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Quickroute is available in 4 different versions (see Table) all of which offer great value for money. Quickroute is available with multi-sheet schematic capture, 1-8 layer auto-routing, copper fill, engineering change, and a range of popular file import/export features allowing connection to simulators and other software packages (details on request). Prices are Personal (£458), Designer (£149), PRO (£249) and PRO+ (£399). Please add P&P and V.A.T to total (see below).

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SMARTRoute 1.0 is a new 32 bit auto-router that offers amazing flexibility & power at an affordable price! Compatible with Windows 3.1/95/NT, SMARTRoute gives you total control over routing strategies including layers used, track & via sizes, design rules, etc.

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MExpress is available in Standard (£99) and Developers Edition (£299). Prices exclude P&P and V.A.T (see below). The Developers Edition includes tools for turning MExpress script files into C++ code. This can be compiled by an MExpress compatible C++ compiler into a stand alone executable!

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focus on: simulation software

mini Flash programmer

electric-bulb tester

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Technical Editor: Jan Buiting
Editorial & Administrative Offices:
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England
Telephone: (01305) 250 995 (National )
or +44 1305 250 985 (International )
Fax: (01305) 250 996 (National )
or +44 1305 250 996 (International )

U.K. Advertising Office:
3 Crescent Terrace
CHELTENHAM GL50 3PE
Telephone: (01242) 510 760
Fax: (01242) 226 626

International Advertising Office:
Segment BV
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 438 9444
Fax: +31 46 437 0161
e-mail: elektuvar @euroserv.nl

Subscriptions:
World Wide Subscription Service Ltd.
Unit 4, Gibbs Reed Farm
Pashley Road
TICEBURST TN5 7HE
Telephone: (01580) 200 657 (National )
or +44 1580 200 657 (International )
Fax: (01580) 200 616 (National )
or +44 1580 200 616 (International )

Head Office:
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 438 9444
Fax: +31 46 437 0161

Managing Director:
Johan H. Boermann
Deputy Managing Director:
Menno M.J. Landman
Editor-in-Chief/Publisher:
Pierre E.L. Kersemakers

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52072 AACHEN
Editor: E.J.A. Krumpensauer

GREECE
Elektor EPE
Karaiskaki 14
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Editor: E. Xanthoulis

INDIA
Elektor Electronics Pvt Ltd
Chhatani Building
52C, Proctor Road, Grant Road (E)
BOMBAY 400 007
Editor: C.R. Chandarana

ISRAEL
Elektoreal
P.O Box 41096
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Segment BV
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Editor: P.H.M. Baggen

POLAND
Elektor Elektronik
02-777 Warszawa 130
Strykta iwierzowa 271
Editor: W. Marcinski

PORTUGAL
Ferreira & Bento Lda.
Campo Grande, 56—879º
1700 LISBOA
Editor: E. Ferreira de Almeida

SPAIN
Larpress S.A.
Plaza República Ecuador, 2º
28010 madrid
Editorial Director: R. Rodriguez Fernandez

SWEDEN
Elektroteknisk Förlag AB
Box 3505
14015 HULDINGE
Editor: Bill Cedrum

Niche Software (UK)
12 Short Hedges Close, Northleach, GL54 3PD
Phone (01451) 869 737

France, Telindel Quartier Les Pradets, Chemin des Veyes, 83390 Cuers, FRANCE. Phone 94 28 66 67
South Africa, JANCA Enterprises, PO Box 32131, 9317 Fichardlpark at R299.00
Phone/FAX (051) 223744, email janca@pixie.co.za

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England
Telephone: (01305) 250 995 (National )
or +44 1305 250 985 (International )
Fax: (01305) 250 996 (National )
or +44 1305 250 996 (International )

U.K. Advertising Office:
3 Crescent Terrace
CHELTENHAM GL50 3PE
Telephone: (01242) 510 760
Fax: (01242) 226 626

International Advertising Office:
Segment BV
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 438 9444
Fax: +31 46 437 0161
e-mail: elektuvar @euroserv.nl

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Pashley Road
TICEBURST TN5 7HE
Telephone: (01580) 200 657 (National )
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Fax: (01580) 200 616 (National )
or +44 1580 200 616 (International )

Head Office:
P.O. Box 75
6190 AB BEEK
The Netherlands
Telephone: +31 46 438 9444
Fax: +31 46 437 0161

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SUPERHIGHWAYS LAWS FOR EUROPE
The European Commission has begun laying down the first bill to regulate information superhighways, such as the Internet. This means that the commission are treating information services separately from broadcasting or telecommunications.

NATIONAL INSTITUTE FOR MICRELECTRONICS
Nine UK based electronics manufacturers are to set up a National Microelectronics Institute (NMI) at Heriot-Watt University in Edinburgh, Scotland. The new centre, which will become the focus for development of the country’s microelectronics industry, has been created by, amongst others, NEC, Motorola, Siemens, GEC Plessey, Philips and Fujitsu in partnership with the UK Department of Trade and Industry, the Scottish and Welsh Offices and the Government Office for North East England.

DIGITAL TO RESTRUCTURE
Digital Equipment, the world’s second largest computer maker is restructuring with the loss of 7000 jobs worldwide (almost 9% of its workforce). The company is refocusing its PC business from the desktop to networks.

Young Woman Engineer of the Year
Interested readers are reminded that the deadline for receipt of completed nomination forms is 4 October 1996. Those wishing to be considered for the prestigious title - which carries an Award for Innovation Forms is 4 October 1996. Those wishing to be considered for the prestigious title - which carries an Award for Innovation are encouraged to provide details of their achievements.

PROGRESSING FROM THE PAST
Funds have been secured from the European Union to support a multi-media project connecting major historical archives in Dorset and Ireland. The funds were granted to the DorSET Technology Centre, based at Bournemouth University and part of the Southern Technology Centre Forum (SSTF). The University’s Centre for the History of Defence Electronics (CHIDE), an electronic archive of key developments in radar already accessible on the Internet, will now be linked to another major scientific archive: Ireland’s Birt Scientific and Heritage Foundation. The purpose of this collaboration is to shed more light on how science, engineering and technology can progress by analysing the contribution of some major technological discoveries of the past.

In the early years of the Second World War, Dorset was the location for some of the most important developments in electronics, which helped lead to today’s computer and space age. Significant breakthroughs in radar made in the country were in the forefront of the move into microelectronics, which drives today’s technology. Similarly in Ireland in the 1840s, the third Earl of Rosse built the world’s largest telescope on his Birr Castle estate. The Earl’s youngest son, Charles Parsons, invented the steam turbine which laid the foundation for today’s technology. Similarly in Ireland in the 1840s, the third Earl of Rosse built the world’s largest telescope on his Birr Castle estate. The Earl’s youngest son, Charles Parsons, invented the steam turbine which laid the foundation for today’s technology. Similarly in Ireland in the 1840s, the third Earl of Rosse built the world’s largest telescope on his Birr Castle estate. The Earl’s youngest son, Charles Parsons, invented the steam turbine which laid the foundation for today’s technology. Similarly in Ireland in the 1840s, the third Earl of Rosse built the world’s largest telescope on his Birr Castle estate. The Earl’s youngest son, Charles Parsons, invented the steam turbine which laid the foundation for today’s technology.

NEW IGBT FROM HARRIS
Harris Semiconductor, the company that invented the IGBT (insulated gate bipolar transistor), has developed a new generation of ultra small IGBTs that outperform much larger power MOSFETs at much lower cost. They are the industry’s first 600V IGBT family fabricated on size-1” die, which measure only 1/5th the size of conventional size-3 MOSFETs. According to Harris, the devices are the first IGBTs to challenge conventional MOSFETs in two major new applications: fractional horse-power motor control and line-voltage switch-mode power supplies.

This measures only 74x89 miles (1.88x2.49 mm); size-3 measures 170x227 miles (4.32x5.77 mm).

EUROPE ON THE WAY TO A STANDARD TELEPHONE CARD
While it has long been possible to use a credit card in special credit card telephones, in future the average user will be able to telephone from any major EU country using a single phone card instead of resorting to plastic credit card money. Germany and the Netherlands have taken the lead, and Switzerland and Denmark are about to follow suit. If one buys a phone card in any of these countries, it can be used in card telephones in partner countries irrespective of the local currency.

The Eurochip is a type of memory chip which means that the chip and also the technology stored on the chip. The design of the card telephones, in future the average user will be able to telephone from any major EU country using a single phone card instead of resorting to plastic credit card money. Germany and the Netherlands have taken the lead, and Switzerland and Denmark are about to follow suit. If one buys a phone card in any of these countries, it can be used in card telephones in partner countries irrespective of the local currency.

The Eurochip is a type of memory chip which means that the chip and also the technology stored on the chip. The design of the device means that it is protected by a transportation factory to the card manufacturers, and subsequently will come available in 1997 and 1998 respectively.

The underlying dynamic authentication system instantly generates a purely random response, which means that the device meets the most stringent security requirements.

The Eurochip’s architecture permits the use, for instance, of two totally different secret keys, so that two different service providers can have access to that card. This is already a step in the direction of a multi-application card which could save considerably on costs without any penalty in terms of security. If the second key is not required, the user’s abbreviated cell numbers, for example, could be stored in the 64-bit EEPROM provided.

The Eurochip concept is based on a data retention time of at least 10 years and 100,000 read/write cycles for each bit. The overall performance is not currently matched by any other telephone chip in the world.

But this far from being the end of the story. Because of the convincing facilities of the Eurochip, it is on the way to becoming the international standard and is being used increasingly in other applications such as prepaid electronic purses. However, the new applications mean that new requirements are continually being placed on the ics which cannot be met with just one device. Consequently, Siemens is developing a Eurochip family to satisfy all the requirements of the market. The second device in the family, the SLE5553, will be available by the end of the year. Its main additional facilities will be Cipher Block Chaining (for authentication) and authentication of the counter status. The range will also include low-cost variants and a rechargeable version which will become available in 1997 and 1998 respectively, thus providing a Eurochip for every application.

[960311]

[960310-1]
Software users -- beware!

An appeals court in the USA has found that software licences -- usually printed on the envelope containing the software disks or CD-ROMs and shrink-wrapped with the accompanying warning 'Read the licence before opening' -- are enforceable.

Hologrammed CDs

Holograms are soon to be used in the fight against one of the biggest threats to the music, games and computer software industries: CD piracy.

The CD hologram system, called 3-D ids, has been developed by Nimbus of Cwmbran, South Wales, and Applied Holographics in Newcastle.

Although hologrammed CDs cannot stop determined criminals, they will at least make it more difficult and expensive.

Sony shows CD-r drives

Almost a year after the welcome agreement between the two sides in the battle for the standard of the DVD (digital versatile disc), Sony have exhibited their Spressa series of CD-r (recordable) drives, both internal and external versions for the PC and Macintosh computers, reading and writing at double speed.

