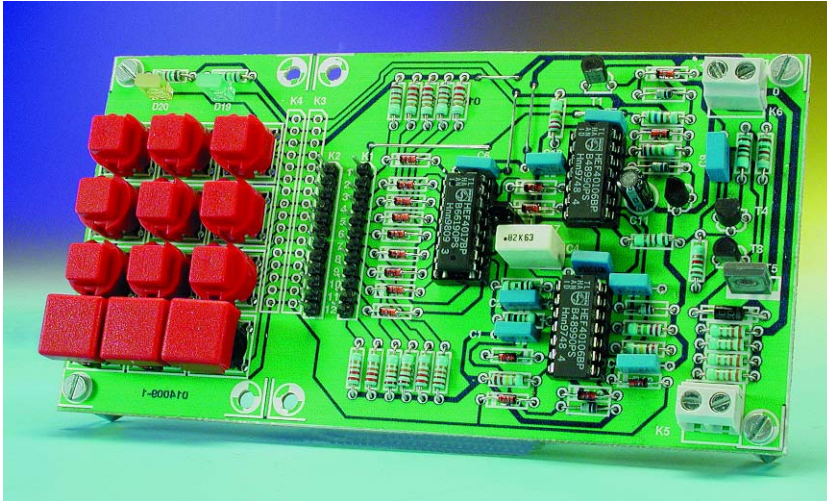
R. Heimann

Nowadays, electronic code locks are usually based on microcontrollers. However, if you like your electronics discrete, you will enjoy the battery-operated circuit shown here. Since the circuit automatically switches off after the door has been opened and draws no current in the idle state, three alkaline batteries (mignon, AA or R6 cells) are good for around 5,000 door openings. The main advantage is that the door opener can also be powered from the battery, so it's not necessary to run any extra cables.

Figure 1 shows the schematic diagram of the circuit, which is split into two parts. The first part is the control panel, which consists of a 12-position keypad and two LEDs. The second part is the programming and evaluation logic, which contains only standard logic ICs. The control panel is connected to the logic board by a 16-way flat cable. The keypad circuit is laid out with separate connections to the individual switches, instead of a matrix. The code is programmed using the two pin connector strips K1 and K2.

The circuit allows any desired combination of numbers to be used for the code, up to a maximum of 9 positions. Pressing a particular button, which in principle is random but which naturally must be specified in advance, awakens the circuit from the zero-current idle state. This Start button cannot be used in the subsequent code sequence. The Start button is programmed by connecting a wire bridge from the associated pin of K2 to pin 1 of K1.

The code sequence is programmed in a similar manner. The first numeral of the code is programmed by connecting the associated pin of K2 to pin 2 of K1, the connection for the second numeral is made to pin 3 of K1, the third to pin 4 and so on. Numerals that are not used in the code do not actually have to be connected. However, if the unused buttons are connected to V_{DD}, the code lock will assume that an error has occurred if any of these buttons is pressed

and will reset the circuit.

Pressing the Start button switches on transistor T1, which connects the supply voltage source to the code lock. This is indicated by the yellow LED (D20). Since the logic ICs are now enabled, the output of IC3f will be High, so T2 also conducts and pulls the base of T1 to ground. This means that the Start button can be released without affecting the circuit. However, C11 can now slowly charge via the high resistance of R12 until the voltage at the inverter input is high enough to cause its output to go Low, which interrupts the supply voltage to the circuit and puts it back into the idle state. The valid code must therefore be entered during the time interval determined by this R–C time constant. Once the supply voltage is disconnected, C11 discharges rapidly via D18. This is important, since otherwise C11 could retain its charge for a long time. This would make the time allowed for entering the code significantly shorter the next time the lock is used.

Pressing the Start button also has other consequences. Via the Start switch, ground potential arrives at IC2d, where it causes a pulse to be generated that places counter IC1 in a defined state (Q0 = 1) prior to the entry of the first code numeral.

The first code numeral can now be entered. If the correct button is pressed, the High potential from Q0 passes through the closed switch to reach IC2d–IC2a. This network generates a positive pulse at the instant that the button is released. This pulse clocks the counter, so that the High level from Q0 moves by one position to Q1. This process repeats itself until all code numerals have been entered.

After the ninth numeral has been entered, the positive voltage jumps to Q9, where it charges C4 (if jumper JP1 is installed). While C4 is charging, the output of IC2e goes Low for approximately two seconds, and the output of IC3d goes high for the same interval. Power transistor T5 is switched on via R19 and T4 to supply current to the door opener. At the same time, IC3a switches on the green LED (D19) to indicate that the door can be opened. T3 limits the current through the door opener to around 700 mA.

Once C4 is sufficiently charged, the output of IC2e changes to High. Not only does this switch off the door opener, but the positive edge also generates a pulse in the network IC2f/IC3c that passes through D14 to reach IC1 as a reset pulse (D14, D17 D13 and R7 together form a 'wired-or' gate). Inverter IC3b also provides the power-up reset to the counter. The reset signal places the circuit back into its initial state.

What happens if an incorrect button is pushed? In such a case a Low level is passed through in place of the High level from the counter output. This has the same consequence as the Low level from the Start button: the counter is reset.

Note that you can also modify the circuit to use fewer than nine numerals for the code. All that is necessary is to connect C4 via a jumper to another counter output in place of Q9 (for example, to Q4 for a four-position code). The diode at the selected output of the counter can be replaced by a wire jumper, and the 'higher level' diodes can also be omitted.

The active 'on' time of the door opener is 2 s. If this seems to be too short, the value of R8 or C4 can be increased. However, this also increases the amount of power drawn from the battery, especially considering that the door opener is by far the biggest power glutton in the circuit. In order to integrate the circuit into an existing door opener or to use it to operate an ac door opener, you should connect a relay to K5.

Before assembling the circuit using the printed circuit board shown in **Figure 2**, you should separate the two sections by sawing between K3 and K4. The logic board should not be fitted directly behind the pushbuttons for entering the code. Instead, it is better to separate the entry pushbuttons, the LEDs and the door opener from the logic
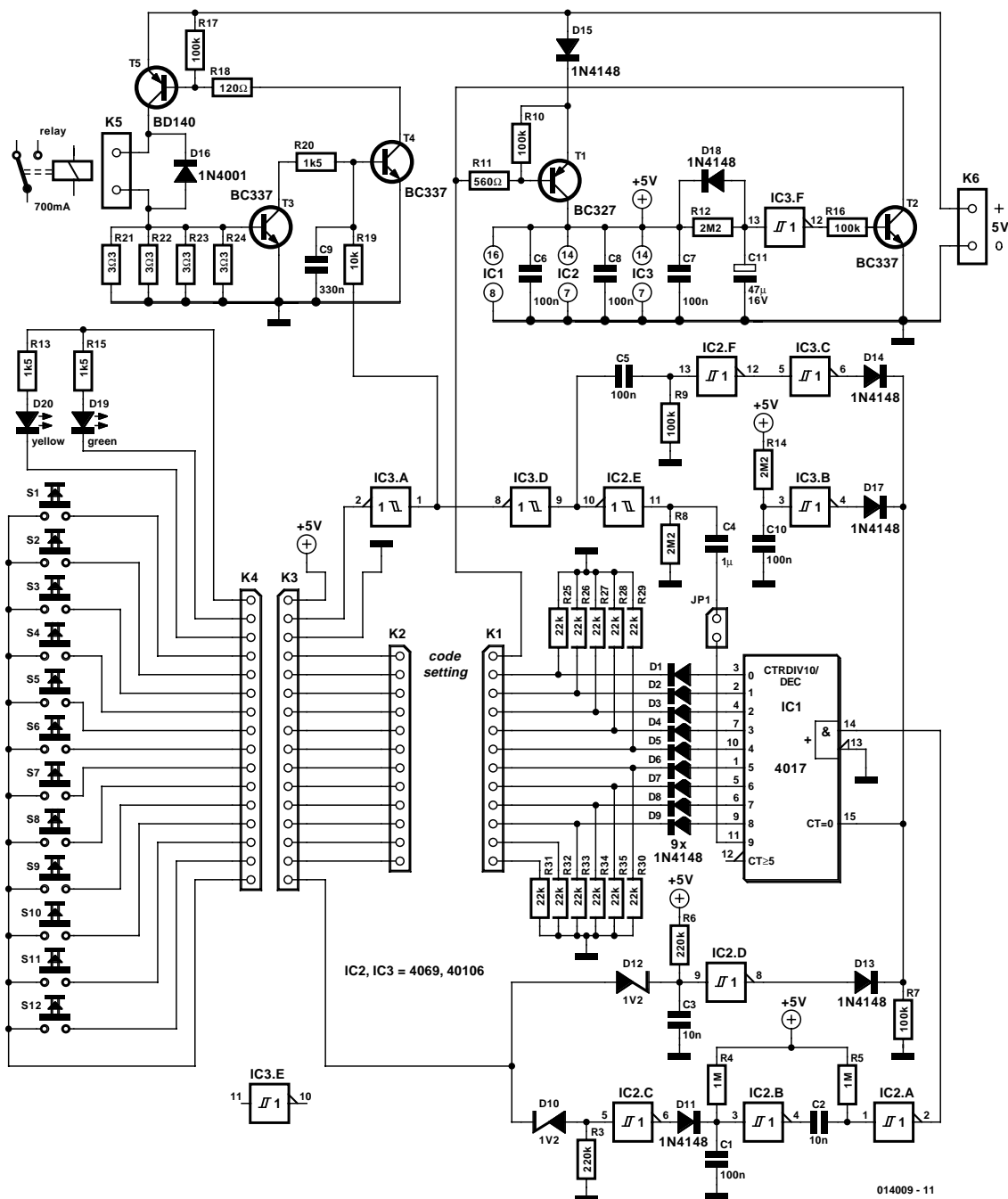
014009 - 11
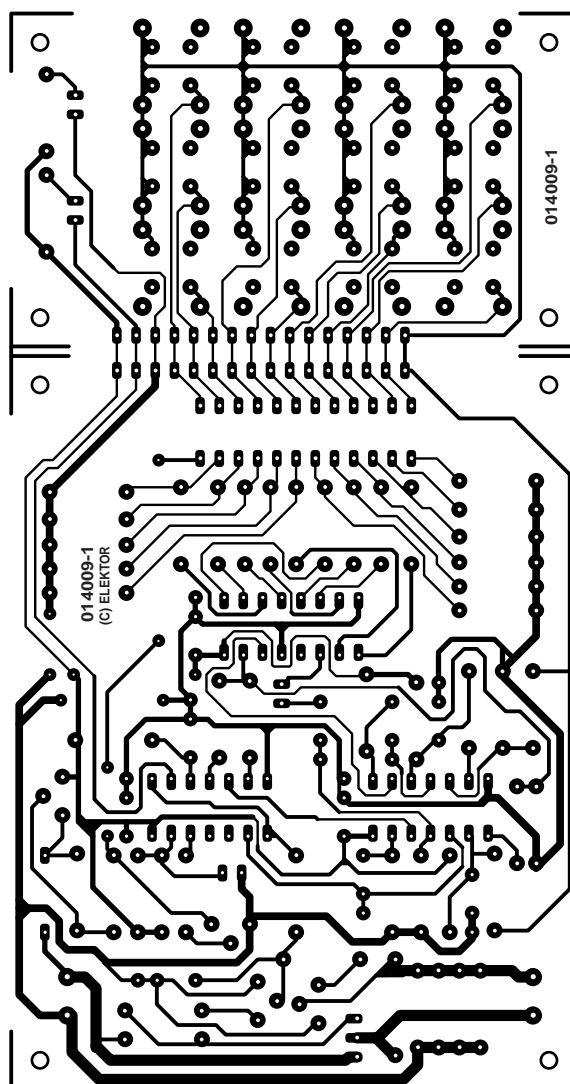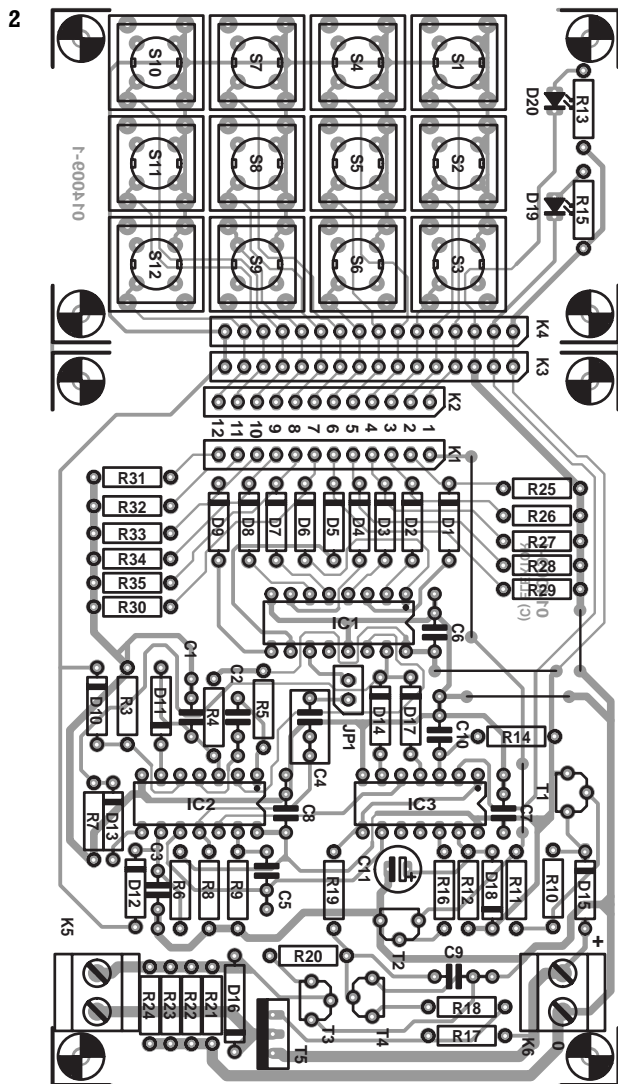
COMPONENTS LIST

Resistors:
R1,R2 = not fitted
R3 = 220kΩ
R4,R5 = 1MΩ
R6 = 220kΩ
R7,R9,R10,R17 = 100kΩ
R8,R12,R14 = 2MΩ2
R11 = 560Ω
R13,R15,R20 = 1kΩ5
R16 = 100kΩ

R18 = 120Ω
R19 = 10k
R21-R24 = 3Ω3
R25-R35 = 22kΩ

Capacitors:
C1,C6,C7,C8,C10 = 100nF
C2,C3,C5 = 10nF
C4 = 1µF
C9 = 330nF
C11 = 47µF 16V radial

Semiconductors:
D1-D9,D11,D13,D14,D15,D17,
  D18 = 1N4148
D10,D12 = zener diode 1V2
0.4W*
D16 = 1N4001
D19 = LED, green
D20 = LED, yellow
T1 = BC327
T2,T3,T4 = BC337
T5 = BD140
IC1 = 4017

IC2,IC3 = 4069 or 40106

Miscellaneous:
JP1 = jumper
K1,K2 = 12-way pinheader or
wire links
K3,K4 = not required (ribbon
cable)
K5, K6 = 2-way PCB terminal
block, lead pitch 5mm
S1-S12 = pushbutton with
make contact

circuit board with a length of cable. Otherwise, a screwdriver or a bit of wire connected between the emitter and collector of T5 is all that is needed to outfox the code lock and open the door.

Fitting the components to the circuit board should not be difficult. The ICs can be mounted in sockets. The author used 4049 inverter ICs, but in the *Elektor Electronics* lab prototype we used 4069's, which are functionally compatible but not pin-compatible, and we also tried a 40106, which has Schmitt-trigger inputs. With a 4069, normal

1N4148 diodes can be used for D10 and D12. The best solution is to use the relatively noise-immune 40106. However, it is then necessary to use Zener diodes for D10 and D12, due to the higher threshold voltage. A 3.3-V type is ideal with an operating voltage of 15 V. There is one thing you should not overlook: with low-voltage zener diodes, the band on the package marks the anode instead of the cathode, as you would normally expect. At least, this is true in most cases, but not always…

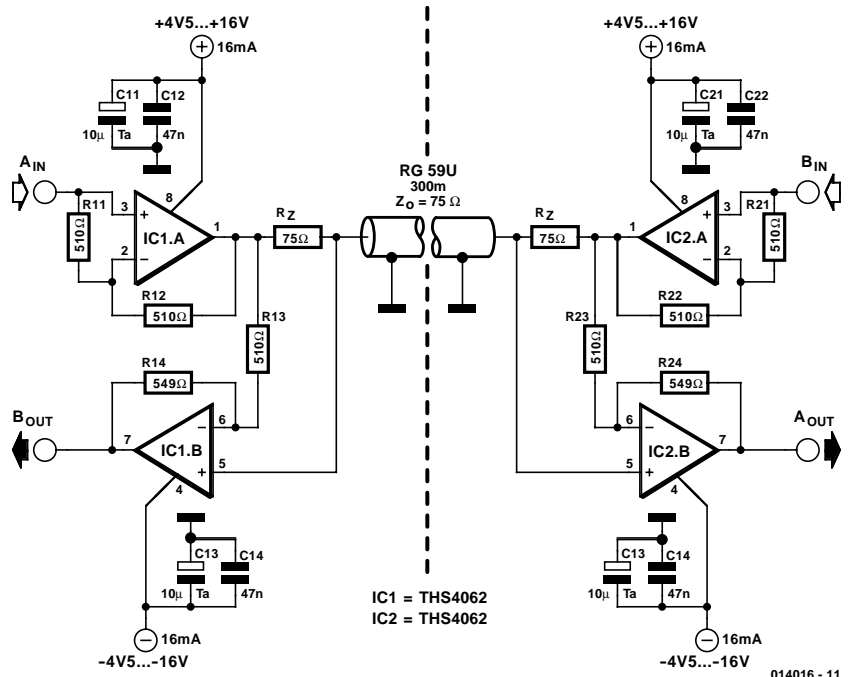(014009-1)

Full-Duplex Data Transmission 006

K.J. Thiesler

The TH4062 is a dual video amplifier with a 3-dB bandwidth of 180 MHz. This video opamp also features low noise, a high output current of ±100 mA, a very high slew rate, extremely low phase and gain errors (0.02 ° and 0.02 %) and outstandingly low crosstalk (–110 dB). These properties make the TH4062 an excellent choice for use in a high-speed data link. The full-duplex capability supports bi-directional communications (without a changeover switch) for distances of up to 300 m using a coaxial or twisted-pair cable.

The circuit diagram shows that all tha is needed is four opamps (housed in two ICs), a few resistors and some capacitors to decouple the supply voltage. Two independent PAL signals are fed into inputs A_{IN} and B_{IN}. These signals appear unchanged at the corresponding remote outputs A_{OUT} and B_{OUT}. Resistor R_Z plays a special role here. In addition to ensuring that the opamps have adequate phase margin with capacitive loads, and thus preventing high-frequency oscillations, it serves as a differential network. At the input amplifier, the signal from the adjacent output amplifier is subtracted from the summed signals on the live conductor of the cable, which is connected to the non-inverting input of the input amplifier. In this way, the undesired signal is eliminated in a simple but effective manner.

In building the circuit, make sure that the decoupling capacitors are located as close as possible to the ICs, and arrange the ICs and circuit tracks so that crosstalk is minimised. Only in this way is it possible to realise the excellent measured results listed below. The stabilised supply voltage may lie between ±4.5 V and ±16 V, and the maximum current load is 16 mA.

The link between the two ends is formed by an RG-59/U cable with a characteristic impedance of 75 Ω, which may be up to 300 m long. If a twisted-pair cable is used, the value of R_Z may be reduced (≥ 20 Ω).

The data sheet for this interesting video opamp (and for a single opamp with the same characteristics, the THS4061), can be found at the following address:

http://www-s.ti.com/sc/psheets/slos234d/slos234d.pdf

Several interesting application notes can also be downloaded from the immediate 'neighbourhood' of the datasheet.