Internet and Yellow Pages

Next year, the Yellow Pages will include a new category: Internet providers and services. This is confirmation that Web Masters, an association of companies whose service is the creation and maintenance of pages for the World Wide Web, has been accepted by British business.

Precious books on screen

The British Library has developed a means of allowing visitors to leaf through precious books without touching them. Called 'Turning the Pages', it is a touch-sensitive screen with the open book displayed. To turn the page, you press the corner, and drag your finger across, bringing the paper over, just as it would in reality.

First chip with 16 KB EEPROM

Siemens has taken another step towards even smaller and more powerful smart card ICs, and is the first manufacturer of these ICs to develop a chip with 16 KB of EEPROM. The chip, designated SLE44C160S, is part of a new controller family and requires less than 15 mm² of space. In addition to the 16 KB of EEPROM, it offers 15 KB of RAM and 256 bytes of ROM. Its speed is evidenced by the fact that the EEPROM can be programmed with 64 bytes in 3.5 ms.

The SLE44C160S is the flagship of the new controller family with even better security functions. These include additional barriers against potential hackers, special protective functions for the EEPROM cells, encryption of the ROM addresses, and measures to prevent simulation of the smart card ICs.

Events

September

17. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)
25-29. Live 96 (consumer electronics show) at Earls Court, London
25-29. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)

October

1. Two-way television. A lecture at Queen's University, Belfast
2-4. Internet 96 at the Business Design Centre, London
3. Two-way television. A lecture at Queen's University, Belfast
8-10: The Euro-EMC exhibition and conference at Sancown Park Exhibition Centre, Esher
11-13. The Connect 96 consumer electronics show at the NEC, Birmingham
14-16. The Electronic components show at the NEC, Birmingham
15-17. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)
17-19. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)
20-22. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)
23-25. Mobile communications via satellites (Conference of the Royal Aeronautical Society in London)
26-28. The Manufacturing Week Exhibition at the NEC, Birmingham
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- Call saver facility at £2.50 per month (with this, all local calls are charged at 10p per minute).
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For not too extensive switching and control applications, microcontrollers with relatively few I/O lines, a limited instruction set and almost no peripherals are far better suited than power boxes like, say, the 8051 with 40 or more pins. Examples of small microcontrollers are RISC (Reduced Instruction Set Computer) processors such as the well-known PICs from Arizona Microchip, the devices in the ST6 family from Thomson, and, recently, the two 8051 compatible Flash controllers type 89C1051 and 89C2051 from Atmel. For the latter devices we describe a programmer with the perfect balance: simple hardware and powerful software.

As regards internal architecture and instruction set, the 89C1051 and 89C2051 are compatible with Intel's industry-standard 8051. As indicated by the overview of their main properties in Table 1, the Atmel processors are actually miniature versions of the 8051 with reduced ROM and RAM ranges. As regards computing power and application range, the Atmel chips are about equivalent to the PIC microcontrollers from Arizona Microchip. The 89C1051 and 2051 do, however, have some distinct advantages:

- Software compatible with the industry standard 8051, allowing you to continue using your favourite assemblers and simulators. Also, you do not have to learn a new programming language!
- Flash technology, so throw away your piggy-backs, EPROMs, UV erasers and expensive OTPs. The Atmel controllers are re-usable all the time.
- Inexpensive. UV-erasable PICs are much more costly!

So far, the 89C1051/2051 have not reached wide publicity despite their advantages. Although the Flash programmer we published in the May 1995 issue of Elektor Electronics was capable of programming the 89C2051, the hardware was fairly extensive. This article not only provides additional information on this controller type, it also presents a low-cost programmer for both the 89C1051 and the 89C2051.

**Special Features of the 89CXX51**

Extensive information on the 8051 family appeared in various articles in Elektor Electronics over the past few years, so that it is not necessary to revert to this subject in the present article.

Two properties of the hardware contained in the Atmel controllers are so unusual, however, that they deserve special attention. These properties, when used in a clever way, can help to simplify the circuit design considerably.
Direct LED drive

Ports P1 and P3 are current-boosted and capable of sinking 20 mA to ground. That enables LEDs, opto-isolators, small relays and similar devices to be controlled directly from the chip.

Integrated comparator

Alternatively, pins P1.0 and P1.1 may be employed as analogue inputs (P1.0 = non-inverting, P1.1 = inverting) of an on-chip comparator. The comparator compares the voltages at these inputs. If the difference is positive, the comparator output is switched high, when the difference is negative, the output is pulled low. This information is read via the (internal!) P3.6 port line. The solution with the comparator makes it easy to detect when an analogue voltage exceeds a certain threshold level. Using the on-chip comparator, all you need to realise a simple A-D converter is an additional R-C network and some software. The input voltages applied to the chip may lie between 0 V and $V_{CC}$.

**Brains, not muscles**

The mini Flash programmer of which the circuit diagram is shown in Figure 2 is proof that a modest hardware setup is sufficient if you are able to fully exploit the possibilities of a PC. Because the control software is very powerful indeed, only a handful of components is required to do the job. The programmer is powered by an ordinary mains adaptor supplying an output voltage of at least 12 V a.c. or d.c. A 7805 on the programmer board then provides a stable supply voltage for

**Figure 1. Internal structure of Flash controllers 89C1051 and 2051 with analogue comparator.**

**Figure 2. The simple hardware of the 89C1051/2051 Flash Programmer. Before starting the programmer, always make sure to have controller pin 1 aligned with ZIF socket slot 1.**
the ICs. LED D10 acts as a ‘power-on’ indicator.

Transistors T1, T2 and T3 form and adjustable voltage source. When T3 is driven, the base of T1 is at 0 V, and the programming voltage is switched off. When only T2 is driven, zener diode D3 stabilizes the base of T1 at a level of 5.6 V, so that a programming voltage, \( V_{pp} \), of 5 V is obtained. When T2 and T3 are switched off, diodes D1 and D2 provide a reference voltage of 12.7 V, so that the second programming voltage of 12 V is obtained. Resistor R1 limits the current to the controller’s programming pin. When the 12-V voltage is actuated, diode D5 conducts also, and the Program LED lights.

The data traffic is arranged by two shift registers type 4021 and 4094. In programming mode, the data are first serially written from the Centronics interface to the 4094. After the enable signal, this data is available via controller port 1 at outputs Q1 through Q8. The read operation (from the Atmel controller in the direction of the PC) is exactly the other way around, this time via the 4021. The data are copied as parallel words by the controller, and sent to the PC as serial words via the DOUT line.

All other data and control lines of the Centronics interface control the different modes of the programmer, coordinate the shift registers and the voltage selection. You need not worry about the exact programming timing, because the actual programming operation is controlled by the chip itself. All the software does in this respect is monitor the BUSY signal which is used by the chip to flag that a byte has been programmed.

You will also look in vain for an addressing circuit around the 89C051. An internal address counter is cleared to zero after a reset (i.e., automatically at the start of the program), and incremented after each byte. Consequently, any program should always be loaded completely, i.e., from the start. Post-editing of a single byte is not possible (else, the device would have been an EEPROM, not a Flash type). The available modes are listed in Table 2.

### Table 1. Main features of Atmel controllers

<table>
<thead>
<tr>
<th>ROM</th>
<th>1 kByte</th>
<th>2 kByte</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAM</td>
<td>64 Byte</td>
<td>128 Byte</td>
</tr>
<tr>
<td>Timer</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Serial Interface</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Interrupt sources</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Supply voltage</td>
<td>2.7 - 6 V</td>
<td></td>
</tr>
<tr>
<td>Ports</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Case</td>
<td>DIL / SO 20 Pin</td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>ATMEL</td>
<td></td>
</tr>
<tr>
<td>Clock frequency</td>
<td>0 - 24 MHz</td>
<td></td>
</tr>
<tr>
<td>Program memory</td>
<td>Flash (&gt; 1000 programming cycles)</td>
<td></td>
</tr>
<tr>
<td>Further features</td>
<td>20-mA ports for direct LED drive</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Operating modes of 89C051

<table>
<thead>
<tr>
<th>Mode</th>
<th>RST</th>
<th>P3.2*</th>
<th>P3.3</th>
<th>P3.4</th>
<th>P3.5</th>
<th>P3.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write Code Data</td>
<td>12 V</td>
<td>#</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Read Code Data</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Write Lock Bit -1</td>
<td>12 V</td>
<td>#</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Write Lock Bit -2</td>
<td>12 V</td>
<td>#</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Chip Erase</td>
<td>12 V</td>
<td>#</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Read Signature Byte</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*: P3.2 = PROG

### Table 3. Lock bit function

<table>
<thead>
<tr>
<th>Program Lock Bits</th>
<th>Protection Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>No program lock features</td>
</tr>
<tr>
<td>P</td>
<td>Further programming of Flash disabled</td>
</tr>
<tr>
<td>P</td>
<td>Further programming of Flash and Verify disabled</td>
</tr>
</tbody>
</table>

Lock bits may only be cleared while the chip is being erased.

### Table 4. Programming voltage control/selection

<table>
<thead>
<tr>
<th>Line</th>
<th>V/3</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volt</td>
<td>+5 V</td>
<td>+5 V</td>
<td>GND</td>
</tr>
<tr>
<td></td>
<td>GND</td>
<td>+5 V</td>
<td>+5 V</td>
</tr>
<tr>
<td></td>
<td>GND</td>
<td>+11.5 - 12.5 V</td>
<td>+4.75 - 5.25 V</td>
</tr>
</tbody>
</table>

The control software written for this project runs under DOS and enables all functions for reading as well as programming of the 89C1051 and 89C2051, including setting the lock bit (Table 3). When the program is started, the hardware is prompted to run a self-diagnostic test. In most cases, existing assembly language programs may be adapted without problems. This is done as follows:

- check the required ROM and RAM size;
- restrict I/O instructions to Ports 1 and 3 (not P3.6);
- check the special function register (Table 5).

Programs which are produced from scratch and intended to run on the Atmel chips may be written with the aid of an ordinary 8051 assembler. Do, however, observe the above restrictions. If you use a table-oriented assembler like TASM, it may be necessary to mask out the registers and ports which are not allowed. All data for the programmer must be in binary form.

### Construction and Practical Use

The single-sided printed circuit board shown in Figure 3 is populated with regular-sized components. Building up the board, we feel, should not cause problems. The LEDs, ST and the programming socket are fitted at some distance above the board, using pieces of component wire or stacked IC sockets. The board should be fitted as low as possible in the case. The programming socket is a 24-pin ZIF (Zero Insertion Force) version with wide slots (20-pin ZIF sockets being few and far between) to accommodate the 0.3-inch wide Atmel ICs. Next to the ZIF socket you have to fit seven wire links, and one near the Centronics connector. There are no adjustment points in the circuit.