(014016-1)

Technical data

Supply voltage range:		U_S	±4.5 to ±16	V
Current consumption		I_S	16	mA
Bandwidth (–3 dB)		GBW	180	MHz
Bandwidth (–0.1 dB) (G = +1)		BW	75	MHz
Slew rate		SR	400	V/µs
Offset voltage		U_{ios}	2.5	mV
Offset drift			15	µV/K
Distortion		THD+N	–72	dBc
Common-mode rejection		CMRR	110	dB
Phase error			0.02	degree
Gain error			0.02	%
Noise		e_n	14.5	nV/√Hz
Output Current		I_{out}	115	mA
Operating temperature THS4062xx	CD (SOP8)		0 to 70	°C
	CDGN (SSOP8)		0 to 70	°C
	ID (SOP8)		–40 to +85	°C
	IDGN (SSOP8)		–40 to +85	°C

Code Lock

007

G. Baars

This is a device, built around a PIC16F84-04, which activates an output when the correct access code has been entered on a keypad. This code consists of six digits in the range 0 to 9. The code can be changed by the user and is also remembered when the power is off. A buzzer has been added to provide input feedback, the number of beeps indicates whether the input has been entered correctly or not. This circuit is eminently suitable as an electronic door lock, the switching section of a burglar alarm or as an ignition blocking device.

The code lock has two outputs. One of these (K2) pro-

vides a TTL signal, which is normally 'low' and becomes 'high' when activated. The other output (K1) consists of a relay (Re1). By changing the jumper from JP2 to JP1 the output can be changed from the 'level' output (continuous switch signal) to the pulse output on the processor. In the latter case, the output is active for about one second after entering the access code; this is common for use with electronic door locks.

The keyboard layout is as follows:

1	2	3
4	5	6
7	8	9
*	0	#

The output is inactive when the circuit is powered up or has been reset. When the * key is pressed, followed by the 6 digit code, the output will go to the 5 V level and the relay will be energised. If the code is correct, the buzzer sounds

COMPONENTS LIST

Resistors:
R1 = 3kΩ3
R2 = 4kΩ7
R3 = 470Ω
R4 = 4-way SIL array 4kΩ7

Capacitors:
C1 = 47µF 16V radial
C2,C4,C5 = 100nF
C3 = 100µF 25V radial
C6 = 27pF

Semiconductors:
D1 = 1N4148
D2 = LED
T1 = BD139
IC1 = PIC16F84-04/P, programmed, order code **006501-1**
IC2 = 78L05

Miscellaneous:
S1-S12 = pushbutton, 1 make contact, e.g. ITT/Schadow type D6
K1,K2,K3 = 2-way PCB terminal block, lead pitch 5mm
JP1,JP2 = jumper
Re1 = 12V relay, e.g., Siemens V23057-B0002-A201
Bz1 = buzzer 5VDC
K4,K5 = 7-way SIL pinheader
Disk, source code files, order code **006001-1** (see Readers Services pages)
PCB, order code **004003-1** (see Readers Services pages)
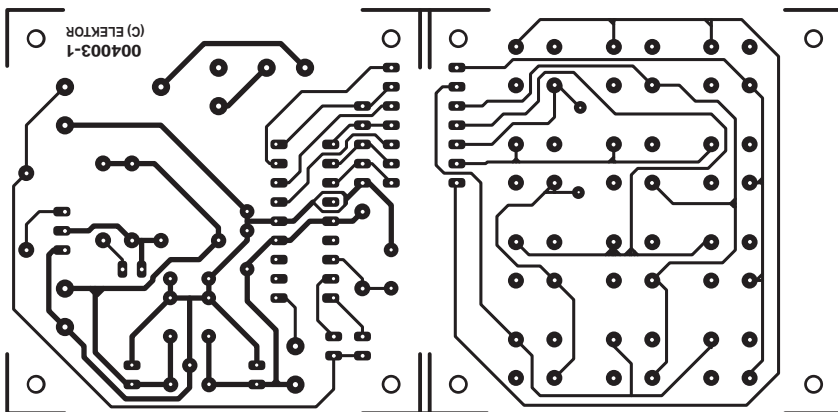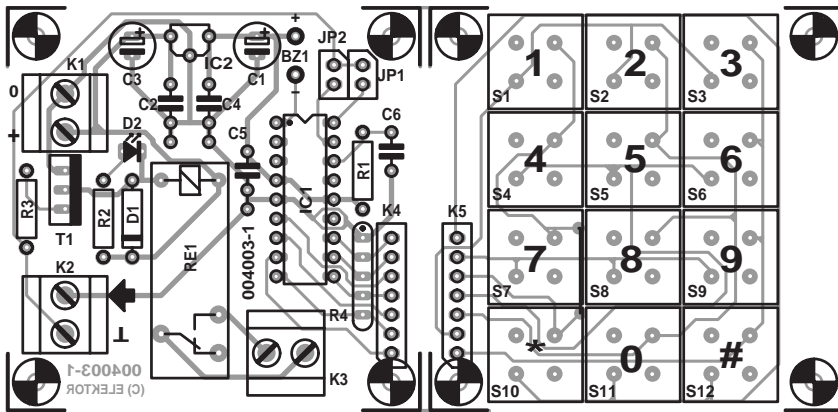
a single beep. If it is incorrect, three beeps will follow in short succession. When the code has been incorrectly entered four times in a row, the code lock will switch to alarm mode. In this state, all key presses are ignored for one minute and at the same time the buzzer will sound the alarm signal. This function thwarts any attempt by 'hackers' to quickly try a large number of codes in sequence.

When the code lock is used for the first time, the access code is 123456. This can be changed to, for example, 654321 by first pressing * followed by #, then the original code, then the new code and finally the new code a second time for confirmation. When the new code has been correctly entered (when the old code corresponds with the one stored in memory and the doubly entered new one are both the same) a single beep will sound after entering the last digit and the new code will be internally stored. If something has gone wrong, the original code remains valid and the three-beep error signal will sound.

By pressing '**' on the keypad, the level output of the processor will go to 0 V and the relay in 'level'-setting will deactivate. When the pulse output is used, the code '**' is never necessary. If the code lock is used to turn something off using the access code, a relay with a change-over or

break contact may be used. A burglar alarm may, for example, be activated with '**' and can only be disarmed by entering the access code. The TTL-output (K2) can be used to drive an enable signal, with which something can be blocked. If just the TTL output is used then there is no need to fit the relay.

A 12 V power supply is indicated, but in principle any voltage between 8 V and 15 V is allowed, provided of course that the relay is suitable for this voltage. In the inactive state, the current consumption of the circuit is about 2.5 mA.

The PCB shown here (available ready-made via Readers' Services) reduces the construction of the circuit to a simple, routine job. In order to make the whole assembly as genera-purpose as possible, the PCB was designed such that the processor part and the keyboard may be separated. Interconnection of the two parts is achieved with a short length of ribbon cable between K4 and K5.

Apart from the ready-made PCB, a programmed PIC and a disk containing the project source code are also available from *Elektor Electronics* Reader's Services.

(004003-1)

RC5 Remote Control

008
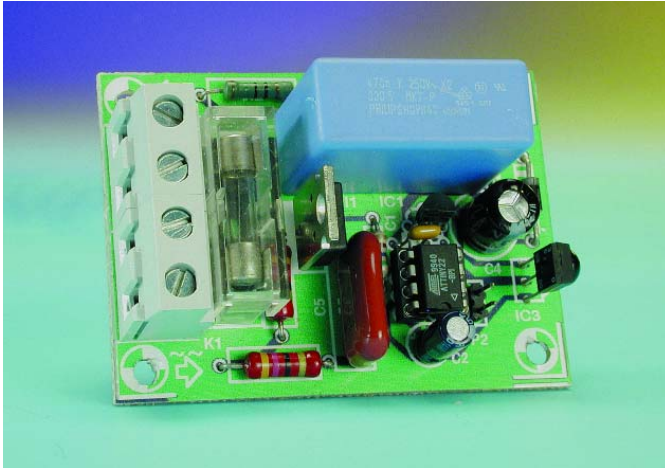
J. van Boxtel

This circuit has been designed to switch lights and other loads on and off, using any RC5-compatible remote control. The receiver can be programmed to respond to any RC5-code, including the address (TV1, TV2, VCR1, etc.). The default address is 'TV1 code 4'.

As can be seen from the circuit diagram, the circuit is very simple and consists of four main parts: an IR receiver module, a microcontroller, a triac driver and a supply section.

The supply for the circuit is derived directly from the mains, via C3, R2 and F1. The voltage is first pre-regulated to 12 V by zener D2, which is followed by voltage regulator IC1 to provide a perfectly regulated 5 V DC.

There is little more to be said about IC3 apart from that it is a standard IR receiver module, which is widely available (e.g., from Conrad Electronics). This module does not require any external components. The triac section will not require any explanation either, since it is a classic implementation of a solid-state relay.

At the heart of the circuit is IC2: a small 8-pin microcontroller from Atmel, which has been programmed to detect RC5 codes and to toggle the triac on or off when the correct code has been received. Space being limited we will not go into detail of the software here, but of course it is available from our website (www.elektor-electronics.co.uk) as a Free Download (ref. **000189-11**) and is also available on floppy disk. If you are unable to program the Atmel microcontroller yourself you can order a programmed chip
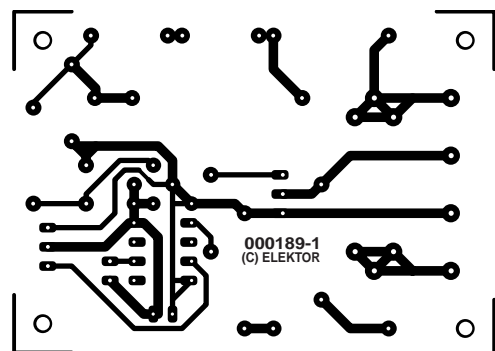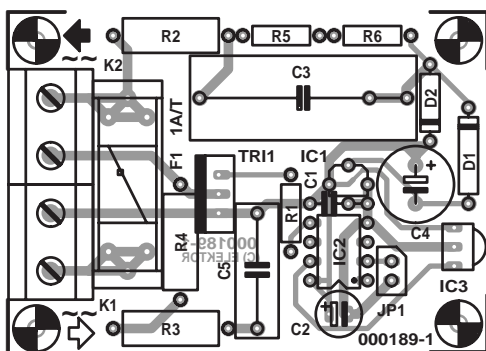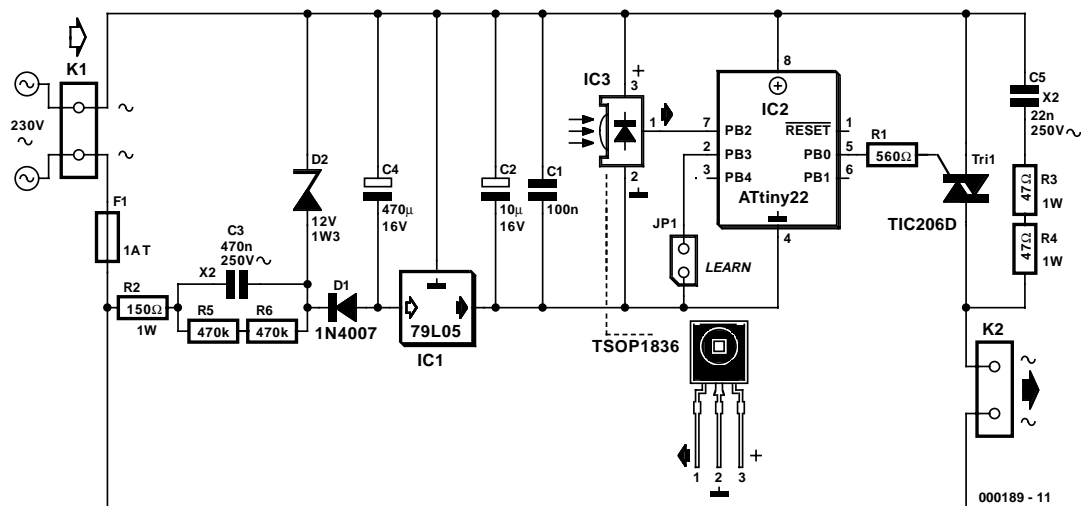
COMPONENTS LIST

Resistors:
R1 = 560Ω
R2 = 150Ω 1W
R3,R4 = 47Ω 1W
R5,R6 = 470kΩ

Capacitors:
C1 = 100nF ceramic
C2 = 10µF 16V radial
C3 = 470nF 250V$_{AC}$ class X2
C4 = 470µF 16V radial
C5 = 22nF 250V$_{AC}$, class X2

Semiconductors:
D1 = 1N4007
D2 = zener diode 12V 1.3W
Tri1 = TIC206D
IC1 = 79L05
IC2 = ATtiny22L-8PC Atmel
  (programmed, order code **000189-41**)

IC3 = TSOP1836 (Vishay-Telefunken) (or
  Infineon SFH5110, Sharp IS1U60)

Miscellaneous:
JP1 = 2-way pinheader +with jumper
K1,K2 = 2-way PCB terminal block, lead
  pitch 7.5 mm
F1 = fuse 1AT (time lag) with PCB mount
  holder
Disk, source code files, order code
  000189-11

from *Elektor Electronics* (order code **000189-41**). Jumper JP1 is normally open. Closing this causes the last received code to be stored in the internal EEPROM memory as the new code that activates the receiver.

The use of the printed circuit board shown here will make construction of the circuit very straightforward.

Remember to take great care during construction and testing, since the complete circuit is at mains potential!

Finally, we would like to point out that the circuit will only work with mainly resistive loads and is therefore unsuitable for fluorescent lights.

(000189-1)

Speed-up for Darlingtons
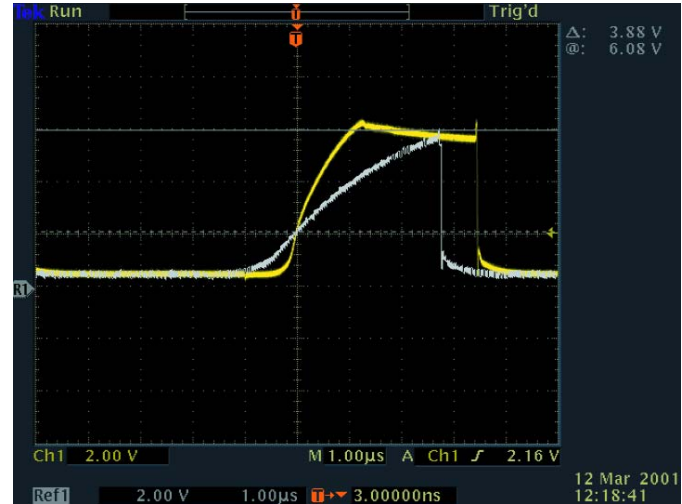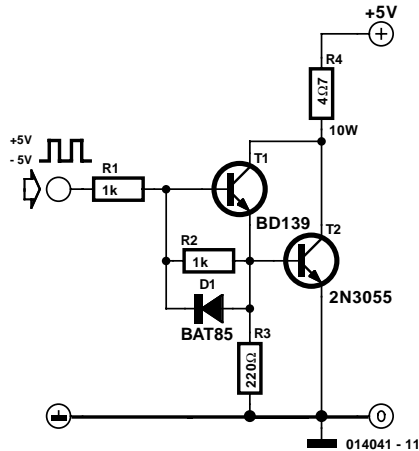
Darlingtons are useful devices because they have a pleasantly high gain. A disadvantage however, is that they are much slower than normal transistors, something that becomes even more of an issue if the two base-emitter resistors have relatively high values. The reason is that the charge in the base can be dissipated only slowly. In reality this can only happen in the base/emitter junction itself or via the relatively high base-emitter resistor (R2). There is not much that can be done with ready-made 'three legged' darlingtons, but with do-it-yourself darlingtons both base connections are readily accessible, which makes it possible to apply 'minor surgery' in the interest of a little

improvement. The operation consists of the addition of a (Schottky-)diode in the blocking direction across the base-emitter junction (D1). This diode can provide a considerable reduction in turn-off time. The consequences for the reproduction of, for example, a 113-kHz square wave are clearly illustrated by the oscilloscope traces shown here, where one trace is with, and one without, the additional diode.

To avoid any misunderstandings, we would like to add that this 'diode trick' really only works well when the input voltage goes negative with respect to ground.

(014041-1)

Audio/Video Switch

010
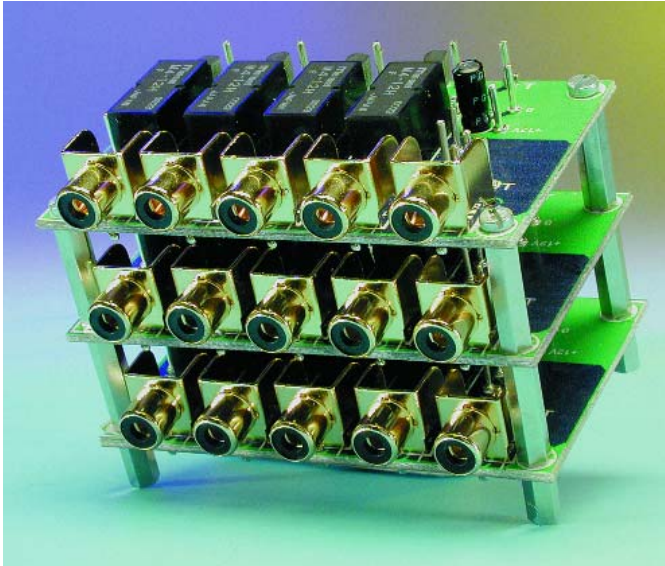
This article is mainly about the board and the uses to which it can be put. The circuit is simplicity itself and consists of four phono sockets, which can be individually switched to a fifth (common) socket. This fifth channel can be used as either an input or output. A big advantage of this type of passive switch is that the channels are electrically isolated from each other, as well as from the supply voltage for the relays. If this is not required, it is of course possible to connect all earths of the boards together.

Each relay is switched by its own transistor, which is driven via a potential divider. This potential divider makes the transistor switch more cleanly. The driving voltage should be a minimum of 4 V. Elsewhere in this issue is a Simple IR Receiver, which makes a perfect match for this switch. The receiver only activates one of the four channels, but of course it would be possible to activate all relays at once if a different driver circuit is used. But when you do this you should take great care that there can't be any short circuit conditions.

The relays used here require an operating voltage of 12 V and consume between 15 to 20 mA each. When the circuit is used to switch 5.1-surround plus video between four channels, a total of seven boards is required in parallel (that won't be cheap!). The layout facilitates the expansion of the number of I/O channels. When adding a second set of four channels the common should not be connected; this is only connected to one set by putting a wire link across JP1. The pins beside the relays should then be joined to the next board using short lengths of isolated cable. Instead of a wire link, it is also possible to connect a buffer/amplifier across JP1. This can either be a pre-amp or power amp, depending on the use of the circuit. In the circuit there are 1 MΩ resistors (R1, R4, R7, R10) mounted in parallel with each of the four channels. These pull the lines to ground when the relay is open and also act as a load for any sources which have AC-coupled signals.

014120 - 11

RE1 ... RE4
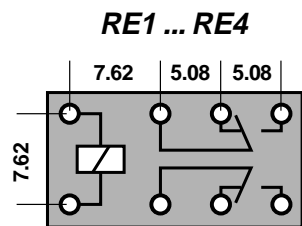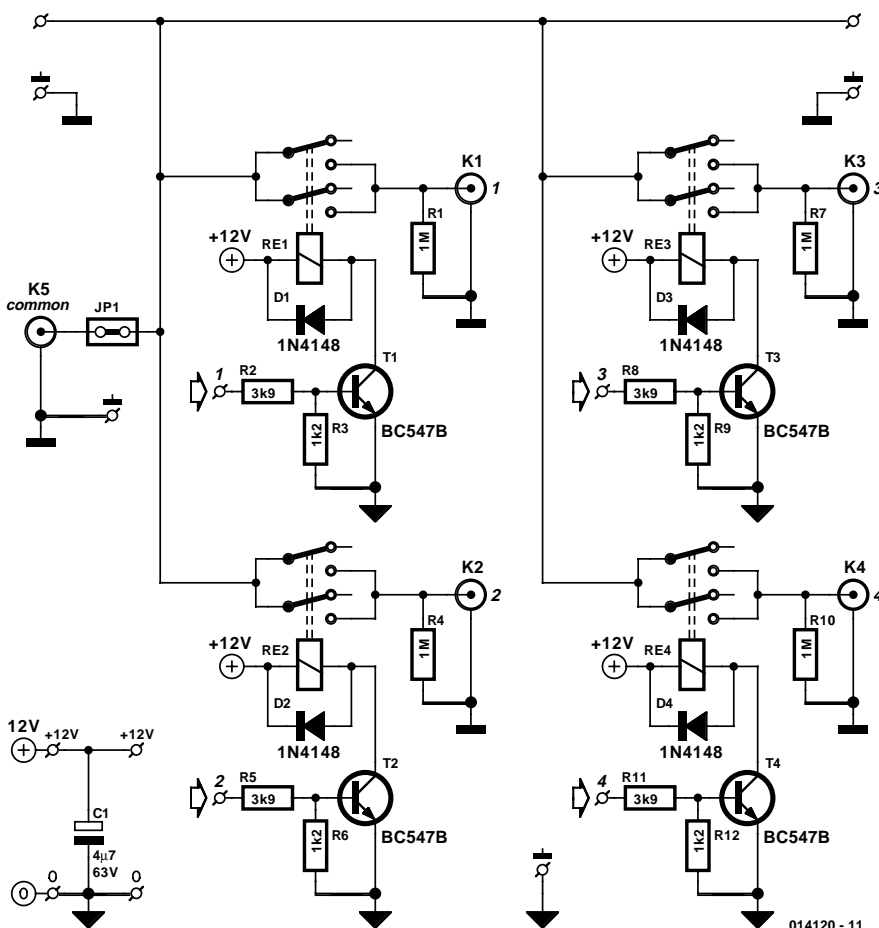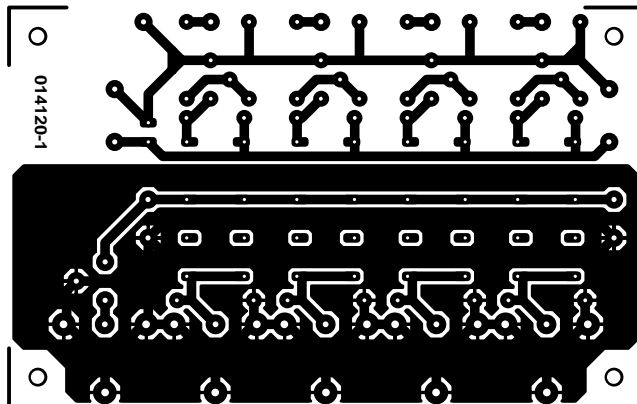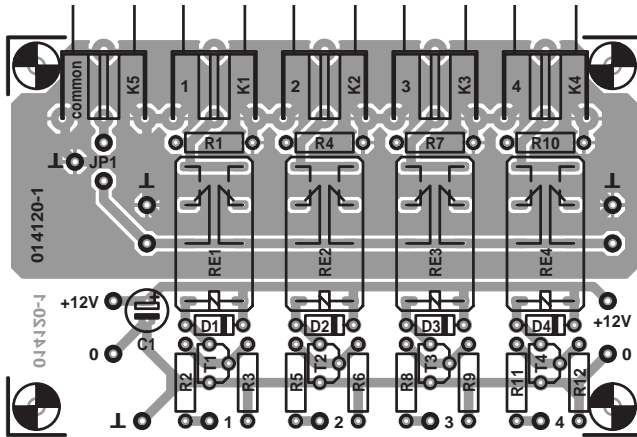
The relays in the parts list have a standard footprint that is commonly used by many other manufacturers, but take care when using polarised relays that the polarity is correct. It is of course possible to use relays with different coil voltages.

(014120-1)

COMPONENTS LIST

Resistors:
R1,R4,R7,R10 = 1MΩ
R2,R5,R8,R11 = 3kΩ9
R3,R6,R9,R12 = 1kΩ2

Capacitors:
C1 = 4µF7 63V radial

Semiconductors:
D1-D4 = 1N4148
T1-T4 = BC547B

Miscellaneous:
JP1 = wire link (see text)
K1-K5 = cinch socket, PCB mount, e.g., Monacor/Monarch # T-709G
Re1-Re4 = mini relay, 2 c/o contacts, e.g., Conrad Electronics # 505170-24 (12V, 720Ω)

Thyristor Switch

K. Lorenz

Normally, two pushbuttons are needed to control a thyristor, namely — you guessed it — one to switch it on and one to switch it off. With the circuit shown here, it is possible to control the thyristor using only one pushbutton. If S1 is pressed, a positive voltage is applied to the gate and the thyristor is triggered on. The LED lights up at the same time, the relay pulls in and the transistor conducts. This causes C1 to be charged, so that the next time the button is pressed, the ground potential is applied to the gate instead of a positive voltage. The thyristor then returns to the nonconductive state. Capacitor C2 provides proper debouncing of the pushbutton. The switching time is consequently around 0.5 s. Devices in the BRX or BRY series can be used for the thyristor.

The current consumption of the thyristor switch is around 12 mA in the On state with a supply voltage of +5 V. In the Off state, the circuit draws practically no current (except for a very small parasitic current). The supply voltage range, at +3 to 5 V, is fairly large. The series resistor for the
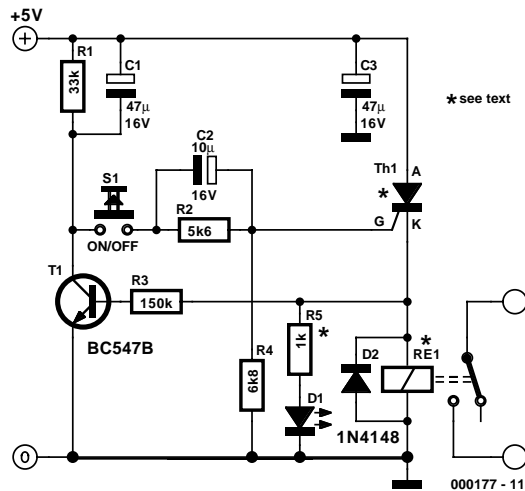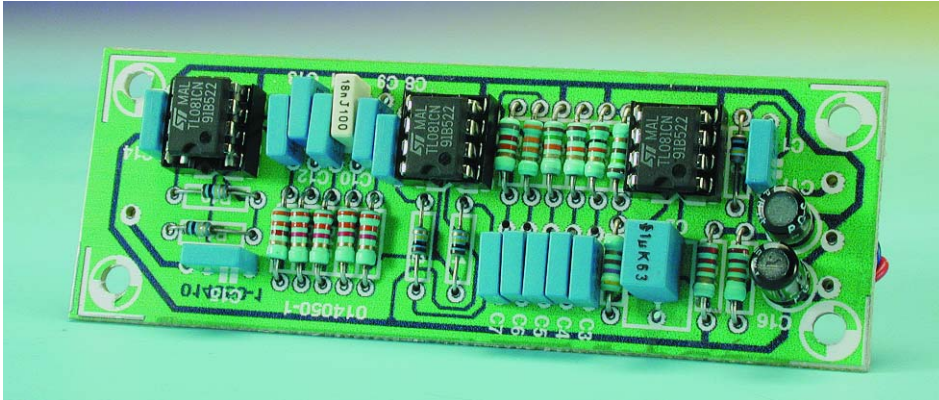

000177 - 11

LED, and if necessary one for the 5-V reed relay (which has a coil resistance of 500 Ω), must be adapted to the value of the supply voltage.

(000177-1)

Speech Filter

012

G.Baars

In communications receivers and microphone amplifiers for transmitting equipment, there is frequently a need for a narrow, low-frequency bandpass filter that lets only the voice band through. This band is usually defined to be the portion of the audio frequency spectrum between approximately 300 Hz and 3300 Hz.

In order to implement such a filter, we have calculated the values for two fifth-order Butterworth filters having these corner frequencies and connected them in series. The result is a bandpass filter for the desired passband

with a skirt steepness of 100 dB/decade.

The first opamp (IC1) acts as a buffer. The circuit can be powered by a unipolar supply voltage between 5 V and 18 V, which is a broad enough range that it should always be possible to find a suitable voltage when building the filter into existing equipment. The current consumption of the filter is only a few milliampères, which should rarely pose a problem.

There is fairly wide selection of suitable candidates for the opamps, since the circuit is not critical in this regard. In addition to the indicated OP27A, you could consider using a TL081N or even an old-fashioned 741.

Due to unavoidable spreads in component values, the passband curve of the filter will never be completely perfect in actual practice. However, the deviations will be very small and in any case inaudible. In the passband region, the gain is approximately unity.

The printed circuit board design shown here allows the speech filter to be built in a very compact form, which can
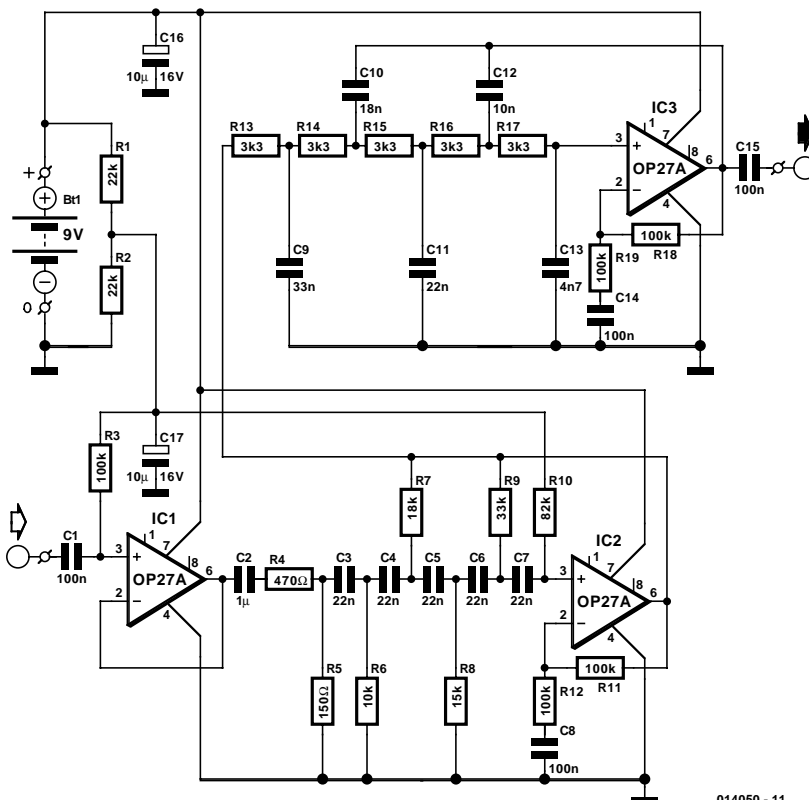
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COMPONENTS LIST

Resistors:
R1.R2 = 22kΩ
R3,R11,R12,R18,R19 = 100kΩ
R4 = 470Ω
R5 = 150Ω
R6 = 10kΩ
R7 = 18kΩ
R8 = 15kΩ
R9 = 33kΩ
R10 = 82kΩ
R13-R17 = 3kΩ3

Capacitors:
C1,C8,C14,C15 = 100nF
C2 = 1µF MKT
C3-C7,C11 = 22nF
C9 = 33nF
C10 = 18nF
C12 = 10nF
C13 = 4nF7
C16,C17 = 10µF 16V

Semiconductors:
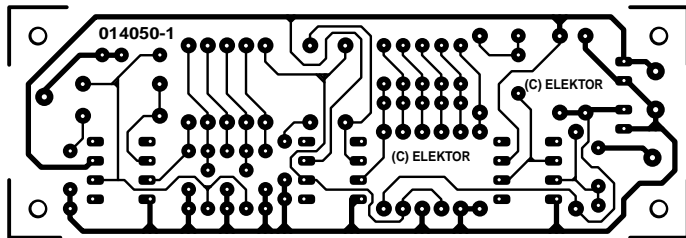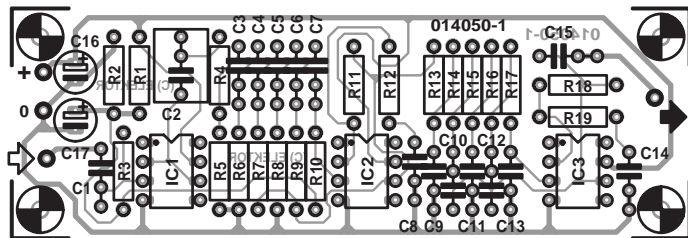IC1,IC2,IC3 = OP27A, TL081CN

Miscellaneous:
Bt1 = 9-V battery

be an important factor if it must be fitted into existing equipment. You can quickly check the fully assembled circuit by momentarily measuring the voltages at the inputs and out-
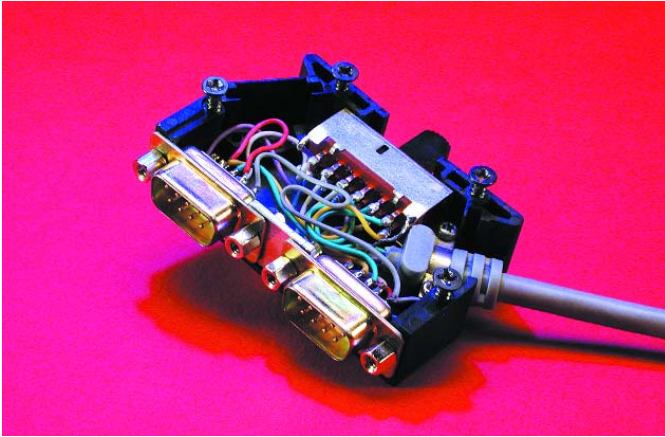
puts of the three opamps. Half of the supply voltage should be present at all of these locations.

(014050-1)

Mini RS232 Data Switch

H.- J. Böhling

Only simple materials and a little bit of skill are needed to build an RS232 switch. All that you need are two 9-way sub-D plugs with solder pins, a small piece of sheet aluminium, two sets of screw retainer posts, a 4-pole double-throw switch, a strain relief sleeve and a suitable plastic connector shell for a 25-way sub-D connector, with both in-line **and** right-angle cable entries (such as Conrad Electronics #711322). What is important is that the side cable entry together with its associated strain relief leaves enough room for the switch. If necessary, you may have to cut away a few square millimetres of the sidewall or a few ribs of the plastic shell.

The switch is operated via the in-line cable opening, as can be seen from the photo. A suitable switch with an overall length of 29 mm can be found in the Conrad catalogue under order number 708232. The only modification that must be made to the connector shell is to drill two holes for the retaining screws for the switch (M2.6 screws) at a spacing of 24 mm.

Connect the two sub-D connectors together using the piece of aluminium and the screw retainer posts. Then solder the cable to the connectors and the switch as indicated. The two connectors are wired somewhat differently. While the upper sub-D plug is connected 1:1 with the input cable (with the switch in the appropriate position), the DCD, DTR, DSR and RI pins of the lower connector are left open. This is because RTS and CTS are fully sufficient for handshaking, as long as DTR and DSR are connected to each other. The only leads that are switched are RXD, RTS, TSD and CTS. The ground potential is fed from the cable to both connectors. After everything has been properly soldered together, you can fit everything into the cable shell as shown.

(014037-1)
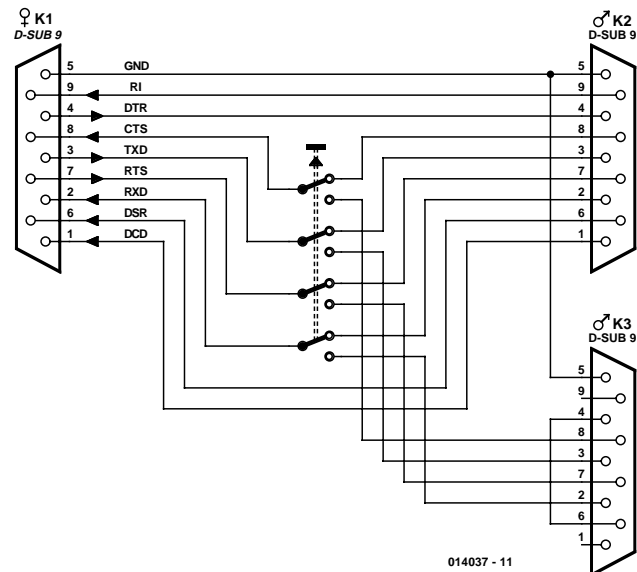
014037 - 11

Remote ADC with RS232 Output 014

K. Haddad Shargh

The circuit converts an analogue voltage to its digital equivalent which is transmitted to a PC via an RS232 link.

This type of circuit is useful for controlling remote equipments using only one PC. For example, you can monitor several furnaces by sending their individual temperatures to a central PC. In combination with a simple program the ADC lets you decide which action must be taken when certain temperatures are measured.

This circuit is composed of three building blocks. The first one handles the conversion of analogue signals to digital data. The second block accepts the digital data and puts it in the standard RS232 data frame before converting it to a bit stream. The last function is the RS232 line driver.

The familiar and low cost ADC0804 is used as ADC in this circuit. This IC converts the analogue voltage in the range of 0 to 5 volts into digital data by means of a 256-level quantisation process. Alternative ICs may be used but you have to consider the communication line capacity.

The ADC0804 is configured as free-running converter. Unfortunately, in this mode, when the conversion is in process, invalid data appears on its data bus. This problem is solved by using a 74F374 octal latch on the data outputs.

When the conversion is completed, the $\overline{\text{INTR}}$ pin is activated and valid data will be saved in 74F374. Next, this data is copied into a shift register for parallel-to-serial conversion. This shift register consists of two cascaded 74F166's (IC5 and IC6). The first and tenth cell of this register chain are connected to ground and Vcc respectively for producing the start bit and stop bit.

In this circuit a 555 IC is used as clock generator. The 555 is configured as a bistable multivibrator for generating a 110-Hz square wave. It is recommended to check this frequency and make sure it is within 2% tolerance. If desired, the oscillator frequency may be changed by modifying the values of C3 and R4.

A programmable down counter type 74F169 (IC4) is used to generate the Load signal for the shift registers. This IC is pre-loaded with the value 10. Consequently it generates pulses for loading IC5 and IC6 at every tenth clock pulse.

The last stage is the RS232 line driver, which shifts the TTL level to +12 V and –12 V while also matching the line impedance. Here, the well-known MAX232 is used in its standard configuration.