After you have checked your construction work, connect the output of the mains adapter to the socket on the board, and switch on ST. LED D10 should light. Check that a voltage between 15 V and 16 V is present across capacitor C3. The supply voltage for all ICs behind the voltage regulator should be a steady 5 V. Next, it is recommended to run an extra check on the programming voltages at pin 1 of the ZIF socket, for all three modes of operation (Table 4). To do so, connect the indicated voltages to control lines ‘Voff’ and ‘Vth’, and check that the relevant programming voltage actually
reaches the ZIF socket. The latter value is particularly important, because the controller may be damaged if it is exceeded. Next, the programmer is connected to the LPT1 or LPT2 port on the PC, and the software is launched.

The mini Flash programmer was designed to be an inexpensive, simple programmer and not intended to intercept gross operating and user errors. Because of this, keep the following in mind if you want to ensure a long lifetime for your Flash controllers:

- The controller may only be inserted into the socket, or removed, if:
  - the mains adaptor is plugged in;
  - the programmer is connected to the PC;
  - the associated software has been launched;
  - the supply voltage has been switched off with S1.

When inserting a controller, make sure that pin 1 of the IC goes to slot 1 of the ZIF socket.

Figure 3. The printed circuit board for the programmer is relatively small and single-sided.

Also, never switch on S1 with a controller installed in the ZIF socket, and with the program not active. This is necessary to make sure that all the necessary logic levels are properly available when a controller is inserted or removed.

FAULTFINDING

A short self-diagnostic test is run when the program is launched. Two bytes, 0AAH and 055H, are written serially and read back again. When the test is finished without problems, the two CMOS ICs and the power supply may safely be assumed to function properly. Current consumption will be between 25 and 30 mA, and about 5 mA more when a controller is fitted in the ZIF socket.

When the self-diagnostic test fails, you should first check whether the supply voltage is present (the green LED should light), and the Centronics link is all right both as regards hardware and software. The program is launched again after selecting the right Centronics port. All user settings are stored safely in a configuration file.

To check the proper operation of the Centronics interface, launch the program again, and select the option 'Program'. Enter any filename you like, and use an oscilloscope to check that clock pulses appear at pin 3 of IC1. Take a good look at the signal levels: a logic low should be lower than 0.8 V, a logic one, higher than 3 V. This also applies to the other Centronics connections. The inputs are the most critical in this respect. There are Centronics cards around with very low-value pull-up resistors (e.g., 1 kΩ) on the input lines. Such a line can not be pulled down sufficiently low by pin 3 of IC2. The same goes for lines which have a 1-kΩ protection resistor. The

COMPONENTS LIST

Resistors:
- R1, R13 = 1000 Ω
- R2 = 680 Ω
- R3, R4, R5 = 3 kΩ
- R6, R11 = 1 kΩ
- R12, R14 = 2 kΩ

Capacitors:
- C1, C2, C4, C6, C7 = 100 nF
- C3 = 470 μF 25 V radial
- C5 = 1 μF 63 V radial

Semiconductors:
- D1 = 12 V 400 mW zener diode
- D2 = 1 N 4148
- D3 = 5 V 6 400 mW zener diode
- D4 = LED red
- D5 = 3 V 3 400 mW zener diode
- D6-D9 = 1 N 4001
- D10 = LED, green
- T1/T2/T3 = BC547B
- IC1 = 4094
- IC2 = 4021
- IC3 = 7805

Miscellaneous:
- K1 = 20-pin or 24-pin ZIF socket, wide slots, for 0.3-in. wide DIL ICs (e.g., Aries)
- K2 = 36-pin Centronics socket, angled pins, PC mount
- K3 = Mains adaptor socket, PCB mount
- Enclosure: Pactec, size 145 x 92 x 28 mm
- Printed circuit board and software on disk: order code 960078 C. Software also available separately: order code 966015-1.
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In passing ...

Is there really nothing new under the sun and does history repeat itself? You don't really want to believe that, but sometimes you wonder as in the case of the network computer (NC) recently announced as 'new' by the American company Oracle. Now, all this 'new' computer does is to shift the emphasis away from the desktop to the network. This at once reminds you of the slogan of another American company, Sun, first used in the late 1980s, that "the network is the computer". In those days, it was difficult to realize — now, with the Internet blooming, it can become reality.

In essence, the NC represents a technology, based on a 1980s design by Britain’s Acorn, which has been trying to be accepted for almost ten years.

In the same way, Java, the language of the Internet, is based on a language originally designed for interactive set-top boxes — a market that has all but collapsed.

It stands to reason that, although Microsoft belittles the concept of Oracle's $500 NC, sooner or later there is bound to be a clash between the old and the new. Nevertheless, whatever the fortunes (or misfortunes) of the NC, the Internet will not replace the PC, at least not in the foreseeable future.

Having said that, it must be admitted that the PC market is becoming boring owing to lack of novelty — it is now just a market with all interest focused on price and quality, rather than on technical facilities.

The move from desktop to network is, of course, a matter not of hardware, but of software, that strange, intangible commodity consisting of bits. These bits — ones and zeros — are by themselves inactive, just like our genetic code, and only come to life when they are placed in the right receptacle. Whether that receptacle is a computer or a network does not matter. What does matter is the realization that a computer exists merely to bring software to life — and this task can also be fulfilled by a network such as the Internet. But let us not believe that we're talking of a new technology.
The earth hides many treasures from its inhabitants. Sometimes precious material is buried deep in the earth's crust, and can be detected with pretty sophisticated measurement systems only. However, small metal objects which are close to the surface may be located fairly easily using simple equipment.

A day's hunting on the beach, for example, using the present metal detector may yield some unexpected finds.

In our experience, metal detectors have always had a very special appeal to many readers. That is not difficult to explain, because few things are more exciting than the question 'is there a valuable object just below the earth's surface?'. Many amateurs will, for example, not want to miss the opportunity to scan an area for lost coins, where a large crowd has gathered. Metal detectors are also used professionally. Mine fields, for example, are minutely examined for buried explosives with the aid of advanced detectors.

Obviously, the requirements for a metal detector are dependent on the application. Most hobbyists will not need a complex, costly and extremely sensitive detector. That is why we present a metal detector which boasts simplicity. From practical experiments, we know that the present detector is capable of locating metal objects which are buried up to 15 cm below the surface. That means that the instrument, despite its simplicity, is suitable for scanning a lawn, a gravel path or a beach for lost metal objects. Those of you who are keen on experimenting will find the circuit very rewarding to build and try out. Because of its simple setup, the circuit has a number of inherent limitations which make it less suitable for professional use.

TREASURE HUNTING

Basically, two effects from elementary physics are employed to detect metal objects buried in the soil.

Firstly, a metal object changes the self-inductance of a coil and, if applicable, the degree of coupling between two coils. The effect may be positive or negative. The property of the materials which plays an important role in these effects is called relative permeability ($\mu_r$). A distinction is made between paramagnetic materials ($\mu_r > 1$), diamagnetic materials ($\mu_r < 1$) and ferromagnetic materials ($\mu_r >> 1$). Although it is fairly difficult to tell exactly which material is being detected just on the basis of the $\mu_r$ property, it is definitely possible to tell apart ferromagnetic materials on the one hand from paramagnetic or diamagnetic materials, on the other.

The second effect employed in the detection of metal objects is based on eddy currents which are generated when a conductor is subject to a varying magnetic field. The level of the eddy currents is determined by the size and the shape of the conducting object, as well as by the resistivity of the material. Strong eddy currents may be induced in, say, a large sheet of metal, while they are much reduced if slots are cut in the same sheet. Finally, the level of the eddy currents is also determined by the position of the object in the magnetic field, and, as a result, by the number of field lines that cross the object.

We also have to take into account the distance of the object to the search head which contains the detection coil, and the effect of the soil. All in all, it will be clear that it is virtually impossible to obtain a reliable material indication on the basis of just one detection method.

Design by Z. Kasztal
**BASIC CIRCUITS**

In practical circuits of metal detectors, you may come across three different types of detection technique. Each of these is briefly discussed below.

**BFO (beat frequency oscillator).** In this system, a signal with a variable frequency is mixed with another signal having a fixed frequency. The difference (or 'beat') frequency produced by the mixer is in the audible range. If the search head comes close to a metal object, the oscillator producing the variable frequency is detuned, resulting in a different tone which the user hears via a loudspeaker.

**TR/IB (transmit-receive/induction balance).** As indicated by the name, this method utilizes a transmitter as well as a receiver. If a metal object comes within the scan range of the search head, the degree of magnetic coupling between the inductors is modified. This change, in turn, produces a change in the oscillator output signal level.

**PI (pulse induction).** In this system pulses are generated and transmitted. The intensity and the shape of the received pulses provide an indication about the presence of metal objects within the scan range.

Each of the three detection methods has its own advantages and disadvantages. The ideal metal detector would, therefore, have to be a combination of all three detection methods. Unfortunately, that would result in a fairly complex circuit.

**A SIMPLE APPROACH**

The circuit diagram of the metal detector we have in mind is shown in Figure 1. A detection method is applied which bears great resemblance to the above mentioned BFO principle. In this case, however, the mixer output signal is not an audible frequency but a current which is used to drive a moving coil meter directly.

Looking at the circuit diagram you will probably agree that it is difficult to think of a metal detector design with fewer components than shown here. Just one 4030, a moving coil meter and a handful of passive parts are assumed to do the job. The total cost of this project should remain well below £10 or so. The circuit utilizes two LC oscillators, built around IC1a and IC1c, which are coupled to some extent via capacitor C7. The oscillator built around IC1a operates at a fixed frequency of about 300 kHz. Normally, the oscillator around IC1c produces the same frequency, but that is no longer so when the self-inductance of L2 is changed by a nearby metal object. Gate IC1d provides an XOR function and combines (actually, multiplies) the oscillator output signals. Assuming that no metal object is detected, the capacitive coupling between the two oscillators maintains a fixed phase difference of 90°. Consequently pin 11 of IC1d supplies a square wave with a double frequency (approx. 600 kHz) and a duty factor of about 0.5. Gate ICib acts as an inverter with meter M1 connected between its input and output. Preset P1 serves to set the meter sensitivity.

The circuit is powered by a single 9-volt battery. Under normal conditions, the battery will last for quite a few hours of treasure hunting.

**Construction and Test**

The printed circuit board designed for the metal detector allows a pretty compact construction (Figure 2). With the exception of coil L2, there are no critical components, so that building up the circuit board will not present
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undue problems. Simply solder each part on to the board at the position indicated by the component overlay (printed on the board). Turn the wiper of P1 to the extreme counter-clockwise position (minimum sensitivity).

The design is based on a simple air-cored coil with a diameter of about 7.5 cm (3 inch), and about 40 turns of enamelled copper wire, or 25 turns on a diameter of 200 mm. The coil former is a small piece cut from a cardboard or solid plastic (PVC) tube. Alternatively, you may use a scaling cap for 3-inch dia. PVC drainage tubing as a former for the coil. The larger the coil diameter, the higher the sensitivity of the metal detector. Inductor L1 is a ready-made type.

If it has an adjustable core, trimmer C8 may be omitted. The circuit is then adjusted with the aid of the core. If the circuit is not sufficiently sensitive in practice, the value of resistor R2 may be increased a little.

Adjusting the completed circuit is quite simple. Switch on the detector, and adjust trimmer C8 until the meter needle swings from the right to the left. Obviously, no metal objects should be in the vicinity of L2 during this adjustment. The correct setting of the trimmer is found when the needle remains steady at the start of the scale. You may want to turn the probe into an external control, so that the sensitivity of the detector may be adapted during actual use of the detector.

Unfortunately, one drawback of the simplicity of the circuit is that its sensitivity is affected to some extent by ambient temperature. If instability turns out to be a problem, it is recommended to fit coil L2 and capacitors C4, C5 and C6 close together so that they are always at the same temperature. So, if the circuit is mounted at some distance from the search coil, the capacitors are fitted close to the coil instead of on the board. The stability may also be improved by covering the search coil, for example, by moulding it in a resin compound, or covering it with selfamalgamating tape.

With ergonomics in mind, the (moulded) search coil is best mounted on a 'stick'. The moving coil meter is then fitted in a small case which is secured close to the handle.

The prototype was fitted in an assembly consisting of PVC drainage tubing and coupling parts which should be available from most DIY stores. The 'stick' is formed by a tube with a diameter of about 32 mm (1¼ in). The tap for the meter is made from a 1-piece. The case containing the meter is fitted on to the 1-piece. The search head is a sealing cap, here, a 200-mm dia. type is used. The junction between the search head and the 'stick' consists of a knee piece having an angle of 135°. A cap is glued on the top end of the 'stick'. The windings of the search coil may be secured at the outside of the search head, and then covered with insulating tape or similar for protection.

The photograph of the prototype gives a good impression of a suitable construction. The total cost of the instrument will be, well, modest!

**START HUNTING**

Having finished the adjustment of the completed instrument you are ready to start treasure hunting. Before you dash out of doors, however, some experiments will be required to get the 'feel' of the detector. In practice, diamagnetic and paramagnetic materials will have a very small effect on the self-inductance of the search coil. Ferromagnetic materials, on the other hand, produce a marked increase in the self-inductance. However, because of the size of the objects you will want to discover (coins, i.e., usually sheet material) and the high oscillator frequency, eddy current losses are an important factor in all categories. Eddy current losses lower the oscillating frequency, but the only thing that matters is the most important factor: the meter on this metal detector will swing in the same direction for all detected materials. If the needle starts to move while you swing the search head over the ground, a diamagnetic or ferromagnetic object is detected within the scan area. Time for further investigations!
It is well known that the frequency of a crystal oscillator depends to some degree on the ambient temperature. Although this is often of no consequence, there are cases when the frequency is needed as a standard and any deviation from its true value is not acceptable. For instance, the crystal oscillator in most frequency meters and in many signal generators is fitted in an oven that keeps the crystal temperature at a stable value.

The temperature at which the crystal is held must at all times be higher than the sum of the ambient temperature and the self-temperature of the equipment in which the crystal is contained. Assuming a top ambient temperature of 30 °C, it is unlikely that the thermostat needs to be rated higher than 50 °C.

The idea of using a power transistor as the heating element is not new. This works in conjunction with a resistor with negative temperature coefficient (NTC) or a silicon sensor acting as the sense element. The output of this element drives the heating transistor via a control circuit and thus influences its dissipation. The difficulty of using this setup in a home-constructed equipment is obtaining good thermal coupling between the heating transistor and the sensor, which is, of course, essential for accurate and fast control of the temperature.

The circuit proposed in this article is based on a different approach. In it, the base-emitter voltage of the heating transistor is used as the control voltage, so that a temperature sensing element is not required. It is known that this voltage in case of a p-n junction through which a constant current flows varies at a rate of ~2.2 mV K⁻¹. Such a voltage applied to an evaluation circuit is very suitable to assume control of the dissipation in the heating transistor. For this purpose, the heating is interrupted periodically for brief instants during which the base-emitter voltage of the heating transistor, through which a constant current flows, is measured. Its value is stored in a sample & hold circuit and used to control the collector current of the power transistor during the next heating phase.

**HEATING AND MEASURING**

The circuit of the practical application of this idea is shown in Figure 1. Transistor T₃ is the heating transistor, which obtains its base current during the heating phase via CMOS switch IC₂ and resistor R₃. The heating current flows from the +ve supply line via T₃ and D₁ to earth.

To measure the base-emitter voltage, IC₂₃ is closed and IC₂₉ opened, whereupon the base of T₃ is at earth potential. Diode D₁ is reverse-biased and a constant base current for T₃ is drawn via R₆. The measured (negative) base-emitter voltage is applied to control amplifier IC₁ where it is compared with a reference potential set with P₁. The resulting voltage is stored in C₁ and used to drive T₁ during the next heating phase.

Circuit IC₃ is arranged as an astable (multivibrator) which provides the requisite pulses for the sample & hold circuit. The width of these pulses is about 1 ms (i.e., 100 Hz), during which the base-emitter voltage is measured.

The output of IC₃ drives IC₂₄ directly. The pulse train is inverted by IC₁₀, so that IC₂₉ and IC₂₃ are closed when IC₃ is open and vice versa.

The heating transistor is a darlington type. Any power darlington whose base-emitter resistances are ≤ 5 kΩ (Rₛₑ) and about 80 Ω (Rₑₑ) respectively may be used. On the one hand, this enables
a small base current to be used, which results in only a tiny dissipation in the CMOS switches, and yet produces, and controls, a large heating current. On the other hand, the two base-emitter voltages are in series and their sum total is perfectly usable as a measurand.

The power supply is traditional. So as to keep the dimensions of the printed-circuit board small, a 3.3 V transformer is used, which, however, can supply the requisite current for the circuit. At a heating temperature of about 40 °C, a current of about 33 mA is drawn from the positive supply line; when the heating temperature rises to 55 °C, the current becomes about 55 mA. The current drain from the negative supply line is independent of the temperature and is about 20 mA.

There is a point to be borne in mind, though. For a short period (about 30 s) following power-on, the heating transistor is cold and draws as much current as the transformer can provide. It is, therefore, essential that the transformer is a short-circuit-proof type.

**CONSTRUCTION**

The thermostat is best built on the printed-circuit board shown in Figure 2. Note that the component layout is not in full accord with the introductory photograph, since during the final test stages it was found necessary to turn a few components about.

Most components, but not the power transistor, should be fitted in the usual order. Preset P1 should be a type with a low long-term temperature coefficient, since it determines the stability of the temperature setting. Ideally, the preset should have a ceramic base plate.

**CALIBRATION**

Adjust P1 for maximum resistance (normally fully clockwise). Connect a piece of 5 mm thick expanded polystyrene (area same as base of box) into the box so that the soldering pins for T1 protrude through it. Then solder the base and emitter, but not the collector, of T1 to the appropriate pins. Make sure that the cooling vane of the transistor is at the top. Be careful not to touch the polystyrene with the soldering iron.

**Temperature dependence of quartz crystals**

Quartz is a crystalline form of silicon dioxide (SiO₂). Most quartz is grown in large bars by dissolving SiO₂ in an alkaline solution at high temperature and pressure. The growing process takes about ten weeks.

The bars of crystal are cut into wafers. The angle at which these wafers are cut is crucial in determining the frequency and temperature stability of the final crystal. The most common cut is the (1) cut where the angle is about 35°, allowing a frequency range of 1 MHz to 300 MHz. Crystals can be made to oscillate at their fundamental frequency, or their third, fifth, or even higher, overtone (harmonic).

Frequency stability is normally specified as a frequency tolerance over a defined operating temperature range with respect to the frequency at reference temperature.

With reference to the generalized S/H vs temperature (parabolic) curves shown, it should be noted that crystals with a small angle of cut show relatively small frequency deviations at the central temperature, but that the deviation is large at very low or very high temperatures.

Crystals with a large angle of cut behave in exactly the opposite way. For these, the deviation is relatively large at the central temperature, but very acceptable over the entire temperature range.

Which angle of cut is specified when maximum precision of frequency is required depends, therefore, on the application. For a laboratory equipment which is constantly in an ambient temperature of 20-30 °C, a small angle of cut is, of course, correct. Whereas in an oscillator that operates over a wide temperature range, a large angle of cut should be specified. Best of all is, of course, to house the crystal in an oven at (near-) constant temperature.

As far as ageing characteristics are concerned, different rules apply. The frequency of the crystal should be as low as possible, that is, it should operate at its fundamental frequency. Moreover, it should be housed in a glass envelope instead of a metal one.

It is always wise in cases of doubt to consult the relevant data book, which are normally available free of charge from manufacturers.
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During the calibration, it is important to monitor the temperature of the cooling vane of $T_1$. This is best done with a contact thermometer, but if this is not available, use an ordinary clinical thermometer. When the collector current has stabilized at 30 mA, the temperature of the vane should be 40–50 °C.

If all this is correct, solder the collector of $T_1$ to the appropriate soldering pin. Apply some heat conducting paste to the vane and fix the crystal onto the vane, keeping it in place with a brass clip or, if need be, with a couple of turns of nylon thread. The two devices normally need not be isolated, since the vane is connected to the collector.

**FINALLY**

Carefully solder two lengths of thin flexible, insulated circuit wire to the crystal terminals. Avoid overheating. Bring the two wires out of the box and fill this with further pieces or, preferably, pellets of expanded polystyrene.

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**FINALLY**

Carefully solder two lengths of thin flexible, insulated circuit wire to the crystal terminals. Avoid overheating. Bring the two wires out of the box and fill this with further pieces or, preferably, pellets of expanded polystyrene.
video test chart generator

part 2: VGA mode, S-VHS and VGA

As explained in Part 1 with the description of EPROM codes, the data for each pixel (R/G/B) consists of bit triplets D2/D1/D0 and D6/D5/D4. Bit D3 is the disable bit for all colours, allowing pixel bits to be used (as byte codes) for control purposes. With one exception, D3 is available in all byte codes. Only XINS (80H) is not allowed to disable the colours, because R/G/B has to be inserted at WSS in line 23. The hexdump of a vertical sync pulse (Figure 1) shows the arrangement of the individual byte codes. FH2 (half horizontal frequency) is always switched on the falling edge of SHV (combined horizontal/vertical sync), in other words, also on each equalizing pulse and raster pulse, but not when D0 is set (detail 1). In the VGA modes, SHV may only contain steady line sync codes, and no vertical pulses with equalization pulses. In VGA modes, D4 (detail 2) ensures that SHV is omitted. In TV mode, D5 has the same function. D3, without D4 or D5, causes SHV to appear in TV as well as in VGA mode (detail 3). Basically the same applies to SV (vertical sync), D6/D3 set (detail 4) means SV in both modes. D1 also set means SV omitted with VGA. The same for D2 and TV mode. The bits allow you to adapt the sync pulses to the relevant mode in any way you like. RESET should be added: D3/D7 works only with TV mode, and with D0 also set, with both modes.