A 'Null Modem' connection must be used to establish
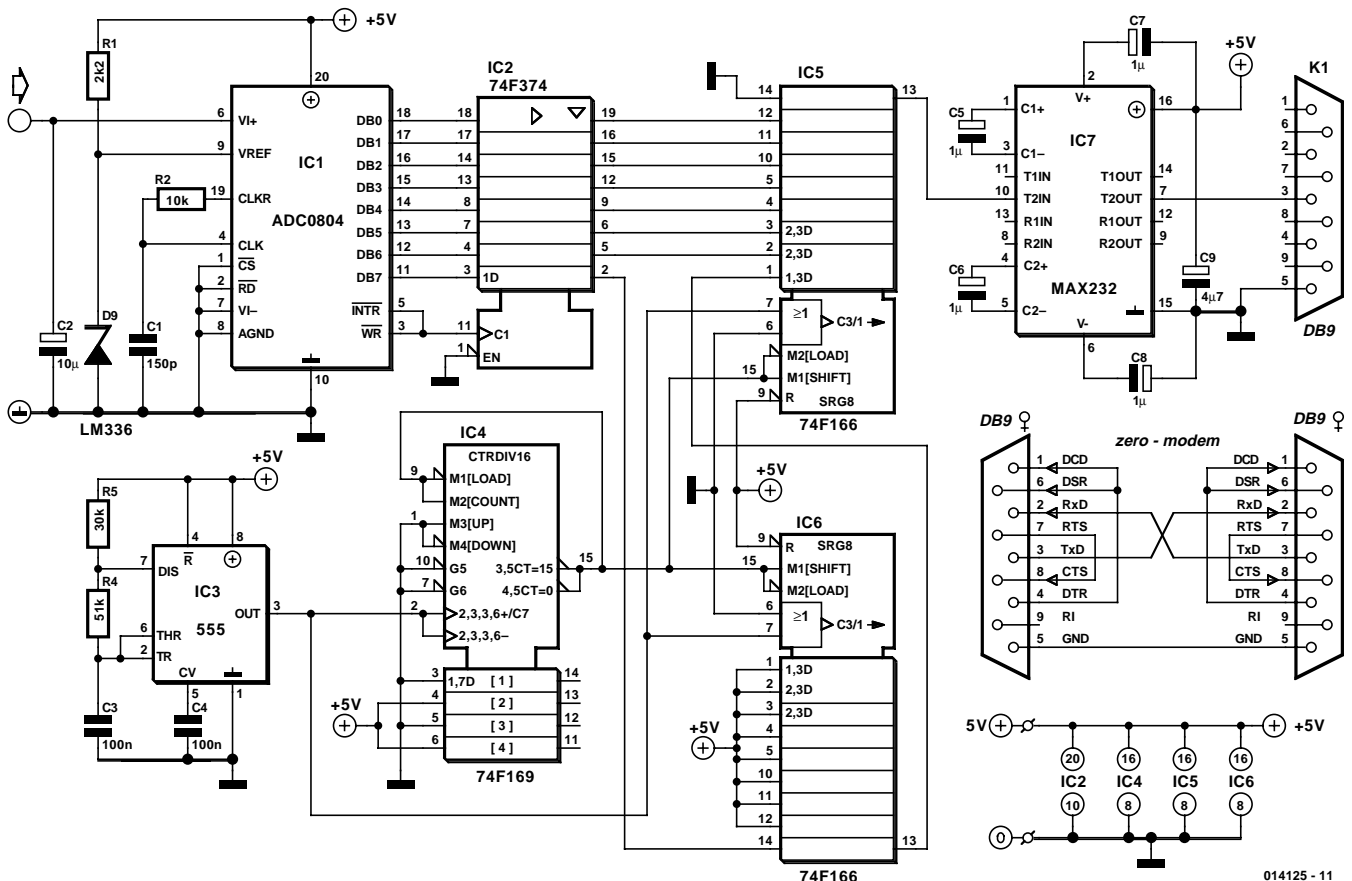
014125 - 11

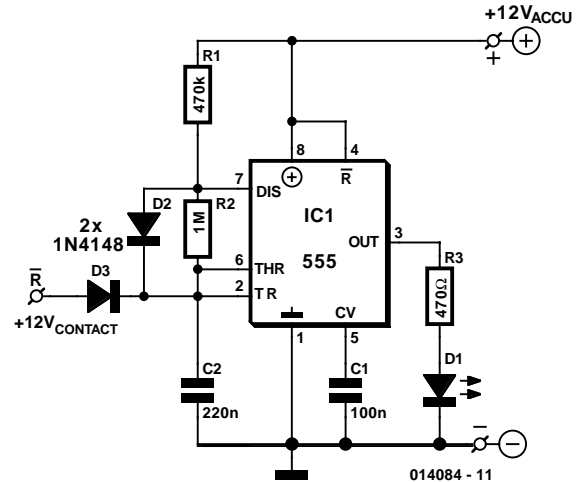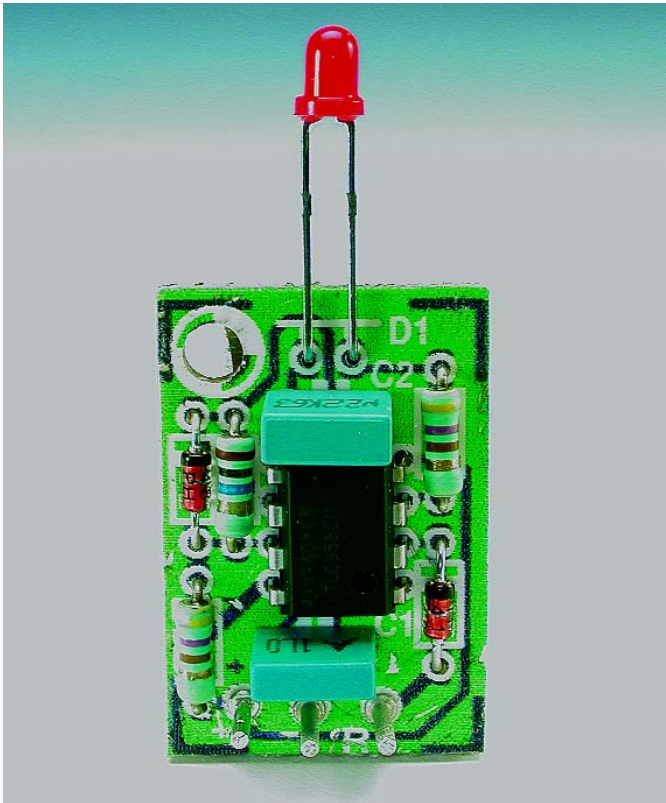communication between this circuit and computer's serial port. For your convenience, the relevant wire connections between two 9-pin sub-D connectors are included in the schematic.

Finally, if difficult to obtain locally, the F (fast) ICs in this circuit may be replaced by LS (low-power Schottky) equivalents.
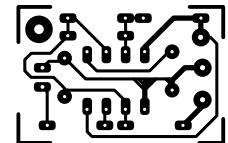
(014125-1)

LED Flasher

A flashing LED based on a 555 is not likely to win the first prize for originality, but such a circuit continues to be useful for all kinds of applications. The thing that makes this version special is the very low current consumption, because the LED flashes only very briefly each time (duty-cycle of only 10%) and because it was specifically designed to serve as a (fake) alarm indicator in a car. The circuit has been configured such that the flashing only starts when the ignition is switched off.

The latter could have been achieved in the usual way with the aid of two resistors and a transistor connected to the reset line. But by using a clever trick instead, this has become even simpler. The +12 V connection from 'behind' the ignition key is connected to the threshold input via diode D3. The astable multi-vibrator is held in the inactive state whenever this point is at +12 V. Only when the ignition is switched off, is the clamp removed and can the cir-

cuit begin to flash. You may then ask what the purpose of D3 is. Well, this has been added in order to prevent the various loads in the car from being connected in parallel with C2 — because that was not the intention, of course.

A minuscule printed circuit board has been designed for the circuit, that, when fully built-up will fit exactly in an old fluorescent tube starter. The latter also immediately solves the problem of finding a suitable enclosure.

(014084-1)

COMPONENTS LIST

Resistors:
R1 = 470kΩ
R2 = 1MΩ

Capacitors:
C1 = 100nF

C2 = 220nF

Semiconductors:
D1 = LED
D2,D3 = 1N4149
IC1 = 555

Digital Three-Phase Sinewave Generator
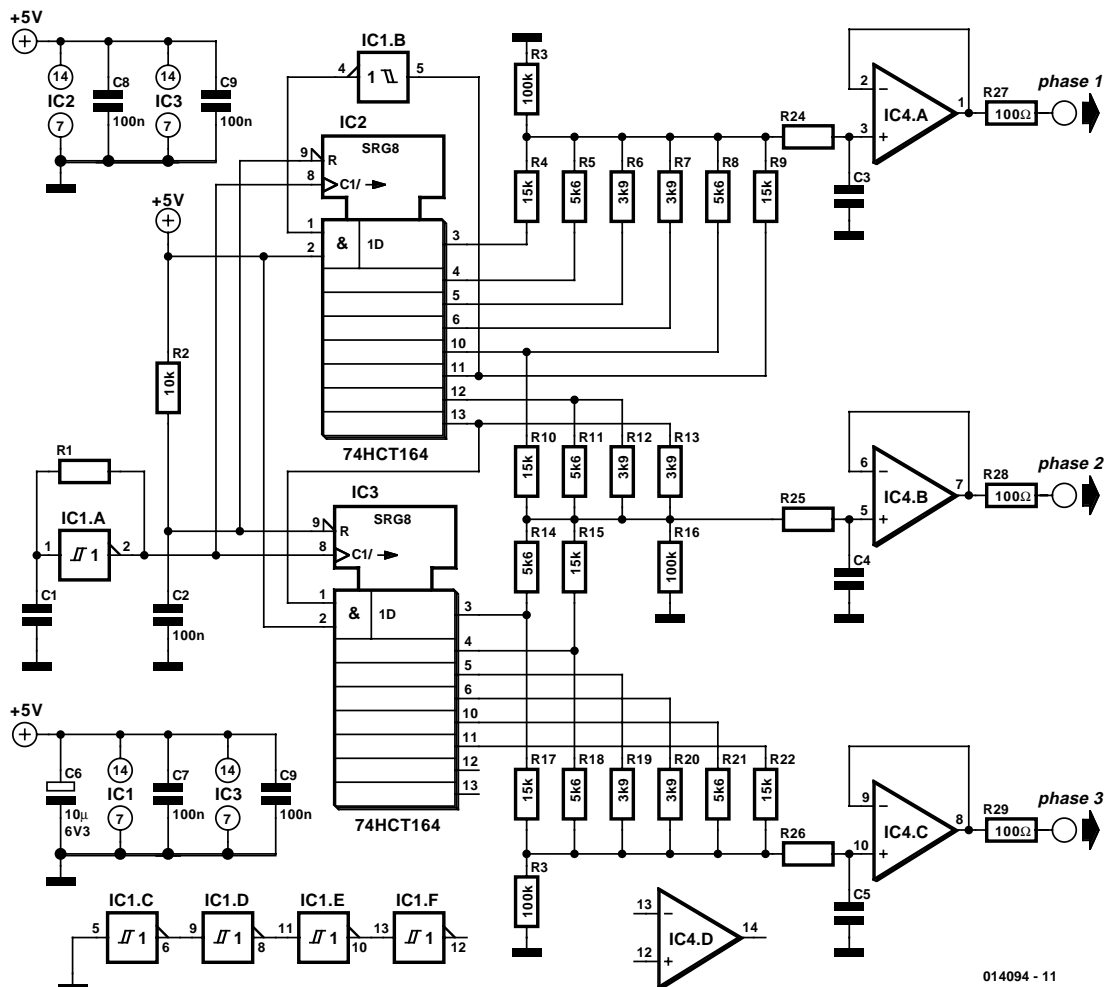
016

C. Valens

Generating three sinewave signals with constant relative phase offsets of 120 degrees using analogue circuitry is not always easy, especially if it is desired to cover a wide frequency range. The circuit shown here solves this problem in a digital manner, which yields a frequency range of nearly 0 Hz to more than 100 MHz with a fully constant phase offset of 120 degrees. Furthermore, it costs only a couple of pounds to build.

The heart of the circuit shown in **Figure 1** is formed by IC2, which is an 8-bit shift register wired as a 6-bit Johnson counter. A Johnson counter does not simply count directly from zero to the maximum possible count in equal increments, but instead jumps around from one count to the next in a more or less complicated manner. Let's see how this works. At the beginning, the shift register contains only 0's. A logic 1 is thus present at the A input (pin 1). With the first clock pulse, the shift register moves all of its bits one position to the right, so the value at the input lands at the first bit (Qa). After six clock pulses, Qa–Qf will all hold logic 1's, and the value at the input of IC2 will change to a logic 0. After six more clock pulses, bits Qa–Qf will again be all logic 0's, and the cycle will start over from the beginning. If we view bits Qa–Qf as a 6-bit binary word, with Qa as the msb and Qf as the lsb, we see the following sequence of numbers: 0, 32, 48, 56, 60, 62, 63, 31, 15, 7, 3, 1. If we plot this series, it looks like a distorted squarewave signal (**Figure 2**). It also bears a certain resemblance to a sinewave. Using a resistor network, we can make a special D/A converter that further shapes this waveform to produce a quite proper sinewave. Admittedly, it still has steps, but we can get rid of them with a low-pass filter.

In order to generate the promised three phases, we only have to repeat the above trick with time-shifted versions of the basic signal. A time shift can easily be implemented in digital form using shift registers. One period of our sinewave contains 12 clock pulses, so each clock pulse corresponds to $360 \div 12 = 30$ degrees. For a phase differ-

014094 - 11

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crystal oscillator. With values of 10 kΩ for R1 and 4.7 nF for C1, this oscillator generates a frequency of around 30 kHz, which yields a sinewave frequency of 2.5 kHz.

We c an conclude with a few practical remarks and tips:
– A low-pass filter is needed to convert the stepped digital sinewave into a smooth analogue sinewave. A simple R–C network followed by a buffer is adequate in most cases. Component values are not given for the filters shown in the schematic drawing, since the proper values depend on the chosen oscillator frequency.
– The length of the Johnson counter can be modified to increase or decrease the accuracy of the generated sinewaves. Don't forget to modify the values of resistors in the D/A networks accordingly, since the sampling points shift when the counter length is changed.
– It is also possible to use other phase offsets. For example, it is very easy to make a quadrature oscillator by shifting the whole network around R10 and its equivalents up a bit.
– The resistance values shown in the schematic can best be approximated using resistors from the E12 series. If you want to be more precise, you can use 1%-tolerance resistors. We leave the necessary calculations as an exercise for the reader. A spreadsheet program and Kirchoff's laws are the most convenient tools for this.
– Resistors R2, R16 and R23 must be large with respect to the remaining resistors, in order to ensure that the available dynamic range can be utilised to the greatest possible extent.
– To generate high frequencies, you naturally must use components that are suitable for operation at such frequencies.

ence of 120 degrees, we need another four bits, and for 240 degrees we need eight bits. That brings the total number of bits needed to generate the three sinewaves to 14. We had two bits left over in the IC, so a second 8-bit shift register IC3) is sufficient.

There's one very small catch here, which has to do with the contents of IC2 immediately after the circuit is switched on. In general, it will contain all zeros, but that is not guaranteed. If one of the initial bits is not a 0, there's not much left of our sinewave generator. We thus have to ensure that the shift register is always empty immediately after the circuit has been switched on. Our solution to this problem is a simple R–C network (R2/C2) that drives the reset inputs of IC2 and IC3.

Naturally, a clock signal is needed to cause the shift registers to shift. In this circuit, the clock is provided by an oscillator composed of IC1a, R1 and C1. This is not a highly stable oscillator, and the clock frequency depends somewhat on the make of the inverter, but it is fully satisfactory as a test clock. If you need a more stable clock, you could use a

Global Time Standard

W. Alexander

This clock functions, for a change, without any hardware. This is because we are dealing with a Windows program, which indicates the time in an entirely new format: the so-called **at:** time. The distinctive feature of this format is that the time indicated is the same around the entire globe. This has advantages, particularly with (worldwide) communications between computers, and it is here were the new time standard is gaining popularity. In full, the official designation is called 'Global **at:** Time Standard', which is abbreviated to 'GaTS'.

The **at:** time system divides the day into 72**at:**'s. This

makes it easy to recognise if it is early or late in the day. Earlier than 36at: is before noon and later than that is after noon. The day starts at 00**at:** at midnight and ends at 72**at:** again at midnight, the exact moment of the start of the next day. Of course, this is only valid for that point on the earth where the day always begins, namely the 180-degree meridian, in the vicinity of New Zealand. For other regions on earth the times mentioned correspond to different parts of the day. However, the time designation remains unal-

tered, so there is no longer the need to convert to local times.

A program written in Delphi makes it easy to convert between GaTS time, local time and GMT-time. The accompanying text is available in Dutch, French, German and English. This program may be downloaded free of charge from our web site (*www.elektor-electronics.co.uk*), the file number is 000154-11.
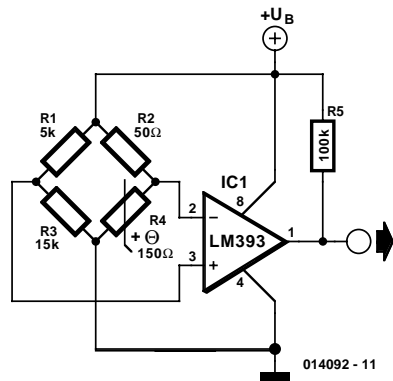
(000154-1)

Novel Liquid-Level Sensor

Normally, the level of a liquid in a container is determined by sensing changes in the capacitance or resistance between a pair of electrodes that are immersed in the liquid. Generally speaking, this technique requires fairly complicated circuitry to protect the electrodes against electrolysis (and associated corrosion). In addition, in many cases the liquid must be conductive for the measurement principle to actually be usable. The circuit presented here shows that an alternative approach is possible.

Here we utilise the fact that a PTC resistor warms up in proportion to the amount of current flowing through it, with the result that its resistance increases. If a PTC resistor is immersed in a liquid, the additional warmth is dissipated in the liquid and the resistance remains nearly constant. If the level of the liquid drops below the immersion depth of the resistor, the change in the resistance can be easily sensed by a subsequent comparator stage.

The PTC resistor should be isolated from the fluid into which it is immersed, in order to prevent undesirable elec-

trolytic processes from taking place. A further improvement in the characteristics of the circuit can be achieved by using a logic circuit — such as a microcontroller — to apply power to the circuit only at predefined times and then switch off the power after sampling the comparator output.

014092 - 11

(014092-1)

Thermostat with Remote p-n Diode Sensor

It is well known that the p-n junction of a diode has a temperature coefficient of –2 mV/°C, and this fact is often used for temperature measurement. With the new MAX651x IC family from Maxim, there is now a range of integrated thermostats with external pn-junction sensors. These devices are particularly suitable for monitoring the temperature of a chip if a diode or transistor is available within the chip for use as a sensor. A two-wire connection to the remote sensor element is necessary, even if one side (DXN) lies at ground potential. Otherwise the measurement result could be corrupted by ground currents.

The MAX651x ICs contain a converter stage that generates the temperature voltage from the forward voltage of the external pn junction. The temperature voltage is compared to a reference potential, and the comparator output switches the output as appropriate. The switching hysteresis can be selected via the HYST pin, in order to avoid output oscillations. When HYST is grounded, the hysteresis is

5 °C. If HYST is connected to V_{DD}, the hysteresis is 10 °C.

The three members of the MAX651x family have different output configurations, as follows:

MAX 6511: active-low CMOS output.
MAX 6512: open drain output (switched to ground in case of overtemperature).
MAX 6513: active-high CMOS output.

Each IC has a fixed switching temperature that is pre-programmed into the IC by the manufacturer. Values ranging from +45 °C to +125 °C in steps of 10 °C are available, or in other words, +45 °C, +55 °C and so on, up to +125 °C. At a supply voltage of 3.0 V to 5.5 V, the IC draws only 400 μA. It is housed in an SOT23 SMD transistor package.

(014078-1)

014078 - 11
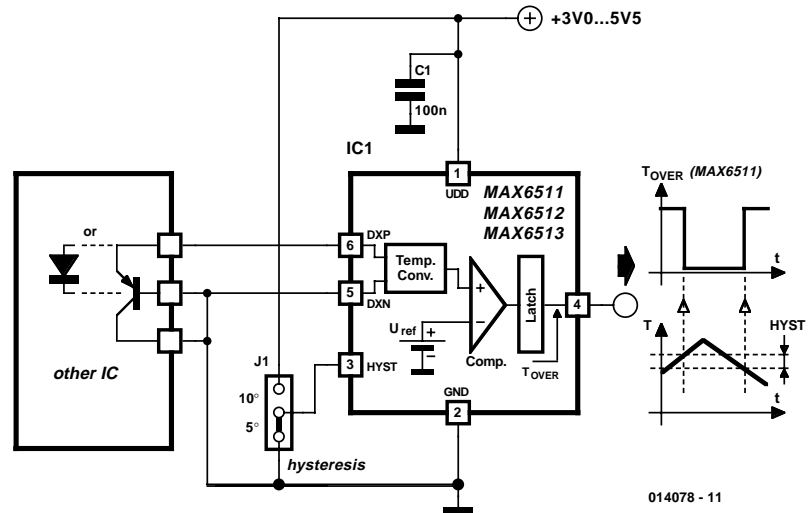
Soft-Start Circuit for Step-Down Switching Regulator

014079 - 11

014079 - 12

$$U_{out} = U_{ref}\left(1 + \frac{R1}{R2}\right)$$
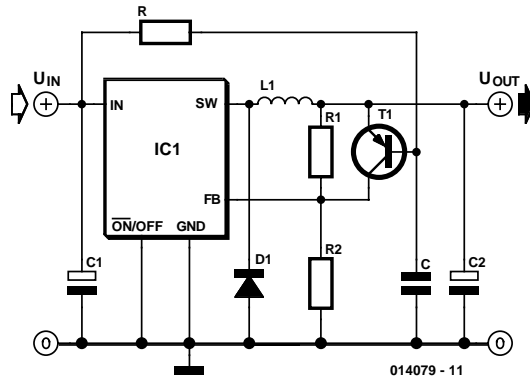
There are very many switching regulator ICs for reducing a dc voltage. In the 'step-down' operating mode, an internal switch connects the input voltage to the charging coil L1. The increasing magnetic field stores energy. When the switch opens, coil L1 attempts to force the current to continue to flow. For this purpose, the flyback diode D1 must be present to allow continued current flow. Output capacitor C1 smoothes the output voltage, while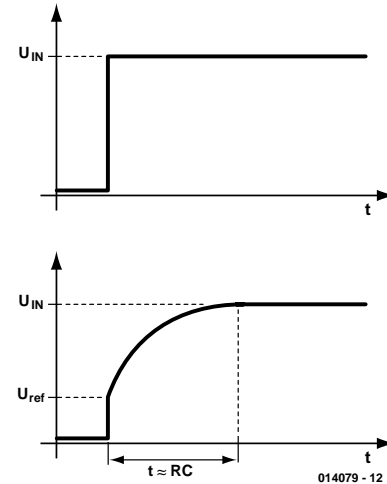 the voltage divider R1/R2 feeds back a portion of the output voltage to the sense input (FB) of the IC. The predefined internal reference voltage U_{ref} causes the indicated output voltage to be achieved. One limitation is that the output voltage must be less than the input voltage (step-down principle). The reference voltage usually lies at 1.2 V.

If it is necessary to have the output voltage rise slowly after the power has been switched on, the circuit trick shown here can be used. Transistor T1 initially shorts out the upper resistor of the output voltage divider, since capacitor C is at first uncharged. This means that the output voltage is equal

to the reference voltage. Capacitor C is slowly charged by the current passing through R, which is connected to the input voltage. Transistor T1 thus conducts increasingly less, so the voltage divider R1/R2 slowly becomes effective. Once the voltage across C is greater than the output voltage, the base-emitter junction of T1 is reverse biased and the transistor remains completely cut off.
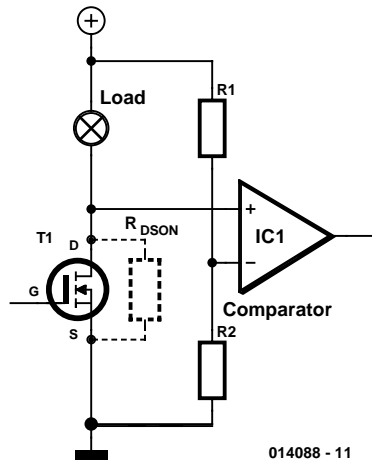
Attention should be given to the base-emitter breakdown voltage of the transistor selected for T1. The difference between the input voltage and the output voltage must not exceed this limit.

Short-Circuit Protection with a MOSFET

If you have an application in which a MOSFET is already used to switch a load, it is relatively easy to add short-circuit or overload protection. Here we make use of the internal resistance $R_{DS(ON)}$, which produces a voltage drop that depends on the amount of current flowing through the MOSFET. The voltage across the internal resistance can be sensed using simple comparator or even a transistor, which switches on at a voltage of around 0.5 V. You can thus avoid the use of a sense resistor (shunt), which usually produces an undesirable extra voltage drop.

The comparator can be monitored by a microcontroller. In case of an overload, the software can initiate suitable countermeasures (PWM regulation, alarm, emergency stop etc.). It is also conceivable to connect the comparator output directly to the gate of the MOSFET, in order to immediately cut off the transistor in case of a short circuit.

(014088-1)

014088 - 11

Economical Transistor Radio 022

014067 - 11

B. Kainka

The schematic diagram shows an audion stage with a common-collector circuit. This does not damp the tuned circuit, but instead actually increases its response. This yields good sensitivity and selectivity. Due to the low supply voltage, the subsequent audio amplifier needs three transistor stages. The volume is adjusted using the potentiometer. This radio works well using an internal ferrite rod (around 1 cm diameter and 10 cm long) with a winding of around 50 turns of enamelled copper wire. With a two-metre external wire aerial, you can receive even more sta-

tions. This radio is not only economical in terms of components, it also needs very little 'juice': since the current consumption is only 10 mA, an alkaline AA cell will easily last for around 200 hours of operation.

The specifications, very briefly stated, are:

– medium-wave receiver with ferrite aerial
– optional supplementary aerial
– power supply 1.5 V/10 mA
– 4 transistors
– loudspeaker output

(014067-1)

LED Photosensor

It is not always necessary to use special photoresistors or phototransistors to make light-sensitive switches. Although it is not well known, normal visible-light and infrared LEDs will also work. A voltage that depends on the intensity of the natural or artificial illumination falling on the LED can be taken from the anode of the LED. This behaviour can be easily verified by connecting a DVM or oscilloscope directly to the two leads of the LED.

Since the load on the photoelectric potential should be kept as small as possible, a JFET is used here as a buffer. The type used is not critical; similar transistors should work equally well. The buffered voltage is fed to the inverting input of comparator IC1. The threshold voltage can be adjusted to meet the desires of the user by means of the potentiometer. A pull-up resistor is connected to the comparator output, since the LM393 has an open-collector output. The supply voltage may be chosen anywhere in the range of 5 to 9 V.

(014091-1)
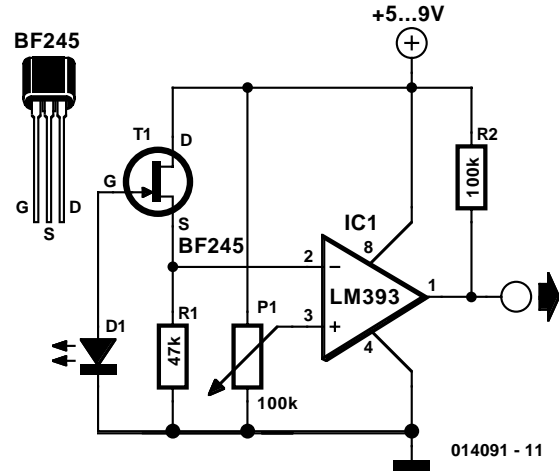
Symmetrical Switching Power Supply

This circuit shows one way to generate both positive and negative output voltages using a step-down switching regulator. The Micrel (www.micrel.com) MIC4680 is used here. Transformer winding T1a, diode D1, voltage divider R1/R2 and the output capacitors together form the well-known output-side circuit of a step-down regulator. The secondary winding L1b and capacitor C2 are used to generate the negative output voltage. The pulses from the switching output SW that have been inverted in this manner are rectified by diode D2, which provides a negative
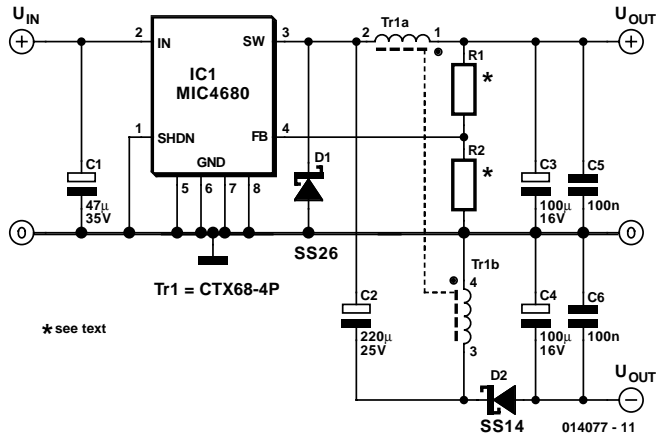
voltage of the same magnitude to capacitors C4 and C6. The SMD transformer is available ready-made from Coiltronics (www.coiltronics.com) and has a winding ratio of 1:1 (268 μH).

Sample component values for use with the MIC4680 shown here are listed in the table. As you can see, the input potential must lie a few volts above the desired output potential.

The upper limit for the input potential is determined only by the specifications of the switching regulator IC used.

(014077-1)

| U_{out}	I_{out}	U_{in}	R1	R2
±5 V	0.5 A max.	+7–34 V	3.01 kΩ	1.01 kΩ
±12 V	0.5 A max.	+ 16–34 V	26 kΩ	3.01 kΩ

Stereo Peak Indicator

F. Jensen

The circuit diagram shows a low-cost, fast responding, peak holding, audio level indicator.

The sensitivity is determined by preset P1, which (sort of) DC-biases the input of Schmitt-trigger gate IC1a to a level close to the switching threshold. When the negative peaks of the audio signal cause the output of the first Schmitt trigger gate to go high, the capacitor on the input of the second Schmitt trigger gate rapidly charges via diode D1. The charge can only disappear via the 1-Mohm resistor, R2, so a fast attack, slow decay is the result. In this way, even the fastest peaks will be caught and indicated by LED D2. Four NAND gates in a single 4093 package make a stereo version. A multiturn quality trimpot will ensure easy adjustment and stable function over time.

The circuit is based on a standard CMOS IC and will work from any supply voltage between 5 and 15 V.

(014074-1)

014074 - 11
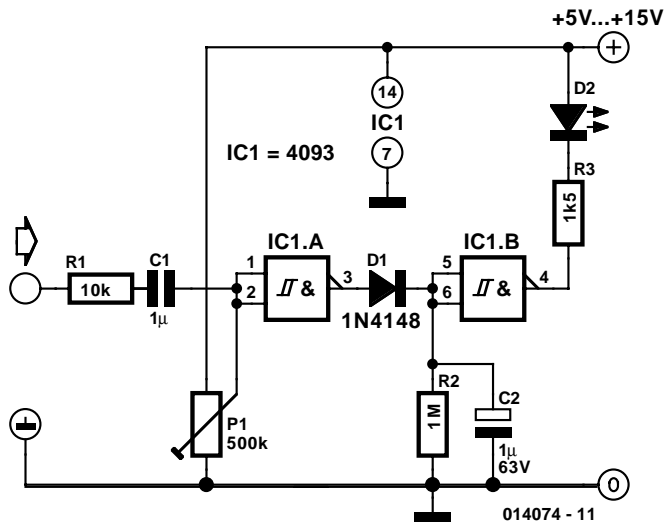
Symmetric Output for USB Audio DAC

H. Sommen

This simple adapter circuit is specially intended for use with the USB Audio DAC published in the December 2000 issue of *Elektor Electronics*. With an easily implemented modification, it is possible to make the output of the D/A converter pseudo-symmetric, so that it can be connected to professional equipment having XLR line inputs. This will do even more justice to the high quality of the USB Audio DAC.

The modification actually amounts to just adding a single resistor (R11a) and changing the value of the existing resistor at the output of the audio DAC (R11) from 100 Ω to 68 Ω.
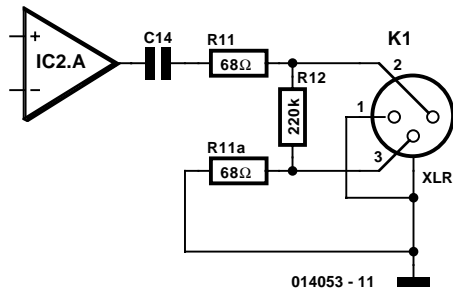
Components C14 and R12 remain unchanged.

It is not difficult to make this change on the printed circuit board of the audio DAC, but a bit of improvisation is necessary. After replacing R11 with a 68-Ω version, unsolder R12 and connect R11a in series with it. Bring out the junction of these two resistors to act as the signal return connection (pin 3 of the XLR socket). The same operation must also be carried out on the right channel, where the affected resistors are labelled R16, R16a and R17.
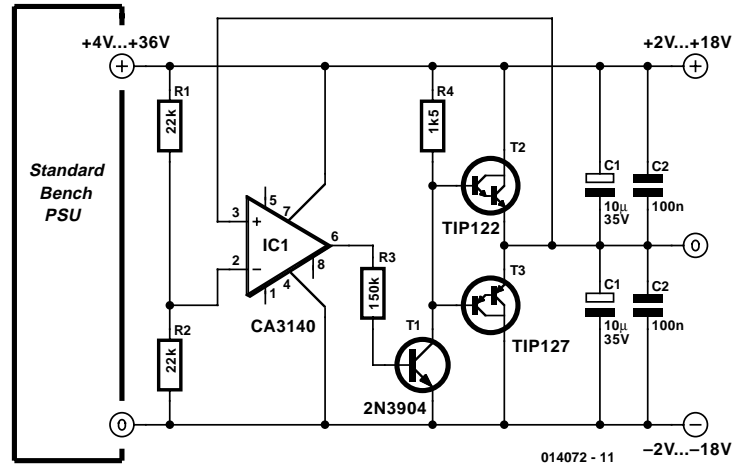
(014053-1)

Turning your Bench Supply into a Dual Supply

F. Jensen

When experimenting with opamp circuits, a dual supply is often needed. The circuit here presents a simple add-on that turns an ordinary bench power supply (PSU) into a dual supply.

The circuit creates, electronically, a midpoint at U/2 which is used as the ground reference for the circuit under test. Basically, the add-on is a non-inverting opamp buffered with a couple of darlington power transistors. The buffering makes the add-on capable of delivering several hundred milliamps. Note that the phase reversal of the buffer circuit means that the feedback has to be returned to the non-inverting input of the CA3140. The CA3140 has a wide supply range, from 4 to 36 Volts. None of the parts are critical and it should be easy to get good results with 'off the shelf' parts. The add-on itself consumes only a few milliamps.

(014072-1)

Getting the Best from Your Clock Radio

P. Lay

Clock radios often give atrocious reception, even when properly tuned in. This is not surprising when you consider that they usually only use a simple ferrite rod antenna. If no telescopic aerial is provided, then there is normally a half metre or so of wire poking out of the back of the radio, connected to the tuned circuit: this usually improves matters somewhat.

Unfortunately, however, it is not always enough: but a simple trick will let us improve the antenna's gain. Fit a single-pole connector to the end of the antenna wire, and to the other part of the connector attach a length of insulated hook-up wire. Using a couple of drawing pins attach the wire to the underside of the bed or the back of the wardrobe. For even more signal strength, fit instead a coaxial connector to the end of the wire and plug it into an aerial socket. It is perfectly adequate to connect only to the sheath and not to the central conductor. The connection can alternatively be made capacitively using a capacitor with a value of the order of a few pF. Indeed, soldering is not necessary: the capacitive effect makes mechanical fixing alone sufficient. If the aerial socket is near enough to the clock radio, then the hook-up wire can be dispensed with altogether and the connection made directly. This method is particularly suitable when the radio is shielded in a steel-reinforced concrete building.

(014055-1)

Precision Level Gauge

029

W. Zeiller

Precision instruments for measuring temperature, altitude and light intensity have all appeared in *Elektor Electronics*, but those of us who utilise rainwater have up to now looked in vain for a precision level gauge for our opaque rainwater tanks. All level gauge designs that have been previously published work on the basis of conductivity, which is not suitable for rainwater with its wide range of pH values. In addition, acidic rainwater converts the copper of the electrodes into green, water-soluble and poisonous copper salts. Here we present a continuously operating, accurate level gauge for rainwater tanks (and other types of containers) that brings an end to this situation.

A good level gauge is not based on the conduction of a current by the liquid, no matter what form this may take (dc, ac or pulses to prevent polarisation of the electrodes). Instead, a probe mechanically samples the position of the upper surface of the contents! With such a system, it is also possible to measure the level of a non-conductive liquid, such as heating oil. This arrangement is relatively simple (see **Figure 1**) and has the following advantages:

– It provides an easily sensed, continuous indication via a moving-coil meter (0 to 100%).
– A DVM can easily be connected in parallel as an indicator for a supplementary remote display.
– The power consumption is very low (e.g. 12 V × 5 mA = 60 mW), even with continuous operation.
– The level indication is accurate (for water or oil, independent of pH value and degree of contamination).
– A simultaneous trend indication is provided while the tank is being filled or emptied, thanks to the continuous display.
– Calibration is easy, with or without any liquid in the tank.

A lightweight, flexible metal or plastic band chain runs over a plastic gearwheel without slipping. A float (which may be a jam jar, for example) is attached to one end of the chain, and a counterweight is attached to the other end to keep the chain under tension. The mass of the counterweight should be around half that of the float.

The chain will travel back and forth as the level of the liquid rises or falls. The motion of the chain alters the position of the wiper of a precision potentiometer (a 10-turn multiturn potentiometer, Spectrol type 534), as can be seen from the circuit diagram (**Figure 2**). The voltage on the wiper (0 to 2.5 V, fixed by the 78L02) is thus proportional to the level of the liquid in the tank.

The 100-μA moving-coil meter connected to the potentiometer is used as a voltmeter instead of an ammeter. A current of 100 μA corresponds to 100% full, which makes

1

010012-11
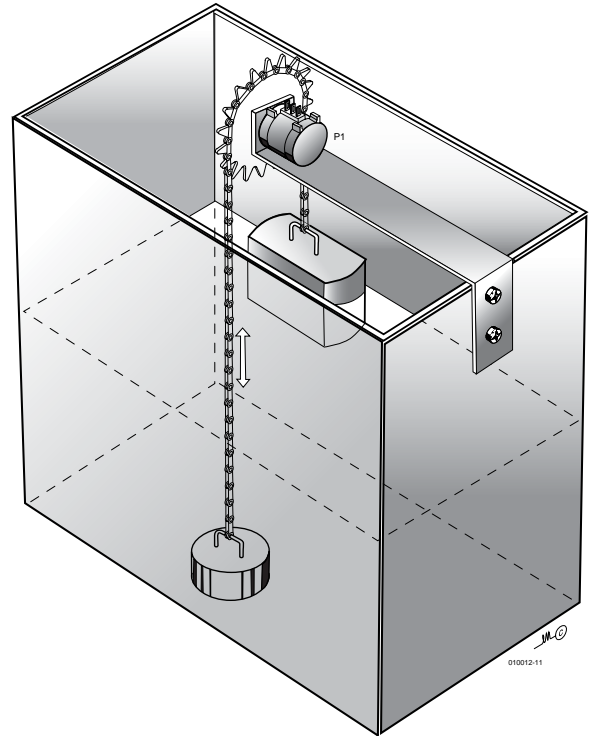
the instrument easy to read. Due to the high resistance of the measurement circuit (P2, R1 and M1), the current consumption of the display is around 0.1 mA, which is comparable to that of a DVM. Nevertheless, the circuit satisfies the 'linearity principle', which states that the resistance of a load connected to a potentiometer (here with a value of 2 kΩ) must be at least 5 to 10 times greater than the resistance of the potentiometer. The internal resistance of the moving-coil meter (around 1 kΩ) adds to that of the fixed resistor R1 (18 kΩ) and a portion of the variable resistor P2. This calibration resistor has to be adjusted only once so that the meter indicates a current of 100 μA with the tank

2

010012 - 12
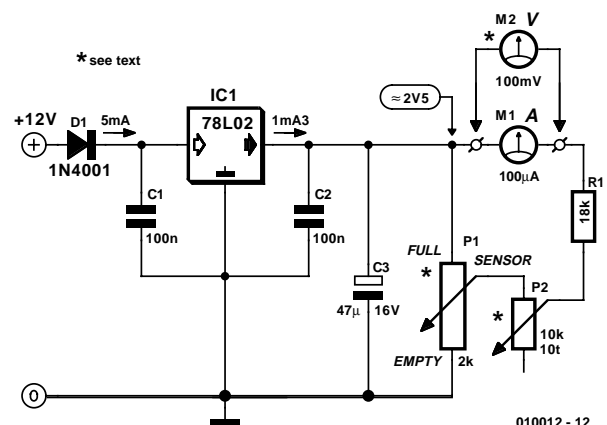
filled or the float is lifted up to the full level. Following this calibration, the 10-kΩ variable resistor can be replaced by a fixed resistor. The maximum full height depends on the diameter d of the Module 1 plastic gearwheel (40, 50 or 60 mm), since with a 10-turn potentiometer, the travel range of the float is given by $h = 10\pi d$. This yields a maximum fill height of 125, 157 or 188 cm. For secure mounting, the potentiometer should be attached to a sturdy aluminium angle bracket, which in turn is mounted on a strip of wood placed over the top opening of the tank. After drilling out the centre bore of the gearwheel from 4 mm to 6 mm, you must carefully but firmly force it over the end of the 6.35-mm diameter potentiometer shaft, which must then be oriented exactly level. The 'missing' 0.35 mm in the gearwheel inner bore ensure a secure fit to the potentiometer shaft. The band chain and gearwheels used to build the prototype were obtained from Conrad Electronics.