As already mentioned, the circuit uses the same EPROM data for the VGA test charts and the TV test charts. The essential difference lies in the doubled clock frequency at which the EPROM is read. None of the other sub-circuits has to be switched separately, however, because the 8.86-MHz clock source (from which all frequencies are derived, with the exception of the WSS PALplus signal), is doubled to 17.7 MHz with the aid of an XOR gate inside the EPLD. The doubled addressing rate with VGA test charts causes a horizontal (line) frequency of 15,625 x 2 = 31,250 Hz, and a vertical frequency (FV) of 50 x 2 = 100 Hz. Although the line frequency is fine, the raster frequency is a little too high for most monitors. That can be changed, however, by a larger number of lines per raster. Each line requires a storage capacity of 284 pixels x 4 bits = 1,136 bit (142 bytes): so, 354,432 bits for 312 lines. The RESET address for TV non-interlaced mode is then 354,432/8 = 44,304 or AD10H. The available memory for a 16-bit address range is, however, 524,288 bits (512 k), allowing a maximum of 524,288/1,136 = 461 full lines to be encoded. When the frame sync pulse is set to the start of the memory, RESET to address AD10H only for TV (88H) and VGA RESET (89H) to 461 lines x 142 bytes = 65,462 (FF'89H), then the VGA picture has 461 lines at FH = 31,250 Hz. That results in a raster frequency of 67.79 Hz, which should be okay for any modern VGA monitor. Provided the picture content is cleverly arranged, for example, colour bars without a circle as in test chart 2 (see table), then the transition from 312 to 461 lines is hardly visible. In VGA mode, TV test charts containing a circle are, of course, reduced in height about 1.5 times, and compressed. TV test charts 5 and 6 have 625 lines per frame, or 312.5 lines per raster, and are, therefore, interlaced. The TV RESET at 625 lines x 142 bytes = 15AAH, is also applied as VGA-RESET (89H), the total memory requirement (17 bit) being 1,048,576 bits. With two vertical sync pulses as with TV, we get FH = 31,250 Hz and FV = 100 Hz, 625 lines interlaced (VGA test chart 5). If the raster sync pulse for the second raster is suppressed, FH is not changed, although FV is halved to 50 Hz, 625 lines non-interlaced (VGA test chart 5). That allows the vertical synchronisation of a multi-sync monitor to be checked from 50 Hz to 100 Hz. By adapting the number of picture lines, any raster frequency may be programmed.

The line frequency, too, is only limited by the smallest pixel duration of 112 ns. The desired line time is n x 112 ns, where n should be an even number, taking into account the byte code for RESET (89H). If the number of pixels per line is reduced, the pixels become wider, as do any vertical lines, of course. When the generator is only
used to test computer monitors, the frequency of crystal X2 may be increased to about 15 MHz, or even higher depending on what the EPROM will tolerate.

**THE TEST CHARTS**

The Altera EPROM type EP17032 is supplied ready-programmed through our Readers Services under order code 966507-1, or through your kit supplier. The functions programmed into this IC are indicated in Figure 2. The 27C040 EPROM containing the data for the test charts listed in Table 1 is also supplied ready-programmed (order code 966507-2).

Test charts 1 through 4 occupy 512 kbit each, numbers 5 and 6, 1 Mbit each. The EPPLD is automatically reset at power-on, so that test chart 1 appears in the first instance. The order in which the test charts are programmed in the EPPLD is as follows: A 3-bit counter, ACTR4, allows you to step through the test charts. Depending on the state of this address counter, A16 of the EPROM is driven either by A15 and ACTR3, or directly by ACTR4 to effect the test chart selection (see Figure 2).

Apart from the preprogrammed ICs for this project, a diskette is available which not only contains the standard test charts as shown in Table 1, but also data for 20 more test charts. The relevant files contain the data for a half-picture (raster). Using the instructions also provided on the disk you should be able to build your own test charts. The disk also contains a number of basic patterns such as sync pulses without picture content, a circle, a rhombus, and a grid, as well as precise indications about picture start, picture centre, picture end, WSS, and more. The test charts are programmed in Pascal because circles and characters are not easily produced manually from just pixels.

The following test discusses test charts numbers 1 (Figure 3a) and 5 (Figure 3b), which are universal charts, really. The foundation is a white grid on a black background, for checking the dynamic convergence and picture geometry. The vertical lines in the grid have the required width of 225 ns. The outer bounds of the grid are marked by white rhombuses. When the geometry is correctly adjusted, these diamonds should just fall outside the visible area. Because sufficient black and white areas are available in the rest of the screen, monochrome areas are not present in the colour bars. The vertical line at the transition from green to violet covers the unavoidable interference caused by the quarter-line offset which is inherent to PAL. The picture is programmed using only one bit per colour. Consequently a green bar is not possible, unless the colour contrast is reduced to nil. The replacement is the dot raster for focussing. The micro-rhombuses in the corners of test chart no. 5 serve the same purpose.

To enable you to run a check on proper helper-line processing, the helper range in test charts 5 (Figure 3b) and 6 (Figure 4b) has a test insert which reads 'PALplus'. It appears as a white line in the helper only. Test chart 5 serves the same purpose. To enable you to run a check on proper helper-line processing, the helper range in test charts 5 (Figure 3b) and 6 (Figure 4b) has a test insert which reads 'PALplus'. It appears as a white line in the helper only.
Figure 3. Test chart 1 (a) is the basic, universal, TV test chart. Test chart 5 (b) is the PALplus version.

A colour-free as possible. The structure of the black/white rhombus and the entire picture in general is such that the circle covers as little white area as possible. Immediately after the vertical pulse of the first raster, all test charts have two test lines, a colour bar and a multiburst up to 4.43 MHz. By selecting TV raster triggering, and operating the oscilloscope in 2-channel mode, it is possible to analyse the colour signal and the video frequency response, independent of the actual test chart used, and without a second timebase. Because both lines are sure to occur in the blanked flyback period, they also allow the function of the cut-off to black during the flyback (picture blanking). VGA monitors are not particularly strong in this area! Fortunately, that is not a problem because the video signal is usually nought during this period.

CONSTRUCTION

A double-sided through-plated printed circuit board (Figure 5) was developed for this project to keep the construction as simple and compact as possible despite the relatively high frequencies used in the circuit. The printed circuit board is available ready-made through our Readers Services. Mind you, the final design of the board has a few layout changes with respect to the first prototype shown in the photographs in last month’s instalment.

The board should be populated with great precision because errors are not easy to trace later. With vertically mounted parts, short-circuits may be prevented by covering the long terminal with isolating pieces of wire sleeving. Take care to observe the polarity of diodes and electrolytic capacitors, and the orientation of the voltage regulator and all other ICs in the circuit. The ICs should be fitted as the last parts, and it is recommended to use IC sockets.

Two options are available for the power supply: either a small PCB mount transformer is used, or an external adaptor which is capable of supplying 9 Vdc at a current of about 150 mA. If the transformer is used, the PCB support pillar in the corner near terminal block K4 must be a plastic type. The alternative is not to secure this corner of the board at all. If the mains adaptor option is chosen, the following parts are not required: Tr1, K4, B1 and, of course, the mains on/off switch. However, parts D5 and K3 are then required.

Whichever supply is used, the ground plane of the PCB and the screening at the inside of the enclosure should be connected by at least one mounting screw.

The test switch on the modulator

Table 1. Test Charts

<table>
<thead>
<tr>
<th>No.</th>
<th>Pattern</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Standard TV test chart</td>
<td>Universal</td>
</tr>
<tr>
<td>2</td>
<td>Colour bars</td>
<td>Fault finding</td>
</tr>
<tr>
<td>3</td>
<td>Micro diamond</td>
<td>Focussing</td>
</tr>
<tr>
<td>4</td>
<td>Red</td>
<td>Colour processor</td>
</tr>
</tbody>
</table>

Interlaced/Line jump (I), PALplus

<table>
<thead>
<tr>
<th>No.</th>
<th>Pattern</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>as 1: 16:9 with PALplus ident</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>as 2: 16:9 with PALplus ident</td>
<td></td>
</tr>
</tbody>
</table>

VGA test charts:

<table>
<thead>
<tr>
<th>No.</th>
<th>Pattern</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>as TV 1; FH = 31.25kHz, FV = 100Hz NI</td>
<td></td>
</tr>
<tr>
<td>2,3,4</td>
<td>as TV 2,3,4; FH = 31.25kHz, FV = 68Hz NI</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>as TV 5; FH = 31.25kHz, FV = 50Hz NI</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Test chart 2 (a) shows colour bars and is suitable for fault finding. The same for test chart 6 (b), which shows the colour bars in PALplus format with an ident.
COMPONENTS LIST

Resistors:
- C6, C8, C9, C12, C17, C20, C21, C24, C25 = 100pF 16V radial
- C5 = 100μF 16V radial
- C2, C3, C7, C10, C18 = 220μF 16V radial
- C4 = 22nF

Capacitors:
- C1, C19 = 100pF
- C2, C3, C7, C10, C18 = 220μF 16V radial
- C4 = 22nF

Semiconductors:
- D1, D2, D3 = 1N4148
- D4 = LED
- D5 = 1N4002 (see text)
- B1 = B80C1500 (round)
- IC1 = EPM7032LC44-15 (Altera) (order code 966507-1)
- IC2 = CXA1845P (Sony)
- IC3 = 27C320 100ns (order code 965507-2)
- IC4 = 74AC040
- IC5 = 7805

Miscellaneous:
- K1 = 15-pin sub-D connector, VGA, high-density, angled pins, PCB mount
- K2 = 2-pin PCB terminal block, pitch 5mm
- K4 = 2-pin PCB terminal block, pitch 7.5mm
- S1 = pushbutton, debounced (Conrad o/n 70 76 00-88)
- X1 = 5 MHz quartz crystal
- X2 = 8.867238 MHz quartz crystal
- Tr1 = Mains transformer, 6V, 2.4VA, Hahn.
- UHF modulator (Conrad o/n 19 27 91-88 or similar)
- Screened case 150x80x45mm (Hammond 1591DGY or 1591DSBK)

Figure 5. Track layouts (75%) and component mounting plan of the printed circuit board. Note that the final layout differs slightly from that of the prototype shown in last month’s installment. Double-sided, through-plated board, available ready-made through the Readers Services.

The unit is converted into a TV/VGA mode selector. Details of the conversion are shown in Figure 6. First, the non-used supply pin for the internal RF amplifier is 'freed' by cutting the track to pin 5 of the modulator at the underside of the module panel. As indicated, a wire connection is made from pin 5. Because of the wire jumper, the pole of the switch is permanently at ground level so that the test mode is no longer available. The third free switch contact now switches the VGA signal applied to pin 5 via the isolated wire.

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the modulator is turned into an audio signal input. This requires 'freeing' the centre pin by a second track-cutting operation, and connecting it, via a length of isolated wire, to the audio input, pin 2. The external signal is injected via R4 (22 MO). The impedance of the modulator AF input is high enough to allow address signal A11 to produce an audible rectangle wave of about 550 Hz. When an external AF sound source is connected, the internal signal is practically quenched because of the low impedance. The AF input sensitivity is about 500 mV at 47 kHz, allowing cassette decks, CD players and the like to be connected. The internal test tone may be muted by short-circuiting the AF input socket.

Figure 6 also shows an additional ceramic capacitor of 47 pF which appears as C25 in the parts list. This capacitor must be fitted with the shortest possible lead length at the indicated location. Without this decoupling device, the modulator picture suffers from sound carrier interference, which is particularly annoying in the decoded PALplus signal.

The modifications should be carried out with great precision, and checked with an ohmmeter. Mind you, that's less of an effort than having to remove the modulator from the finished board.

The five connecting pins of the modulator are bent at right angles. The modulator is then fitted flush on the board using four solder pins at the corners. In addition to the connecting pins, four mounting pins at the top corners are soldered to the board.

Figure 7. Connections and adjustment points of the UHF modulator.

**Figure 6.** As described in the text, the modulator panel is slightly modified.

**Table 2. Video connector pinout overview**

<table>
<thead>
<tr>
<th>Video generator</th>
<th>SCART* S-VHS</th>
<th>SCART CVBS</th>
<th>SCART RGB</th>
<th>DIN AV*</th>
<th>HOSIDEN S-VHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin 1 +R</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 2 +G</td>
<td>1</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 3 +B</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 4 NC (ID0)</td>
<td></td>
<td>20</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 5 +FBAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 6 GND R</td>
<td>4, 17</td>
<td></td>
<td>4, 5</td>
<td>3, 1, 2</td>
<td></td>
</tr>
<tr>
<td>Pin 7 GND G</td>
<td>14</td>
<td>4, 17</td>
<td>9, 13</td>
<td>3, 1, 2</td>
<td></td>
</tr>
<tr>
<td>Pin 8 GND B</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 9 +Y (NC)</td>
<td>20</td>
<td></td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Pin 10 GND</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 11 C (ID0)</td>
<td>15</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Pin 12 NC (ID1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 13 -SHV (SH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 14 +SHV (SH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin 15 AU (ID3)</td>
<td>2, 6</td>
<td>2, 6</td>
<td>2, 6</td>
<td>4, 5</td>
<td>5</td>
</tr>
<tr>
<td>GND screening</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>RF Audio/Out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Audio/IN</td>
</tr>
</tbody>
</table>

* links pins 1 and 5 in plug
Although there are still dyed-in-the-wool sound technicians who swear by the good old analogue recording technology, most others, bitten by the digital audio recording bug, do not want to revert to analogue recording. They have experienced the pleasures of loss-free processing and copying of recordings at digital level. These pleasures turn to frustration, however, when they want to convert a DAT recording on to a CD. This cannot be done just like that because the two have different sampling frequencies: DAT 48 kHz, and CD 44.1 kHz. To overcome this difficulty, a converter as described in this article is required.

Design by T. Giesberts

It is a regrettable fact, with which we will have to learn to live, that different audio techniques use incongruous sampling frequencies (CD - 18.9 kHz; 8 mm VCR - 31.3 kHz; NICAM - 32 kHz; CDI - 37.8 kHz; VCR - 44.056 kHz; CD - 44.1 kHz; DAT - 48 kHz; and others). The growing popularity of digital audio is creating an increasing need of some means of coupling equipment using such different techniques - without loss of quality, of course. This can be done by altering the sampling rate in one of the two units to be coupled, while ensuring that the two sampled signals are adequately synchronized. Clearly, this requires a well-designed intelligent converter.

The design of the present converter is based on a dedicated IC: the Type TDA1373H from Philips. This circuit is very versatile and may be used for almost any imaginable conversion (but not quite - see later). Thus, it can be used for converting a DAT recording into a CD recording. Also, it enables CD data to be recorded on a DAT machine with a sampling rate of only 32 kHz, which, of course, results in a much longer playing time. Another possibility is converting the consumer standard S/PDIF to the professional AES/EBU format. True, the converter has no AES/EBU connectors, but the conversion is possible.

Apart from as a converter, the circuit may be used as a copybit eliminator. In that case, the two sampling rates are made equal (as in the converter), but the category code, the copybit and the generation-status bit are set. The sampling rate used must correspond with the code set in most DAT machines to ensure that the signal is accepted. Finally, the circuit may also serve as a jitter killer since the first-in-first-out (FIFO) and gain stage in the TDA1373H suppresses any jitter.

DESIGN

The circuit of the converter is shown in the diagram of Figure 1. Circuit IC1 is the integrated digital converter, IC2 is the controller, and IC3 is the output interface.

The most important property of the TDA1373H is the Integrated Audio Digital Input Circuit (ADIC), which enables the chip to decode IEC958 signals (S/PDIF or AES/EBU). The circuit can work on a stand-alone basis or be controlled by a microprocessor. In the present circuit, it is controlled by IC2, since this gives a wider choice of output formats. The circuit can process up to 20 bits and afterwards provides the con-
converted data in 16-, 18-, or 20-bit format.

The TDA373H is designed to provide up to four different applications, but since the present circuit is geared to being used as a sampling rate converter, the circuit is limited to this application.

The input of the converter may be optical (via IC4) or coaxial (via K1). The selection between these two is by jumper JP1, since it is assumed that the converter will be used invariably in a fixed setup in which there is seldom or never a need for changing from one to the other. The remaining two input pins of IC1 are linked to earth.

Correct operation of IC1 requires the setting of six command registers, which is effected by controller IC2.

After a brief power-up reset (by R14-Cr), IC1 sends twelve 8-bit words (six addresses and data) to IC1 via a serial connection.

The in-band noise shaper and the stop-band suppression of the x64
oversampling filter are set by, respectively, sections 2, 3 and 1 of quadruple op switch S2. The switches are debounced by a delay of 1–1/2 seconds between their being operated and the relevant function being actuated. This delay is effected by the controller.

The sampling rate of the output signal, \( f_{\text{op}} \), of IC1 is determined by the crystal between pins 21 and 22, according to equation

\[
f_{\text{at}} = 768f_{\text{op}}
\]

Thus, the crystal frequency should be 33.8688 MHz for a sampling rate of 44.1 kHz, and 24.576 MHz for a sampling rate of 32 kHz.

The sampling rate of the input, \( f_{\text{in}} \), must be not lower than 0.35 \( f_{\text{op}} \), nor higher than 1.45 \( f_{\text{op}} \). Thus, if the circuit is used as IEC98 decoder only, the input sampling rate should not exceed 45 kHz if the output sampling rate is 32 kHz. If conversion from 48 kHz to 32 kHz is required, consideration should be given to using two converters in cascade.

The converted data are available at serial digital audio output 1 and applied to output interface IC3 via resistors \( R_5 - R_8 \), which provide d/dt limiting.

Circuit IC3 is a digital audio interface transmitter Type CS8402. This IC can also process various formats, but in the present circuit the serial input (pins 6, 7 and 8) is fixed for 16-bit codes by the levels at inputs M0, M1 and M2. Virtually all functions of IC3 may be obtained by appropriate setting of the various sections of DIP switch S2.

The symmetrical output at \( \text{v}_{\text{OUT}} \), \( \text{v}_{\text{SS}} \), is converted into a standard \( \text{v}_{\text{OUT}} \), \( \text{v}_{\text{SS}} \) output (0.5 Vpp into 75 \( \Omega \)). The electrical isolation provided by the transformer has the benefit of preventing earth loops.

An optical output is provided by optoisolator IC5.

The power supply may be based on a standard 9 V mains transformer or mains adaptors rated at not less than 300 mA. The supply lines are stabilized by regulator IC6 and lavishly decoupled by a delay of \( 0.04 \) sec to limit any switching noise.

The TDA1373H

The TDA1373H, called general digital input, is a circuit that provides four different modes of operation. However, the present application is that of sampling rate converter, SRC, and, therefore, only the parts relevant to this will be discussed in this section.

In the block diagram in Figure 2 the relevant signal paths are shown in bold lines.

The input signal is applied to the data slicer via pin D15. The slicer can handle signals at levels from 200 mVpp to 5 Vpp.

The output of the slicer is applied to the audio digital input circuit, ADIC, which decodes the stereo audio signal to obtain four data (v, u, c and e) bits. The last function is not used here.

The ADIC locks to a 44.1 kHz signal in not more than 1 ms. Until it has locked, there is no word clock, and the stereo audio loops are decoupled as shown in the diagram.

Table 1. Two different response curves of the x64 oversampling filter can be selected with section 1 of the switch S2.

<table>
<thead>
<tr>
<th>S2-1:</th>
<th>bit SS</th>
<th>pass band</th>
<th>stop band</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0-0.45351</td>
<td>( \pm 0.004 ) dB</td>
<td>0.54648-110</td>
</tr>
<tr>
<td>1</td>
<td>0-0.46875</td>
<td>( \pm 0.004 ) dB</td>
<td>0.53125-110</td>
</tr>
</tbody>
</table>
Test results

The quality and properties of the sampling rate converter were tested in the digital domain at the various output formats. The (analogue) generator of an Audio Precision Analyser was used as the digital signal source, and this was coupled to a 20-bit analogue-to-digital converter (ADC).

Of the four characteristics shown, I represents the output spectrum of the ADC. The other three characteristics may be compared with this.

II: 16 bit rounded off (section 2 of S3 on; section 3 of S2 on).
III: 16 bit INS (section 2 of S3 on; section 3 of S2 off).
IV: 18 bit ms (section 2 of S3 off; section 3 of S2 off).

No characteristic is shown for the 20-bit mode (section 2 of S3 off; section 3 of S2 on), since, at least up to 20 kHz, this is all but identical to the input signal of the converter (Characteristic I).

Note how well the action of the in-band noise shaper is seen in Characteristic IV; a clear rise is discernible only in the (virtually inaudible) range above 18 kHz.