(010012-1)

12-V Light Organ

B. Kainka

Many people would like to build a light organ but are scared off by the dangerous mains voltage. A direct electrical connection to the amplifier should also be avoided. The light organ circuit presented here has been developed for 12-V halogen lamps and is controlled by sound waves. All you need is a triac, a condenser microphone and a few other components.

The electret condenser microphone needs a supply voltage, since it has a build-in amplifier. A supplementary transistor stage amplifies the microphone signal and feeds it to the gate of the triac. Nearly any type of triac in a TO220 package can be used here (such as a TIC206, TIC216 or TIC226). The circuit is powered from the halogen lamp transformer. A mini power supply, consisting of a rectifier diode and a filter capacitor, generates an unregulated but still satisfactory dc voltage for the amplifier.
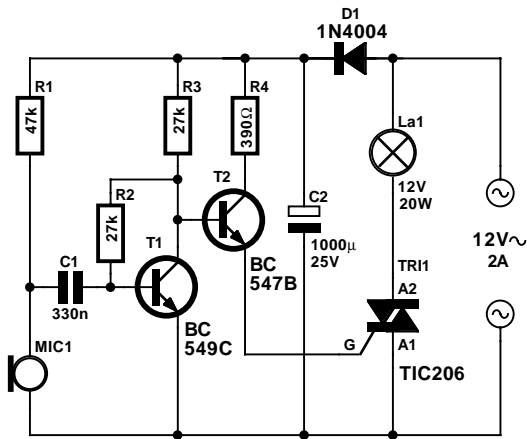
(014068-1)

014068 - 11

1.5-V White LED

Thanks to their high light output and long lifetimes, a white LED is an excellent choice as a replacement for the incandescent bulb in a penlight torch. However, there is a 'but'. Depending on the current level, white LEDs need a voltage of 3 to 4 V. You thus need a penlight with at least three batteries, which is not exactly what you can call compact. Fortunately, this problem can be remedied using a simple adapter circuit.

The design described here allows a white LED to be operated from a single 1.5-V battery. It consists of a simple step-up converter and an oscillator. If the circuit is built using SMD components as much as possible, it will not be difficult to fit everything into the torch.

The actual step-up converter consists of L1 and T1. The coil is wound on an EP7 core, which consists of a spool, two core halves (T-38 core material) and a clip/screen. It is available from Farnell, among others. Wind 17 turns of 0.5-mm enamelled copper wire on the spool. If you make the windings neat and tight, the core halves will just pass over the wound coil. Handle the spool carefully, since it breaks easily. The inductance of the coil made in this manner is around 360 μH, and it has a Q of 50 (at 1 kHz.).

A Zetex SMD transistor (ZXM61N02F) was used for the prototype. This miniscule MOSFET has a very low $R_{DS(ON)}$ and a low threshold voltage.

The driver oscillator for T1 is a classical R–C oscillator using a Schmitt-trigger inverter (IC1a, a Texas Instruments 74HC14). This proved to still work at 1.5 V. The frequency has been made adjustable so that the brightness can be increased when the battery is low by changing the frequency. There is an optimum setting, since the battery voltage drops when the battery is nearly empty and a large current is drawn. With a full battery, the lowest frequency gives the largest current. With the indicated component values, the frequency can be set between 50 kHz and 300 kHz. The brightness is greatest at the lowest frequency with a full battery; in this situation the current consumption is 16 mA and the efficiency is 84%.

The working principle of the converter is simple. When T1 conducts, the current through L steadily increases; at 50 kHz and a duty cycle of 50%, it will reach a value of 40 mA. When T1 stops conducting, the current in the coil continues to flow through D1. The inductive voltage across T1 is limited by D1.

The current through the white LED may be as high as 20 mA (in our case). Although the current peaks rise as
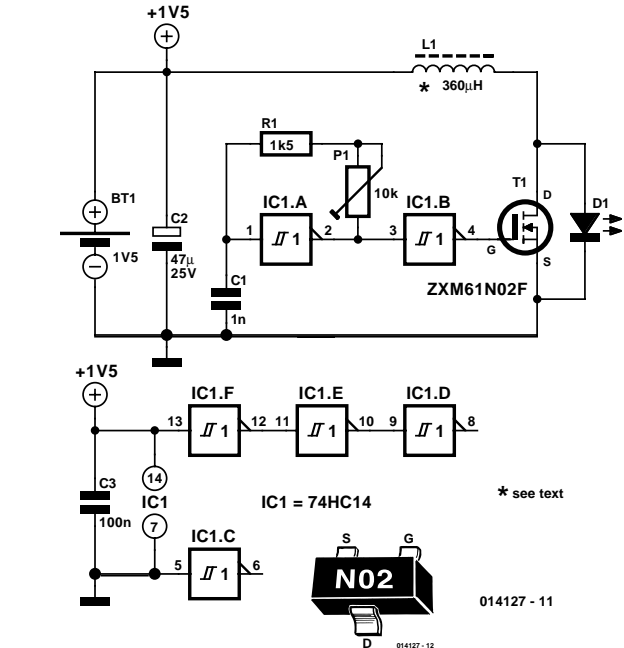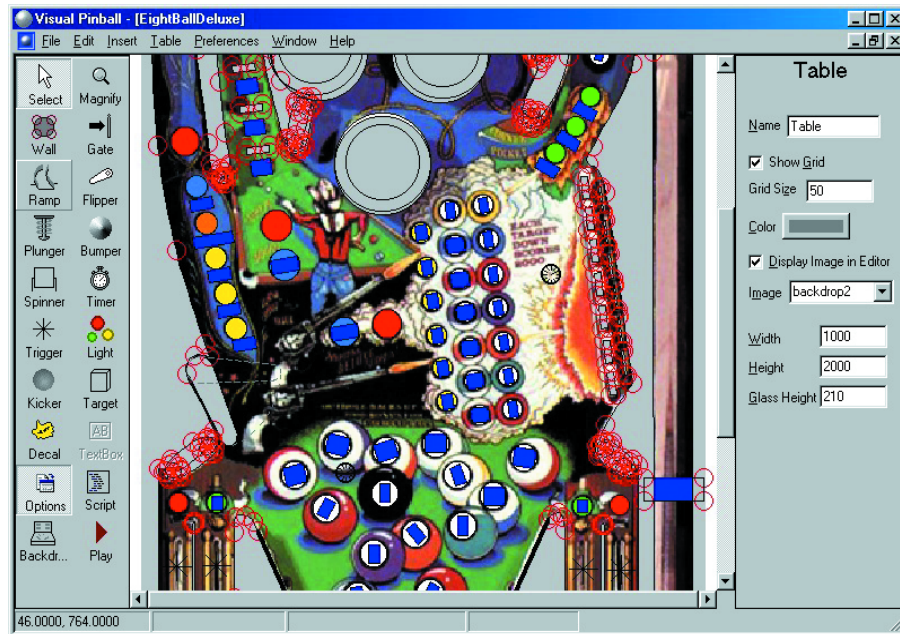
high as 40 mA, the average value is significantly lower.

Virtual PC Pinball Kit

Pinball simulators are nothing new. There is probably not a single computer system in existence for which no pinball game has been made. A few years ago, the Pinball Construction Kit made its debut. Using this, everyone could make their own pinball table on the PC from the standard virtual parts and supplied artwork. Time and progress haven't stalled, of course, and today you can download the beta-version of Visual Pinball for free from the Internet. A nice development environment, within which you can build you own fancy table or modify an existing table and prepare it for real play. For those who would prefer only to play, it is possible to download ready-made tables.

After starting Visual Pinball you are presented with a large grey area on the screen. On the left is a toolbox with all the parts that can also be found in the real game: spinners, bumpers, slingshots, flippers, etc. From the File-menu it is possible to either 'Open' an existing table or start from scratch with 'New'. The latter option presents you with the standard layout of the 'classic pinball table'. After that, it is just a mat-

ter of selecting the components from the toolbox and placing them in the desired locations on the table.

When you click the button 'Options' in the tool box, a window opens on the right of the screen with the properties of the selected object. This way it is possible to adjust, for example, the start and finish angle, the force, the size and the colour of a flipper, select the images of the playing field, etc. The accompanying help file provides elaborate details for all the parts.

Naturally, there has to be some interaction between the various game elements and the points score. The so-called 'script' handles this. When you click the box 'Script' in the toolbox you will find yourself in an edit window, which already contains a few lines that could have come straight from Visual Basic. These are all subroutines that define

what action should occur when a certain event happens, for example when a key on the PC keyboard is pressed, when a target or bumper on the table has been hit, etc. It will be obvious that writing the script will take the most amount of time, particularly when the rules of the table are complex.

Up to now, we have only looked straight down on the table, but once the table is ready for its the first test run and we start the game it will tilt to the correct angle and it appears as if we are in front of a real pinball table. Now play!

The current release of Visual Pinball is a beta-version. It doesn't work entirely smoothly, but is still very serviceable. The program can be found at

http://www.randydavis.com/vp.

(014100-1)

9-way sub-D Connector Adapter 033

A. Grace

You may soon find this pair of simple adapters invaluable when it comes to dealing with wiring problems caused by that 'can of worms' the serial (RS232) connection between PCs and peripherals.

The adapter allows the user to terminate bare wires into the terminal blocks rather than use a soldering iron — possibly in locations where the use of a soldering iron is not feasible. The authors, for instance, used it as a experimental connector whilst working out the wiring colour code of the cable. The adaptor was also used whilst debugging RS232 problems, and to terminate a temporary cable which passed through a bulkhead fitting on a GTEM cell during EMC testing.

There is no PCB design as such, and the circuit diagram appears more complicated than the final product! The only

from PC

to peripheral
000127 - 11
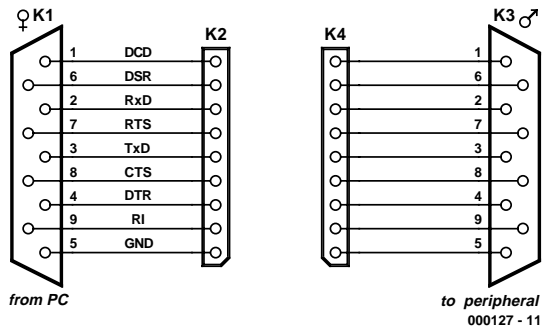
thing to watch out for during assembly, is that all connectors are fitted facing the outer edge of the board.

K1 is a 9 way 'D' female connector (socket), with right angled pins for board mounting. K3 is a similar type, but male (plug). K2 and K4 are simple 9-way screw terminal blocks.

Shoo Dog!

P. Lay

We've all had occasion to be annoyed at inconsiderate dog owners whose animals relieve themselves on the private property of others. This problem can hardly be solved in a lasting manner using verbal (or even physical) means, so recourse to an electronic remedy is better and friendlier. The starting point for this circuit is a ready-made passive infrared sensor (PIR), such as can be found in inexpensive movement detectors. The relay contact of the PIR energises the power supply of the circuit shown here. The power supply generates a voltage of around 15 V after rectification by
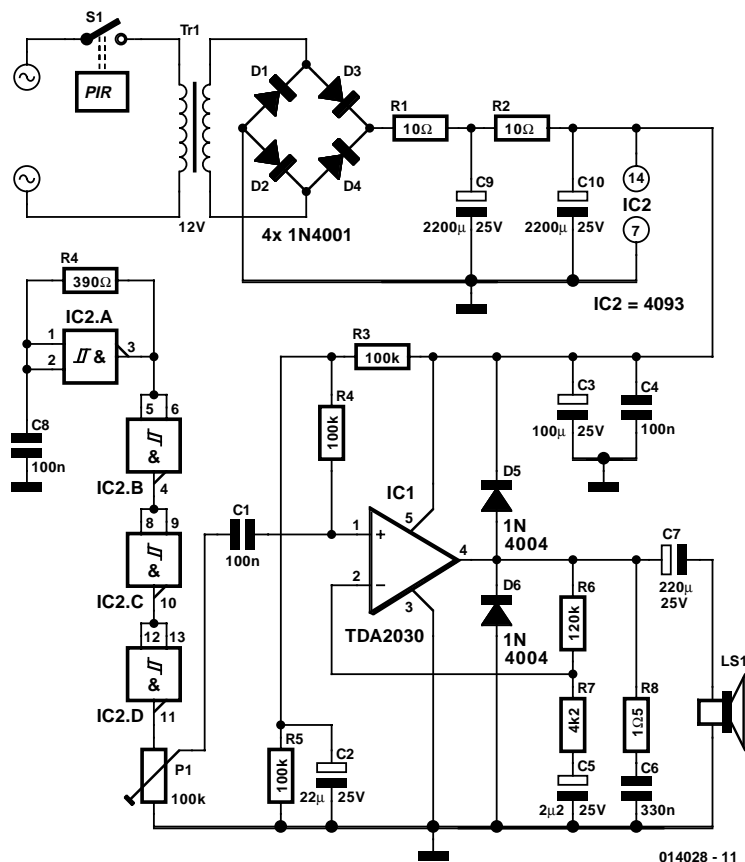
D1-D4 and filtering by R1/C3 and R2/C2. This voltage powers a square-wave oscillator comprising IC1a, R3/C1 and IC1b (acting as a buffer). The two unnecessary gates are simply connected in series with the buffer, so that they work with defined levels. The R-C network is dimensioned such that frequency of oscillation is greater than 20 kHz. The amplitude can be set using P1.

An IC power amplifier follows the oscillator to amplify this tone to a level that will be deafening for dogs (and other small creatures). We use the ST Microelectronics TDA2030 (http://us.st.com/stonline/books/ pdf/docs/1458.pdf), which has been used for some time in *Elektor Electronics* projects (at least since June 1995). The peripheral circuitry corresponds to the specifications in the data sheet. With a supply voltage of 15 V, the TDA2030 can generate around 5 W into a 4-Ω speaker. According to the data sheet, the supply voltage of the TDA2030 can be increased to as much as 30 V, at which level it generates a hefty 16 W into 4 Ω (or 11 W into 8 Ω). However, the 4093 still must be operated at 15 V, which is the maximum allowable supply voltage for a CMOS IC. In principle, any inexpensive piezoelectric tweeter whose frequency response extends past 20 kHz can be used for the speaker; it should have the highest possible sound pressure level (>100 dB). A suitable type is listed on page 626 of the Conrad Electronics catalogue. The imped-ance of such speakers rises to around 40 to 50 Ω at 20 kHz, so it is naturally not possible to obtain the power listed in the data sheet using this circuit. Nevertheless, it should be more than enough to scare off dog and master.

(014028-1)

Intelligent Fan Controller

014104 - 11
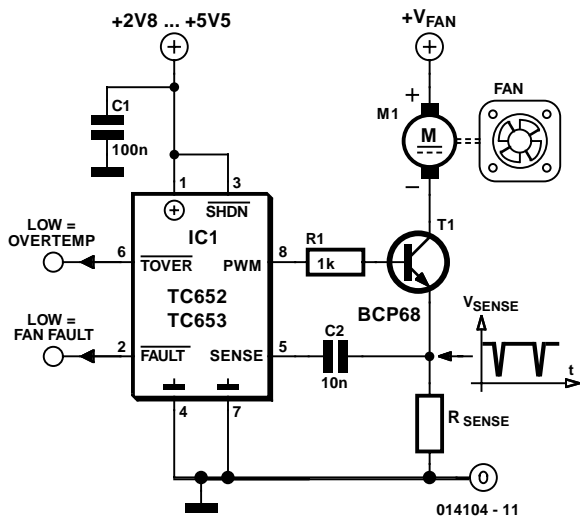
The commutation of a fan motor as the rotor moves from one pole to the next can be clearly observed as pulses in its current consumption. This property is exploited by the TC652 and TC653 fan controller ICs from Microchip Technology (www.microchip.com). The 'FanSense' feature, as the manufacturer calls it, derives an error signal from the commutation pulses. The devices also detect if the fan is jammed or has failed by the absence of these pulses. Resistor R_{sense} should be chosen so that about 0.5 V is dropped across it at the nominal fan current.

The fan is controlled via a switching transistor which is driven with a 15 Hz PWM (pulse width modulated) signal from the IC. The duty cycle of the signal is set to one of six values by the TC652/3. Below an internally set threshold temperature the duty cycle is set to 40% and then rises in

six steps to 100%. The 100% threshold temperature is also preset by the manufacturer. The following temperature options are available:

Code letter	A	B	C	D	E	F	G
Temperature in °C	25	30	35	40	45	50	55

The code letters form part of the order code for the device. The first code letter indicates the temperature threshold for 40% duty cycle operation, the second for 100%. The following preferred combinations are available (for the TC653 as well):
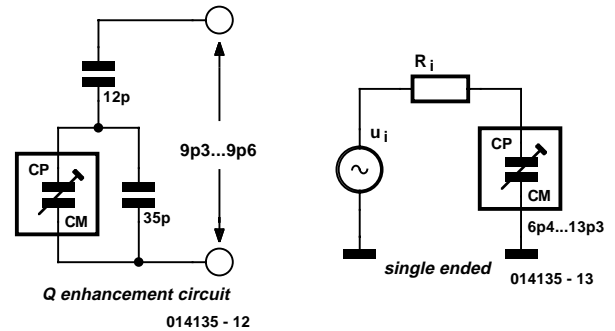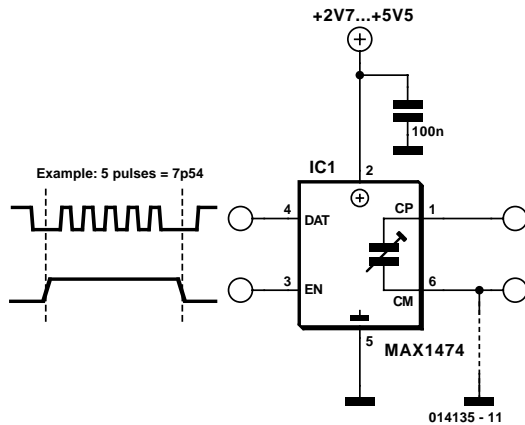
TC 652 AC	25 °C to 35 °C
TC 652 AE	25 °C to 45 °C
TC 652 BE	30 °C to 45 °C
TC 652 AG	25 °C to 55 °C

The TC653 also provides an auto-shutdown mode, where the fan is turned off completely below the lower temperature threshold (duty cycle = 0%), where the TC652 would operate at 40%.

A further feature of the fan controller is an over-temperature output. This is an active low output on the TC652/3 which indicates when the temperature is more than 10 °C higher than the upper threshold. The IC operates from a power supply of between 2.8 V and 5.5 V and consumes less than 100 µA (excluding its PWM output). (014104-1)

Electronically Trimmable Capacitor

Example: 5 pulses = 7p54

+2V7...+5V5

100n

IC1 MAX1474

4 DAT   CP 1
3 EN   CM 6
5

014135 - 11

12p

9p3...9p6

CP
CM

35p

Q enhancement circuit

014135 - 12

R_i

u_i

CP
CM

6p4...13p3

single ended

014135 - 13

Maxim (www.maxim-ic.com) have recently introduced an innovative IC the MAX1474 also called a FLECAP (Fine Line Electronically trimmable Capacitor). This device is basically a capacitor that can be electronically adjusted through the range of 6.4 pF to 13.3 pF in steps of 0.22 pF and is supplied as a tiny SC70 outline package. Capacitor adjustment is performed by sending a series of pulses to the DAT input while holding the EN input high. The number of pulses (up to a maximum of 31) are counted and latched into an in internal register on the falling edge of the EN input. At power-up with no pulses sent, the capacitance would be 6.4 pF in a single-ended application or 0.42 pF in a differential application.