At the same time, and with the same setup, the signal-to-noise ratio for the various output formats was determined:
- 16 bit rounded off: -94.5 dB;
- 16 bit INS: -89.7 dB;
- 18 bit INS: -95.5 dB;
- 20 bit: -97 dB.

Note that the signal-to-distortion ratio of the ADC was 97.5 dB (measured without noise).

The signal-to-noise of the ADC plus sampling rate converter (without distortion) in the same test setup was about -107 dB (dynamic range of the ADC). The dynamic range, measured at a digital-to-analogue converter, DAC, was about 5 dB better with 16 bit INS than with 16 bit rounded off.

The gain section enables the signal to be amplified or attenuated. In the present application, the signal is attenuated by 0.068 dB to prevent clipping in the digital filters.

The samples are fed for interpolation to a x64 oversampling filter. This filter consists of a x6 section and a x16 section. There is a choice of two filter characteristics: one with...
stop-band suppression of 70 dB and the other with a stop-band suppression of 50 dB but with steeper skirts. The second is intended especially for use with signals with a sampling rate of 32 kHz, and a pass-band of 0–15 kHz as, for instance, in digital satellite radio. The characteristics are selected by section 1 of DIP switch S₂—see also Table 1.

The samples are applied from the filter to the variable hold stage in which the actual sampling rate conversion takes place. Depending on the ratio of the input sampling rate and the output sampling rate, the sample is used once or twice, whence the name variable hold. When the ratio is 1:1, all samples are used twice, since the down sampling is x128.

The variable hold function is controlled by a digital phase-locked loop, PLL, formed by the phase detector, loop filter, hold, and VCO (voltage-controlled oscillator) stages. The loop filter ensures that the PLL locks rapidly. This is necessary because, after power-up, the bandwidth of the filter is reduced in two steps from 500 Hz to 50 Hz and then from 50 Hz to 0.5 Hz. The frequency difference is only 1 Hz for 512 input samples (10 ms for a sampling rate of 44.1 kHz).

After the PLL has locked in, the audio signals are demuted and the conversion commences. To prevent any errors, the FIFO is monitored continuously in the variable-hold phase. As soon as the slightest tracking error is detected, the bandwidth of the loop filter is enlarged.

To convert the sampling rate to the requisite output value, the samples are passed through a x128 down-sampling filter, which consists of a x32 section and a x4 section. The overall filter provides a stop-band suppression of 80 dB from 0.34 kHz of the output sampling rate.

Finally, the samples are applied to an in-band noise shaper, INS, which adapts the word-length of the samples to specific requirements. The standard length of 20 bits may be reduced to 16 bits or 18 bits by the relevant sections of DIP switch S₂.

There are four possibilities as enumerated in Table 2, the first of which is 20 bits.

The INS has a facility for adapting the digitization noise in a psychoacoustical manner, whereby the noise to which human hearing is most sensitive is shifted upwards in frequency. This facility gives a subjective improvement of two bits with respect to the real quantization level.

Finally, the 20 bit length may be reduced to a 16-bit length by a simple rounding off action.

**Coding & Control**

The digital audio interface transmitter, IC₃, is intended primarily for coding and sending audio data according to usual interface standards. The circuit provides the possibility of setting the most important channel status bits via seven inputs: pins 3, 4, 5, 6, 8, and 12 and 14 in Figure 3. These inputs are controlled by octal DIP switch S₁ (see Figure 1). All seven inputs have a double function, which depends on the level at pin 2. This level is set with section 8 of S₁ and determines whether the IC works in the professional (AES/EBU) or in the consumer (S/PDIF) mode. The audio data are coded to the standard associated with the selected mode.

In the professional mode, a CRC code may be generated (channel status byte 23) as shown in dashed lines. The serial input, pins 6, 7, and 8, can handle seven different formats and audio samples of 16–24 bits. In the present circuit, the format is fixed for I²S with M0, M1, and M2.

The serial inputs for channel status, C, user data, U, and validity, V, are not used and linked to earth. The V bit must be low to indicate that audio data are being processed which can be converted to analogue signals.

Pin 15, channel block start, CBL, is not used in the present application either. Normally, it is an output that may be used for writing C, U and V bits. CBL is an input only when in the professional mode the transparent option is chosen (in which the C, U and V bits can be looped in via a receiver). In this way, synchronization of signals coming from separate equipment is possible. Normally, the master clock, MCK, is 128fₛ, where fₛ is the signal frequency, but in the transparent mode, MCK = 256fₛ. The multiplier is set with jumper JP₂.

**Professional Mode**

When pin 2, PRO, is low, that is, when section 8 of S₁ is closed, the digital audio interface transmitter, IC₃, is in the professional mode. In this mode, bits 1, 2, 3, 4, 6, 7 and 9 may be set after a 1 has been sent for channel status bit 0.

C0 indicates whether the channel status block applies to the professional (1) or the consumer (0) mode. C1 determines whether the data are audio (0—section 6 of S₁ closed) or

---

**Table 2. The word-length of the samples may be adapted with section 2 and 3 of DIP switch S₂.**

<table>
<thead>
<tr>
<th>S₂-2:</th>
<th>S₂-3:</th>
<th>length of word</th>
</tr>
</thead>
<tbody>
<tr>
<td>bit QU0</td>
<td>bit QU1</td>
<td>16 bit (rounded off)</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>16 bit INS</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>20 bit</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>16 bit INS</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>18 bit INS</td>
</tr>
</tbody>
</table>

---

The serial input, pins 6, 7, and 8, can handle seven different formats and audio samples of 16–24 bits. In the present circuit, the format is fixed for I²S with M0, M1, and M2.

The serial inputs for channel status, C, user data, U, and validity, V, are not used and linked to earth. The V bit must be low to indicate that audio data are being processed which can be converted to analogue signals.

Pin 15, channel block start, CBL, is not used in the present application either. Normally, it is an output that may be used for writing C, U and V bits. CBL is an input only when in the professional mode the transparent option is chosen (in which the C, U and V bits can be looped in via a receiver). In this way, synchronization of signals coming from separate equipment is possible. Normally, the master clock, MCK, is 128fₛ, where fₛ is the signal frequency, but in the transparent mode, MCK = 256fₛ. The multiplier is set with jumper JP₂.

**Professional Mode**

When pin 2, PRO, is low, that is, when section 8 of S₁ is closed, the digital audio interface transmitter, IC₃, is in the professional mode. In this mode, bits 1, 2, 3, 4, 6, 7 and 9 may be set after a 1 has been sent for channel status bit 0.

C0 indicates whether the channel status block applies to the professional (1) or the consumer (0) mode. C1 determines whether the data are audio (0—section 6 of S₁ closed) or

---

**Table 3a. Sampling rates in professional mode.**

<table>
<thead>
<tr>
<th>S₁-8:</th>
<th>S₁-5:</th>
<th>S₁-4:</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRO</td>
<td>C6</td>
<td>C7</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

---

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not audio (1 – section 6 of S1 open).

C2, C5 and C4 are coded by EM0 (section 2 of S1) and EM1 (section 3 of S1) and determine the emphasis to be used: for instance, 110 is 50/15 μs.

C6 and C7 determine the sampling rate. The requisite setting of the relevant sections of S1 is given in Table 3a.

A 1 at C9 (section 2 of S1 open) indicates a stereo signal; a 0 means that the mode is indeterminate.

In the transparent mode, none of the stated pins is used: the channel code is read at the c input only.

CONSUMER MODE

When pin 2, PRO, is high (section 8 of S1 open), the digital audio interface transmitter is in the S/prof (consumer) mode. In this mode, bits 2, 3, 8, 9, 15, 24 and 25 may be set after a 0 has been sent for channel status bit 0.

C0 – 0 – indicates that the channel status block applies to the consumer mode.

FC0 and FC1 determine the sampling rate. The requisite setting of the relevant sections of S1 is given in Table 3b.

C2 gives a choice between copy prohibit (0 – section 5 of S1 closed) or copy permit (1 – section 5 of S1 open).

C3 determines whether emphasis (50/15 μs) will be applied (1 – section 4 of S1 open) or not (0 – section 4 of S1 closed).

C8 and C9 determine the category code: the requisite setting of the relevant sections of S1 is shown in Table 4.

C15 is the generation status bit. Depending on the category code, the function of this bit, determined by the setting of section 1 of S1, is inverted. When the category code is 001xxxx, 011xxx or 100xxx, a 0 indicates that the bit is an original and a 1 that it is a copy. With all other category codes, the reverse is true.

When the copy bit is 1, there is no copy protection, so that copying is possible. If the copy bit is 0, the generation status bit, in combination with the category code, determines whether copying may be carried out or not.

CONSTRUCTION

The converter is best built on the printed-circuit board shown in Figure 4. Although the board is compact, it affords ample space for all parts and components, including audio sockets K1 and K2 and optoisolators IC4 and IC5. It does not have space for the mains transformer, however. Note that controller IC2 is available ready programmed through our Readers services (see towards the end of this issue).
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### Parts List

#### Resistors:
- R1, R16 = 75 Ω
- R2, R17 = 10 kΩ
- R3 = 100 kΩ
- R4-R5 = 47 Ω
- R6-R13, R18 = 4.7 Ω
- R19 = 8x10 kΩ array
- R16 = 270 Ω
- R17 = 8.2 kΩ
- R18 = 2.2 kΩ

#### Capacitors:
- C1 = 100 pF
- C2, C4, C6, C10, C12, C14, C16, C18, C20, C22, C24, C26, C28, C30, C32, C34 = 100 nF ceramic
- C5, C7, C13, C15, C17, C19, C21, C23, C25, C27 = 47 μF, 25 V, radial
- C29, C31 = 47 μF, 63 V, radial
- C35 = 470 μF, 16 V, radial

#### Inductors:
- L1 = 2.2 μH
- L2-L6 = 47 μH

#### Semiconductors:
- D1, D6 = LED, low current

#### Integrated Circuits:
- IC1 = TDA1373H (Philips)
- IC2 = TST6210 (see Readers services)
- IC3 = CS8402A (Crystal)
- IC4 = TOLX173 (Toshiba)

#### Miscellaneous:
- JP1, JP2 = 3-way pin header and jumper
- K1, K2 = audio socket for board
- K3 = terminal block, pitch 5 mm
- S1 = octal slide switch
- S2 = quadrupole dial switch
- TR1 = wound on G2/2FT12 core - see text
- B1 = rectifier Type 660C1500
- X1 = see text
- Heat sink for IC6: 29 W/K, for instance, Fischer IKC26, ISA, available from Dau, telephone 01243 553 031

#### PCB Order numbers:
- 950000 (see Readers services)

#### Figure 5. Top view of the completed prototype converter board.

Note that IC6 is mounted on an appropriate heat sink.