DC voltage at the variable capacitance pins must be within the chip supply voltage and the signal swing can be up to 300 mV either side of V_{DD} and V_{SS}. For optimum performance it is recommended to connect the CM capacitor pin to the lowest impedance node in your application (ground or supply if possible).

R_i CM R_e

u_i CP u_e

0p4...10p9

differential

014135 - 14
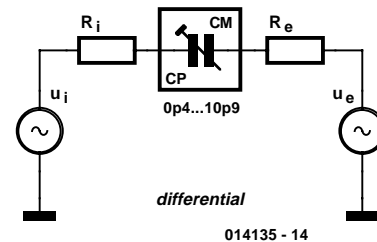
An internal multiplexer introduces a series resistance with the trimmable capacitor elements and this leads to a relatively poor quality (Q) factor of the capacitor. The diagram shows a method of enhancing the Q factor with fixed capacitors this will however reduce the range of the FLE-CAP.

One major application for this device will be to replace the variable trimmers usually necessary in quartz oscillator circuits. To increase capacitance range several FLE-CAP's can of course be connected in parallel or series.

(014135-1)

Battery Cooler

037
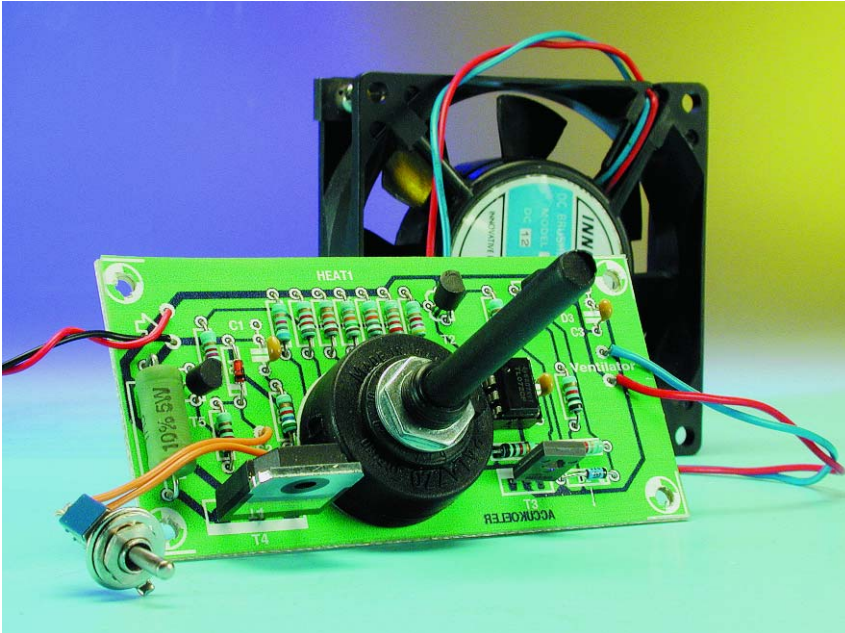
This battery cooler is used to cool and discharge lead-acid battery packs found in model planes, boats and cars, so that they can then be safely recharged.

In electrically driven model planes, boats and cars the battery can become fairly warm during use. It is therefore unwise to recharge them directly after use. This circuit cools the battery using its residual charge after a (hopefully successful) landing. If the battery still contains too much charge, it can be safely removed by the integrated discharge circuit. Whilst the circuit is on (and the average cell voltage is greater than 0.8 V), LED D3 will be lit. This

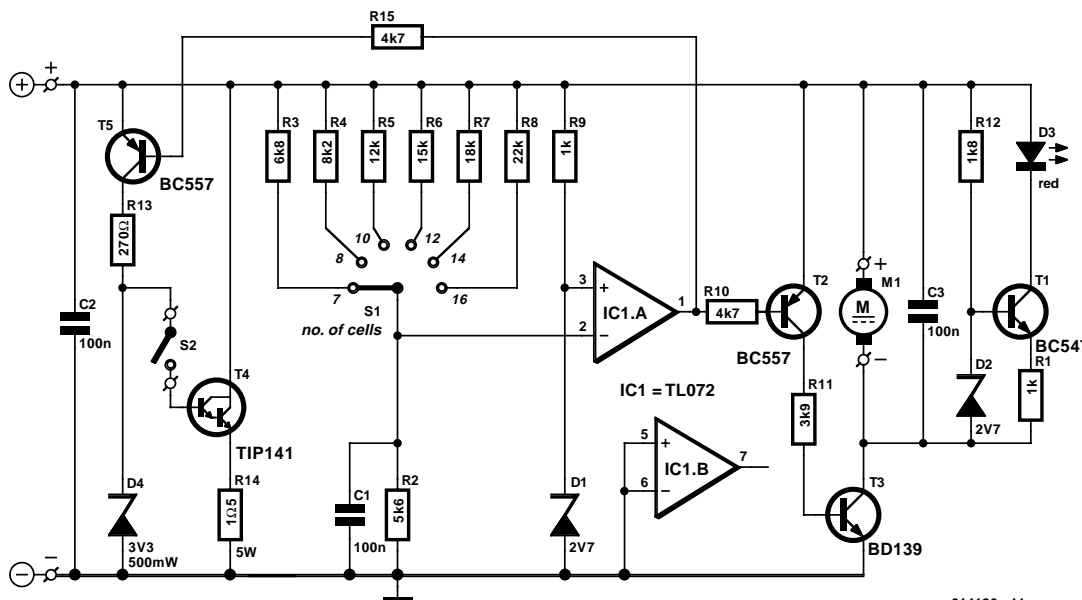makes it possible to check the state of the battery from a distance.

The design of the circuit is very simple. The battery which is to be cooled is connected to the '+' and '−' terminals. The battery also provides power to the circuit, which is very convenient. The supply voltage is fed to a potential divider and reduced by a factor selected with S1. This switch is used to specify how many cells the battery contains.

The voltage from the potential divider is compared with a fixed reference voltage of 2.7 V by opamp IC1A (wired as a comparator). When the voltage at the inverting input is greater than 2.7 V, transistors T2 and T5 will switch on.
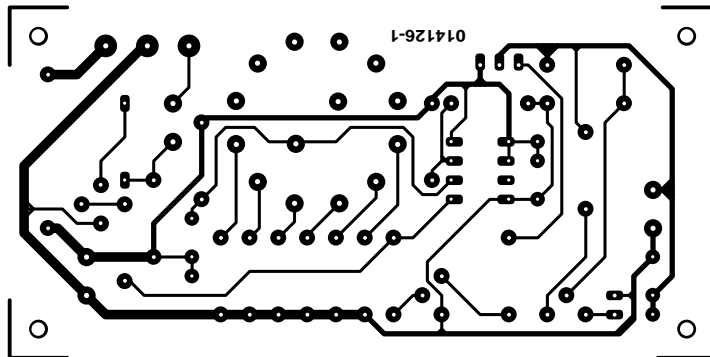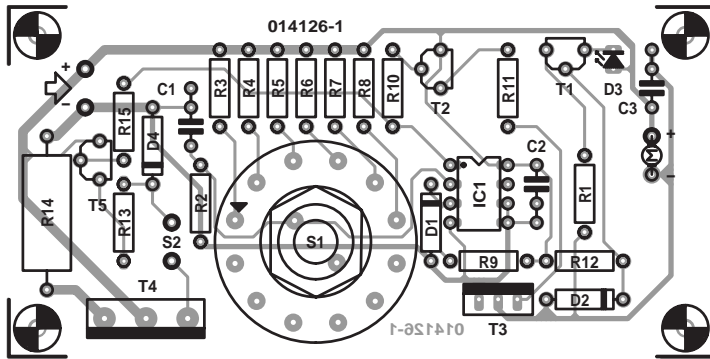
Transistor T2 drives transistor T3, feeding the battery voltage to the fan (M1), which starts blowing. T3 also drives a constant current source, built round T1. This drives LED D3 and provides a visual indication that the battery is still discharging. D3 has been purposely driven by a constant current of about 2 mA, making the LED light up with the same brightness, independent of the number of cells (between 7 and 16!) or the state of the battery.

Transistor T5 is used to switch on the discharge circuit built round darlington T4. With switch S2 closed, a voltage of 3.3 V is fed to the base of T4. The voltage drop across the two base-emitter junctions will be 1.2 V. This leaves a voltage across R14 of 3.3–1.2 = 2.1 V. This causes a current of 1.4 A to flow through R14. Since 99.9% of this current comes from T4, this transistor will convert most of the

014126 - 11

014126-1

energy into heat. This does mean that T4 needs to be cooled well, with a heatsink rated at 3 K/W or better.

Constructing the circuit is a simple job when the PCB shown here is used. For an enclosure you could use a short length of PVC pipe, with the fan mounted at one of its ends. A wooden 'rail' could be fixed in the other end, on which to place the battery to be cooled.

(014126-1)

Energising Coils with a Polyswitch

038

J.-M. Brassart

Despite the fact that fuses have had almost exclusive reign during much of the previous century, the impact made by resetable fuses such as the Polyswitch series from Raychem over the last decade is clearly noticeable. The resistance of these components (which have a positive temperature coefficient) increases suddenly when the temperature is raised. They may be used as a replacement for a fuse, with the convenience that it is no longer necessary to replace this fuse once it has done its job.

The application possibilities for the Polyswitch are diverse and include batteries, power supplies of various types, as well as small motors, transformers and loudspeakers.

014057 - 11
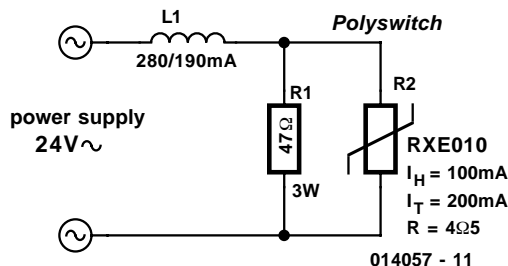
In the circuit shown here, a Polyswitch is used to reduce the current through a 24 V electromagnet from 280 mA to 190 mA (holding current). The coil is part of an electrically operated valve which forms part an automatic sprinkler installation, but this method is universally applicable. After determining, by either empirical or theoretical method, the

value of the series resistor, a shunt in the shape of a Polyswitch fuse is connected in parallel with it.

In our case, we needed a 47 Ω, 3 W resistor and a Polyswitch type RXE 010. The latter remains passive with currents up to 100 mA (I_H = 0.1 A) and becomes high impedance when the current is greater than 200 mA (I_T = 0.2 A). The resetable fuse remains in the 'open' position as long as the power supply is present. The Polyswitch device suggested here requires about 15 s before tripping. This allows the electric valve sufficient time to operate.

The author made use of an RXE 010 from Raychem (R = 4.5 Ω). The MF-R010 from Bourns has the same characteristics.

More information about these Polyswitches may be obtained from the manufacturers' web sites, www.raychem.com and www.bourns.com. A PDF (Adobe Acrobat Reader) datasheet for the Polyswitch family can be found at www.bourns.com/pdf/MFR.pdf.

(014057-1)

Lithium-Ion Charger I
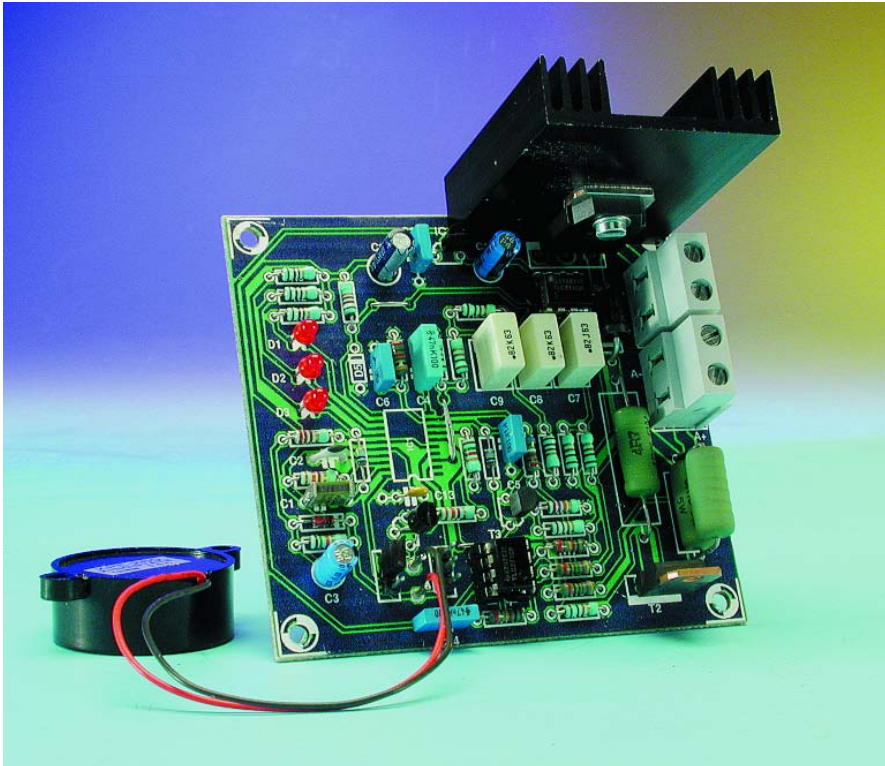
There are several ICs on the market that are specially designed for charging Lithium-Ion batteries. The LM3647 from National Semiconductor is one of those. The manufacturer describes this clever, 20-pins integrated electronics as a universal charge controller for Ni-Cd, Ni-MH and Li-Ion batteries. The IC can use a pulsed or constant charge current and can also be set up to discharge the battery before the charging process starts. During this process the LM3647 monitors the battery voltage, the time and (if required) the temperature. As soon as anything appears to go wrong, the charge current is stopped.

The circuit described here is only suitable for Li-Ion batteries. The discharge function is not used here because Li-Ion batteries do not require this.

Before you enthusiastically start building the circuit, it is wise to check that the IC is actually available. It is very recent and we had to work with samples that came direct from the manufacturer. Due to the lack of space we can only give a general overview of the operation of the IC and its use in the circuit based on that in the application note. We would advise that constructors download the data sheet and 'reference design user's manual' from the website at www.national.com. These contain much more detailed information.

For those who don't like to use the latest ICs and/or complex charge methods, we'd like to point out that there are also simpler solutions. Another article, 'Lithium-Ion charger II', which can be found elsewhere in this issue describes a method of charging Li-Ion batteries without the use of dedicated ICs.

The circuit shown here generally works as follows. A mains-derived supply is connected to K2 and the Li-Ion battery goes to K1. The controller (IC1) detects when a battery is connected and begins a test phase during which the charging current is 0.2 of its maximum. If the battery voltage remains too low it is assumed that the battery is defective and an error condition is indicated by the LEDs. If the battery voltage rises too much during this period, the battery is fully charged and the charging process stops.
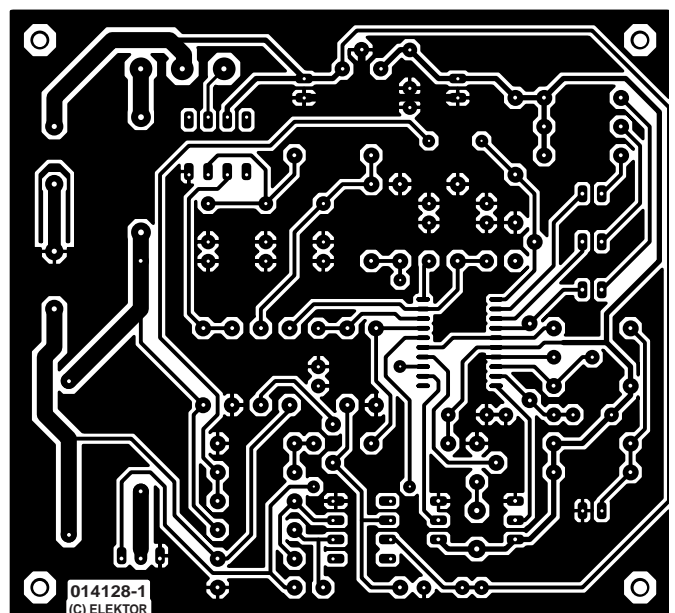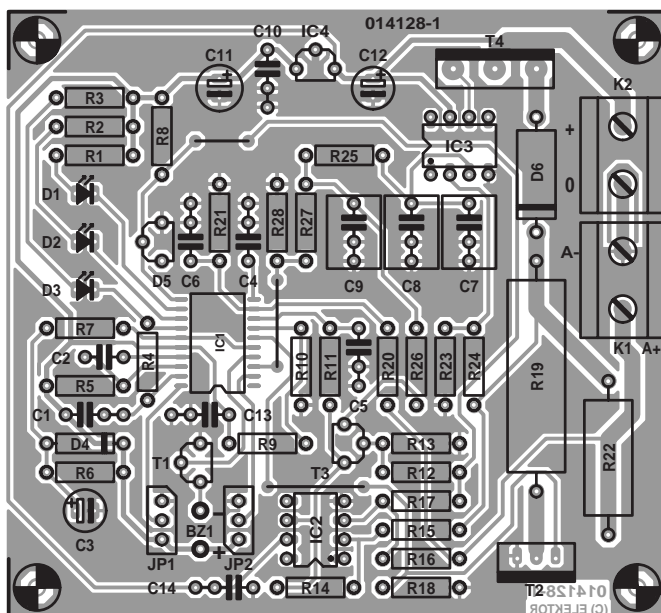
If the battery voltage is between these two limits, the battery will be charged at the maximum current (charge phase 1) after a short period of time (anywhere between tens of seconds to several minutes). That continues until the maximum battery voltage is reached; the current is then

014128 - 11
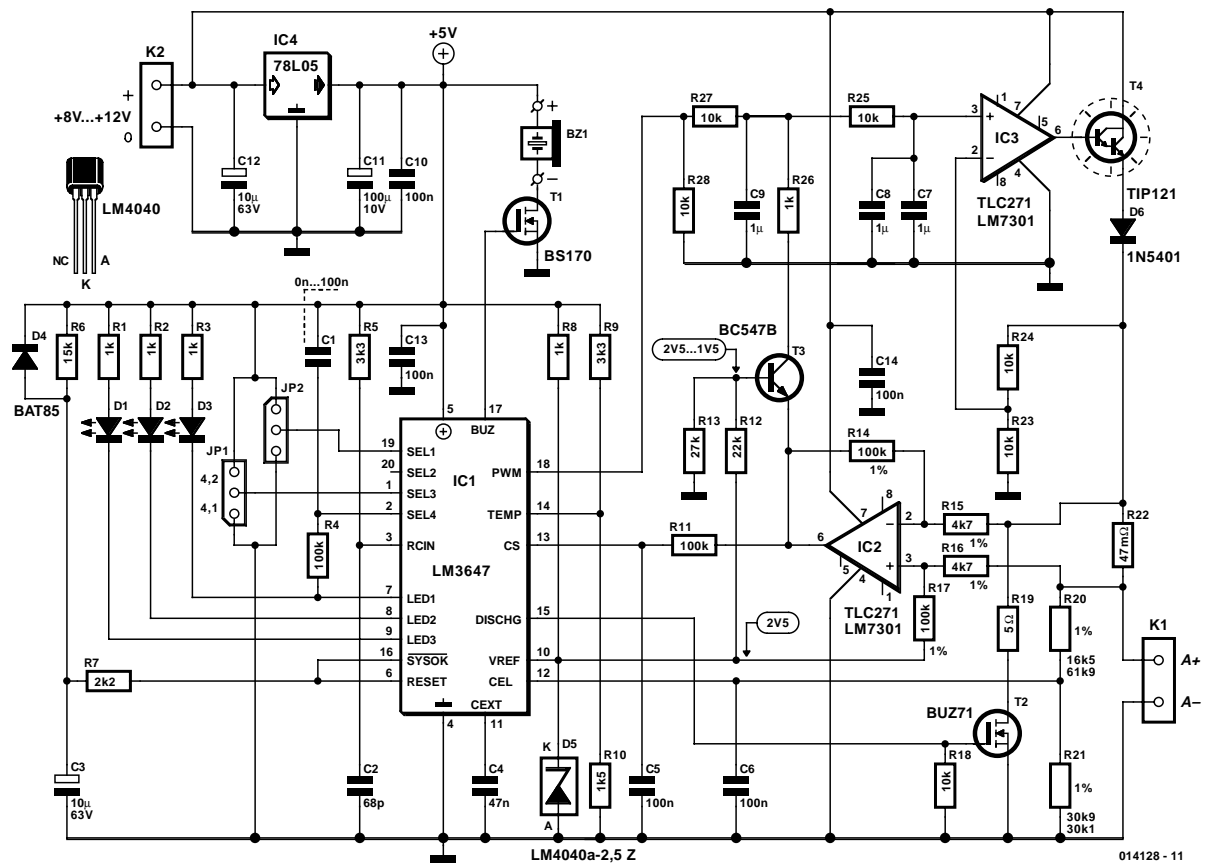
reduced such that the battery voltage remains constant (charge phase 2). When the current drops below 0.2 of the maximum charge current the battery is fully charged. Each of these conditions is listed in **Table 1**.

In fact, only the charge voltage is regulated by the controller via its pulse width output (pin 18). This PWM signal is averaged and fed to IC3, which makes the voltage at the

junction of D6 and R22 correspond to the PWM signal. With an oscilloscope it can be clearly seen how IC1 carefully increases the pulse width until a current begins to flow through the battery. This current is measured using R22. The voltage drop across R22 is amplified by IC2 and fed to the CS input of IC1. At the same time the charging voltage is measured via R20/R21 and the CEL input. This provides

SMALL CIRCUITS COLLECTION

COMPONENTS LIST

Resistors:
R1,R2,R3,R8,R26 = 1kΩ
R4,R11 = 100kΩ
R5,R9 = 3kΩ3
R6 = 15kΩ
R7 = 2kΩ2
R10 = 1kΩ5
R12 = 22kΩ
R13 = 27kΩ
R14,R17 = 100kΩ 1%
R15,R16 = 4kΩ7 1%
R18,R23,R24,R25,R27,R28 =
10kΩ
R19 = 5Ω 10W
R20 = 16kΩ5 1% (61kΩ9 1%)
R21 = 30kΩ9 1% (30kΩ1 1%)
R22 = 0.05 Ω 1W

Capacitors:
C1 = 0-100nF (22nF)
C2 = 68pF
C3,C12 = 10μF 63V radial
C4 = 47nF
C5,C6,C10,C13,C14 = 100nF
C7,C8,C9 = 1μF MKT
C11 = 100μF 10V radial

Semiconductors:
D1,D2,D3 = LED, high efficiency
D4 = BAT85
D5 = LM4040a-2.5 Z
D6 = 1N5401/SB530
T1 = BS170
T2 = BUZ71/BUZ 11
T3 = BC547B
T4 = TIP121/TIP142
IC1 = LM3647 IM (National Semiconductor)
IC2,IC3 = LM7301 / TLC271
IC4 = 78L05

Miscellaneous:
JP1,JP2 = 3-way jumper
K1,K2 = 2-way PCB treminal block, lead pitch 7.5mm
BZ1 = buzzer 6V
Heatsink for T4: e.g., Fischer type SK59 (Dau Components)

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the IC with all the details to charge the battery.

The IC has an extra safety feature that terminates a charging phase after a certain amount of time, which is dependent on the value of C1 (see **Table 2**). Apart from that, the temperature of the battery can also be monitored. In that case R9 is replaced by a NTC, mounted in the battery holder. More information on this can be found in the previously mentioned data sheets.

Construction of the charger shouldn't cause any problems when the PCB shown here is used. There are a few practical points that should be mentioned.

As we said earlier, the battery is connected to terminal block K1 and the supply is connected to K2. This needs to be at least 8 V when one cell is charged or 12 V for two cells; obviously the supply should be capable of providing the required charging current. Transistor T4 has to dissipate a fair amount of heat and requires a heatsink.

The pins marked 'BZ1' (next to T1) are intended for an active buzzer. Components R19, T2 and R18 can simply be left out. These are never used in Li-Ion mode. But because these components are shown on National Semiconductor's application note, they were inadvertently added to the circuit. You should also pay attention to the value of oscillator capacitor C2; this really should be 68 p and not 8p2 as stated by the manufacturer.

When jumper JP1 is connected to earth, 3.6 V cells are charged, a jumper to the positive is for 3.7 V cells. Connecting JP2 to earth causes a small maintenance current to flow after charging is complete and the controller will automatically restart the charging process should the battery voltage become too low.

When charging one cell, R20 and R21 should have values of 16k5 and 30k9, for two cells in series they should be 61k9 and 30k1. In this design the maximum charging current is about 1 A (50 mV across R22). As you can see from the photograph, we've used two resistors of 0.1 Ω in parallel for R22, because we could not obtain one with a value of 0.05 Ω. Other currents can be selected by changing the value of R22.

And finally a very important observation: check that the maximum output voltage is not exceeded during the charging process. The voltage may never rise above 4.1 (4.2) volt per cell. If it seems that this limit may be exceeded the values of R20/R21 should be adjusted accordingly. Above this voltage there is a real chance that the battery could explode, **so pay particular attention to this**!

I²C Temperature Sensor

In the July/August issue of 1998 we introduced the LM75, a 9-bit temperature sensor. Since then, the same company (National Semiconductor) has made a 13-bit version available with part number LM76. The resolution has become 0.0625 (!) degrees. The component has an absolute accuracy between 0.5 and 2.5 degrees, depending on the type. It is made available for use with supply voltages of 5V or 3.3V.

Apart from the LM76, the company has introduced a new part: the LM92, of which the internal block diagram is shown here. This sensor has the same properties as the LM76, but has the big advantage that it works with any supply voltage between 2.65V en 5.5V

Both the LM76 and the LM92 fit on the PCB which we designed for the 'old' LM75 and which we again have reproduced here. The only difference is that pin 5 is no longer an I²C address input, but an interrupt-output. So it is still possible to use the old PCB for the experiments, but remember that jumper JP3 should never be closed. R5 is the pull-up resistor for the interrupt and can stay where it is.

As far as we are aware, no new version of the software
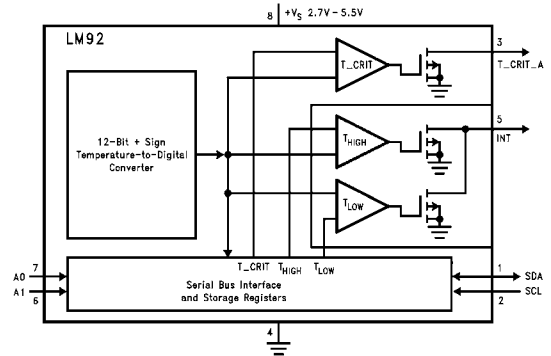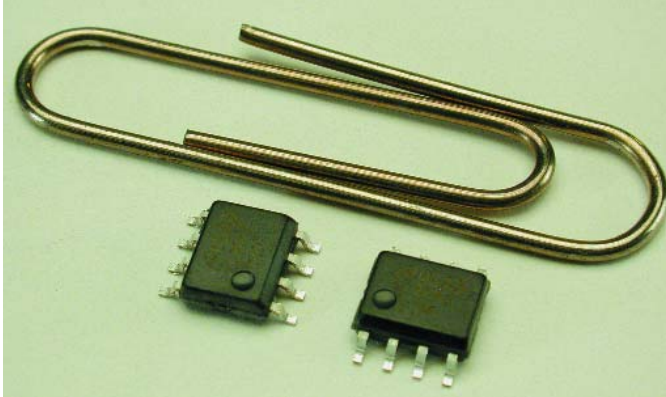
is available, so you will have to write your own routines. The interrupt output becomes active-low when the temperature goes outside the programmed limits (above the highest or below the lowest). The T-Crit output goes Low when the temperature exceeds the programmed limit. All limits can be easily programmed via the I^{2}C bus.

A datasheet with full details on the LM92 can be found on the Internet site of National Semiconductor: http://www.national.com

(014136-1)

Polyswitch Thermal Protection 041

J.-M. Brassart

A Polyswitch is an electronic fuse, which interrupts a protected circuit when the nominal current has been exceeded, but returns to its original state once it has cooled down.

In reality, the Polyswitch performs the same function as a fuse, namely interrupting the current when this has reached an excessive level. The classical fuse simply gives up the ghost — it is either 'ok' or 'blown'. There is no other solution then to replace it, once the electrical problem has been resolved. The Polyswitch however, may be returned to its serviceable state by switching off the power supply. It is no longer necessary to replace the fuse.

As yet, the most conventional areas of application for a Polyswitch are loudspeakers, batteries, motors, power supplies, chargers and other equipment with a coil.

Investigating the operation of the Polyswitch a little closer, it can be seen that the resistance (which is of the order of a few ohms at room temperature) rapidly increases above about 110 °C.

It may be assumed that everyone knows that the heating element of an electric kettle or coffee maker will quickly burn out if it is allowed to boil dry. Putting one and two together, the author had the idea to use a circuit with a Polyswitch, as is shown here, for the previously mentioned household appliances that are not protected or, potentially, as a replacement of the original protection.

The Polyswitch depicted here is in thermal contact with

014063 - 11
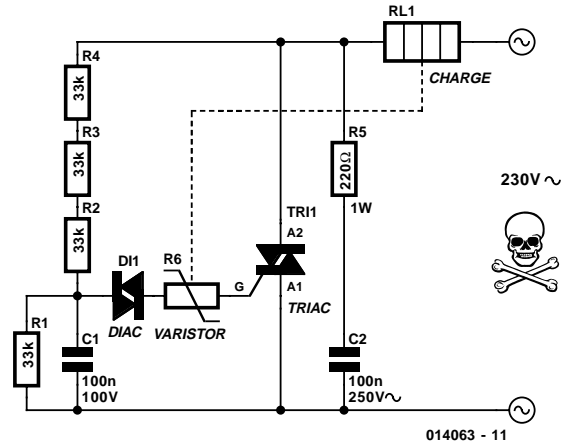
the heating element. Together with the triac, which drives the load, it acts like a kind of thermostat that limits the temperature to about 120 °C. The size of the Polyswitch is not important, but because of its small dimensions an RXE 010 was selected.

The Polyswitch from Raychem used here has the following characteristics:

Holding current:	0.1 A
Trip current:	0.2 A
Initial resistance:	4.5 Ω

Visiting the Internet sites www.raychem.com and www.bourns.com respectively is highly recommended. You have a good chance of finding these parts in the catalogues of the well-known mail order supply houses.

(014063-1)

LF DAC Driver

042

A. Grace

This simple circuit was developed as a low-frequency (LF) signal generator to exercise a temperature control system used to control a process that can have a very large time constant (i.e., the time taken for the output to reach equilibrium after a change of input signal) of tens of minutes to several hours. The circuit can be used to test a control system out on the bench before being re-installed back in the plant, or used as part of a demonstration rig.

The test circuit outputs a triangular voltage signal on K2 that ramps from zero to +5 V and then back down again to 0 V. The time taken for one cycle is dependent upon the clock signal fed into the circuit at K1. The circuit contains an 8-bit DAC whose output will cycle from zero to maximum in 256 steps. With a 1 Hz clock signal at K1, the period of the signal will take 2 times 256 seconds or approx. 8.5 minutes. If this is too fast, the input to K1 could be predivided by a second counter.

The AD7224 DAC IC4 lies at the heart of the circuit. This is a voltage output DAC whose output voltage signal ranges from zero to the reference voltage on pin 3, which in this case is the +5 V logic supply voltage. If higher accuracy is needed, then pin 3 should be fed from a suitable voltage reference (if an elevated output voltage is required, then have a look at Application Note AN-316 from Analog Devices which explains how this can be achieved). The AD7224 is manufactured by Analog Devices as well as

Maxim, with various suffixes. It may be obtained from RS Electronics at a price of about £8. Note that the AD7224 is not equivalent with the ICM7224, which is a display driver! The double-buffered interface logic of the DAC consists of two 8-bit registers — an input register and a DAC register. Both registers are made transparent by grounding the three control lines ($\overline{CS}$, $\overline{WR}$, $\overline{LDAC}$). Under these conditions, the $\overline{RESET}$ line functions as a zero override. This is achieved at power up via the transistor buffered RC circuit of T2, R4 and C4.

The voltage output signal of the DAC is incremented under the control of the outputs of a 12-bit counter type 4040 whose outputs are incremented in a binary fashion on the falling edge of the clock pulse applied to pin 10 via K1. Nine of the counter's twelve outputs are used in this design. Q0 to Q7 provide the 8 bit data for the DAC, and Q8 is used to control the slope of the DAC output signal via XOR gates in IC2 and IC3. With output Q8 at logic 0 (count less than 256), the outputs of IC2 and IC3 will have the same output polarity as the output of the counter and the output voltage of the DAC will increment. When the counter reaches 256, Q8 will go high, and the outputs of the counter will be inverted via XOR gates. This gives the effect of the output voltage of the DAC decrementing, whilst the counter continues to increment. The counter is also reset at power up via a second reset circuit comprising of T1, R1 and C2. The counter has the longer time constant to allow the DAC

014003 - 11
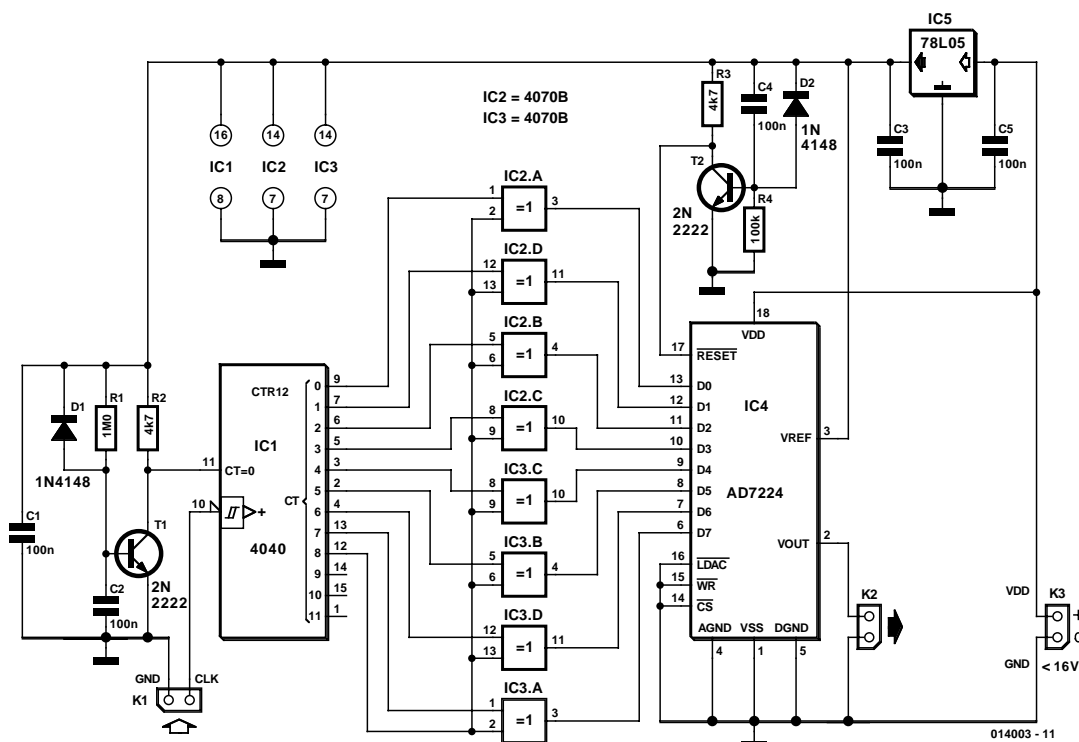
to settle first before the counter is incremented.
The whole circuit is powered via K3. Note that the supply voltage to the AD7224 must be a minimum of 4 V higher than the reference voltage, up to a maximum of 16 V. See the AD7224 data sheet for further details.

(014003-1)

KITT Scanner

014038 - 11
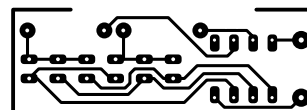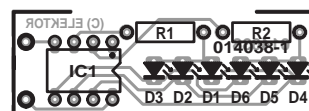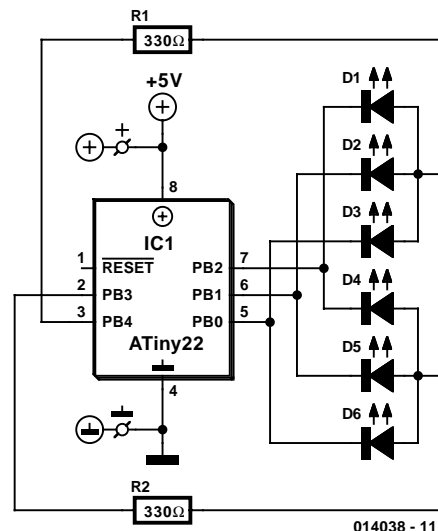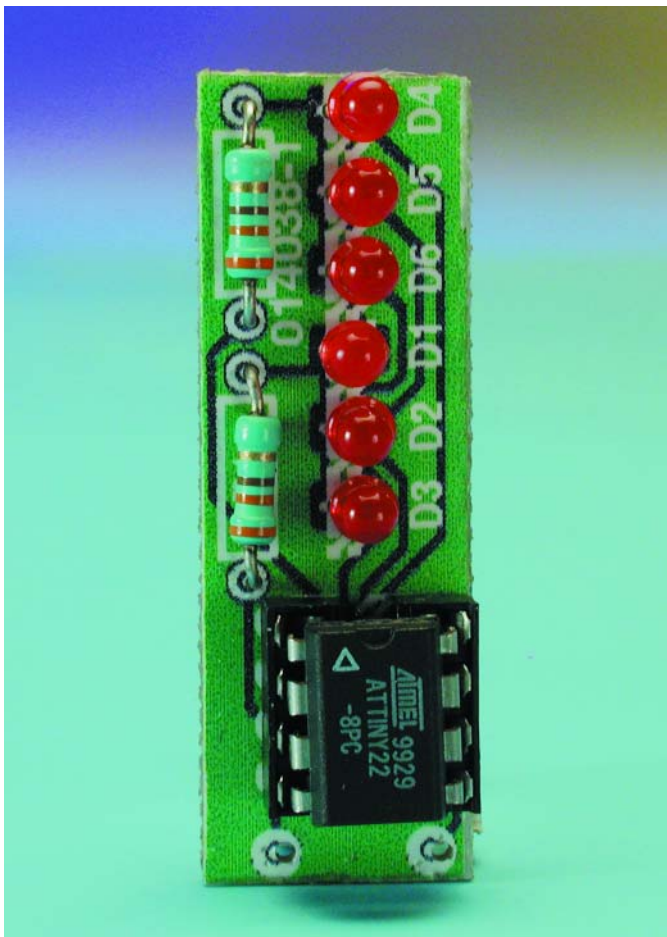
COMPONENTS LIST

Resistors:
R1,R2 = 330Ω

Semiconductors:
D1-D5 = LED,
  high-efficiency
IC1 = Atiny22 (Atmel)

R. van Arum

Among all the designs for running and flashing light displays we have published over the years — and that's a respectable number — there is one that can be said to have generated truly phenomenal interest: the 'KITT scanner'. Although it appeared quite a while back (16 years ago already!), we still receive requests for it. Was it such a wonderful design? Not at all; it was just a simple light pattern that continuously ran from left to right and back again – but as luck would have it, the hero of a TV series that was very popular at the time drove around in a car with exactly the same type of display mounted in the grille. Naturally, all of his enthusiastic fans wanted to have exactly the same thing. Since, as we have mentioned, the interest in this display has

not completely died out, we think that the mini version described here will be appreciated by many of our (younger) readers. It is based on a small Atmel microcontroller (the Atiny22), and if you use the printed circuit board layout shown here, you can work it into an extremely original brooch or earring for the disco. As can be seen from the schematic diagram, the circuit contains only two resistors and six high-efficiency LEDs in addition to the controller.

Although the control program is very simple, it is still too big to be printed here. However, if you are interested you can download it (free of charge) from our website at www.elektor-electronics. co.uk. Look for file number **014038-11**, Free Downloads section.

(014038-1)