Less experienced constructors may find the mounting of IC1 and the construction of output transformer TR1 not so straightforward.

Circuit IC1 is a surface-mount device, SMD, which should be soldered at the track side (underside) of the board using an iron with a very fine tip - see Figure 6. Note the correct way of fitting pin 1 is identified by a small disk on the case: this side must point towards the connectors on the board.

Transformer TR1 is a DIY device which is wound on a G2/2FT12 core. The primary winding consists of 20 turns, and the secondary of two turns, of enamelled copper wire with a diameter of 0.7 mm (swg22). Spread the primary evenly across the core, but leave some space at the centre for the two secondary turns that have to be wound subsequently.

When the board has been completed and checked thoroughly, a suitable mains transformer (9 V, 300 mA) or a 9 V mains adaptor may be connected to K3. Indicator D1 should then light.

Using a multimeter, check whether a stable potential of 5 V exists across C32 and C33. If so, it is virtually certain that the converter will work satisfactorily. If it does not, recheck the board thoroughly. It is not possible to give suitable test points, since all that can really be checked are the supply lines.

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Recently, ULTImate Technology made an agreement with the leader in the high end auto router market: Cooper & Chyan, by which the ULTiboard Designer family is supplied with the SPECCTRA SP4 shape based Router. Not only new customers receive this famous Autorouter, all existing users were given the opportunity to apply for a free maintenance upgrade.

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Never before was the purchase of a professional electronics design system so attractive!
One of the first accessories almost any camcorder user will want to have is a simple fader which can help to soften the rather abrupt transitions between filmed shots. The circuit discussed here does just that without any power supply whatsoever. What's more, its component count being down to three, the fader is easily inserted into the video cable.

As long as audio signals are involved, a simple fader (level control) is no problem at all. A voltage divider in the form of an ordinary potentiometer will be just fine in many cases. Of course, the value of the potentiometer needs to be matched to the relevant input and output impedance, but that is rather easy. If quality is at stake, however, more components will be involved than just the one potentiometer. In professional mixing desks, the pot is usually surrounded by complex electronics, which serves to maintain steady terminating impedances at the input and output of each level control unit. The circuitry around the pot then also prevents the characteristic of the level control from being affected by the signal source. Be that as it may, a simple 'passive' volume control will be sufficient for many applications.

With a video signal, the situation is slightly more complex. Video signals are more complex than audio signals because they contain synchronisation pulses which cannot be 'pinched off' just like that using an ordinary potentiometer.

**VIDEO, BLANKING, SYNC.**

The function of the basic components is discussed below, mind you, without going into details as regards the intricate structure of a video signal. Figure 1 shows one line period.

The video signal is sometimes also referred to as 'composite video' or CVBS, which stands for colour, video, blanking, sync. For simplicity's sake, the colour component will not be discussed here. The drawing in Fig. 1 clearly shows that the larger part of the total swing of the signal (approx. 67%) is reserved for the V (video) component. This component determines the

---

**Figure 1. Composition of a video signal during one line period. For a video fader, it is essential that the sync pulses (B) arrive intact at the output.**
conspicuous part, of course. In combination with the input impedance of the video input on the monitor, it forms an adjustable voltage divider for the video signal. The trick is the shunt diode which creates a kind of by-pass for the sync pulses. The input and output of electrolytic capacitors in the camcorder and the video recorder cause the video signal level to be 'clamped' at a certain average value. Relative to that level, the sync signal forms a train of negative-going pulses which are allowed to travel (almost) freely through the diode. This little circuit appears to fit the bill perfectly: the pot allows you to turn the brightness down without the monitor losing sync suddenly.

PERFECTING THE DESIGN

In practice, the circuit of Fig. 2 does have a few drawbacks, as some readers informed us. The operation of the fader is quite acceptable at high-impedance loads. However, when a terminating impedance of 75 Ω is used (which is customary with video equipment), the fade characteristic is far from ideal. Also, problems with sync degradation were sometimes reported. These problems are probably caused by the threshold voltage of the diode. All in all, sufficient reason to see if the circuit might be improved a little, provided, of course, it retains its charming simplicity.

Improving the 'flow' of the sync pulses was not difficult: all we had to do was replace the ubiquitous 1N4148 diode by a Schottky type BAT82. The lower threshold voltage of the Schottky diode ensures that the sync level remains intact at all times.

Improving the fade characteristic was far more difficult, as it turned out. It was clear that a parallel-connected potentiometer would be a better level control by definition, while also causing less of a mismatch. A practical problem arises, however: when the 'lower' terminal of the pot is simply connected to ground, and the wiper acts as the output, the inherent disadvantage is that the sync pulse is increasingly short-circuited to ground, together with the video components, as the brightness is reduced (fade-out). The diode, unfortunately, can not do anything about this situation.

One extra part, however, does the trick, see Figure 3. It may be too simple for words, but the crux of the revised video fader is the way R1 is connected into the circuit. When the wiper of P1 is at the top position, R1 is just a harmless series resistor, and the video signal is passed with virtually no attenuation. When the wiper of P1 is turned to ground (fade-out), R1 prevents the signal from being short-circuited to ground behind the diode. Functionally, R1 changes from a series into a parallel resistor as the pot is turned. At the end of the travel, it is just a harmless terminating resistance.

It will be clear that no passive control will ever form a perfect match between a 75-Ω input and output. Fortunately, the mismatch of the circuit shown here is so small that annoying effects will not occur. On the contrary, this video fader gaves a quite acceptable fading characteristic while still offering the advantage of an unfairly unrivalled simplicity.

MATCHBOX SIZE

There is hardly a point in discussing the construction of the circuit. Obviously, there is no printed circuit board, while none of the regular construction problems will occur in practice. The only thing to keep in mind is that the wiring between the three components must be kept as short as possible.

BY-ROAD: FOR SYNCS ONLY

If you want to build a video fader which provides an acceptable fading range without sync loss, then care should be taken to attenuate the video component only, i.e., leave the sync pulses intact. If simplicity is not an issue, that may be achieved by using a range without sync loss, then care which provides an acceptable fading characteristic. If you want to build a video fader which provides an acceptable fading characteristic, it is not suitable as a level control for a TV receiver, the video level will suddenly lose sync, and the picture cannot be viewed altogether. One extra partcurtains an adjustable voltage divider for the video signal.

Figure 2. The trick with the diode: when the video level is reduced with P1, diode D1 provides a safe by-pass for the sync pulses.

Figure 3. The operation of the circuit in Fig. 2 may be perfected by adding a single resistor.

Diode D1 and resistor R1 are, therefore, soldered directly to the terminals of potentiometer P1. Add two pieces of coax cable, and Bob's your uncle.

An ultra-small enclosure, say, the size of a matchbox, and preferably made of metal, is sufficient to house the circuit. If small size is not your foremost concern, then a small diecast case like the Hammond type 1590LB is worth going for. Also consider using a slide potentiometer for P1, in which a type 1590A enclosure (also from Hammond) will offer the necessary space.
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28 Stephenson Road
Industrial Estate
St. Ives
Cambridgeshire PE17 4WJ
England

Tel: 01480 300 695
Fax: 01480 451 654
The digital compass published in last month's issue of this magazine used a Pewatron Type 6945 magnetic sensor. This device was shown to enable the construction of an electronic compass with relatively few additional components. True, it has a resolution of only 45°, but this is perfectly acceptable for many applications. The analogue sensor, Type 4070, also from the Swiss firm Pewatron, enables a fully fledged replacement (resolution 0.5°!) for a magnetic compass to be constructed. As already pointed out in last month's article, this requires fairly complex circuitry. Moreover, the data provided by the sensor cannot easily be evaluated without the use of a microcontroller.

Although the (analogue) Type 6070 sensor from the outside looks similar to the (digital) Type 6945, internally it is quite different. The Type 6070 sensor provides two voltages that represent the orthogonal (right-angled) components of the direction vector within a quadrant—see Figure 1. In other words, the direction is resolved in a sine function and a cosine function. The functions, $U_{\sin} = U_{\text{max}} \sin \alpha$ and $U_{\cos} = U_{\text{max}} \cos \alpha$, are represented in the lower part of Figure 1. The sine and cosine curves have the same value, but in different directions, that is, 45°, or NE, and 225°, or SW, respectively.

These potentials determine the upper and lower intersections, $U_d$ and $U_u$ respectively. The voltage at the centre between them, $U_c$, is taken as the zero point. The output signal swings between 2.1 V and 2.9 V approximately, so that the centre voltage is 2.5 V. The exact value is very accurate, but plays no further role, since it is excluded in the subsequent signal process.

The output voltage range is ±350 mV to ±375 mV, but between the intersections it is only ±250 mV. To evaluate the two output potentials, the section of the curves between the two intersections is taken as linear. Only the voltage outside the range between the upper and lower intersections determines the quadrants as follows:

- **sine curve above $U_d$**: 45°–135° (NE–SE)
- **cosine curve below $U_u$**: 135°–225° (SE–SW)
- **sine curve below $U_u$**: 225°–315° (SW–NW)
- **cosine curve above $U_d$**: 315°–45° (NW–NE)

The remainder of the curve lies in the relatively linear range with a voltage sweep of some 500 mV/90°, that is, about 5.5 mV per degree. If this range is evaluated with a resolution of 8 bits = 225 steps, each step is 2 mV or 0.35°. The inherent error owing to the non-linearity

![Figure 1. One output signal determines the quadrant, the other the exact direction.](image-url)
of the curve is about ±5 per cent, which does not do the accuracy of the sensor justice.

Fortunately, the use of a microcontroller allows a much more precise evaluation. In this way, a correction table can be stored in an EPROM, or the measurement result can be made more accurate by an appropriate algorithm (angular function).

SOME PROPERTIES OF THE SENSOR

The Type 6070 sensor is 12.7 mm high, has a diameter of 12.7 mm, and weighs 2.3 g. It is suitable for operation over the temperature range of -40 °C to +85 °C. It has six terminals, of which four are used for connecting to the supply lines (see Figure 2). The sensor requires a simple but well-regulated power supply of +5 V. It is well worth bearing in mind that this expensive device (about £70 or SUS 110) is easily damaged beyond repair by pulses and other interference on the supply lines. The regulation should, therefore, be as close to the sensor as possible and certainly provide good protection against voltage peaks and, in case of mobile use, polarity reversal. The sensor draws a current of 18-19 mA.

The sensor is a combination of a miniature motor with sapphire bearings, a Hall effect chip, and a magnet. It is mechanically damped so that the output needs about 2.5 s to follow a change in direction of 90°. This is similar to the fluid damping in a magnetic compass and prevents the reading from overswing and fluttering around the real value.

The construction is such that when the sensor is mounted vertically it does not respond to the horizontal component of the earth's magnetic field. If it is not exactly vertical, inclination errors are likely to occur.

APPLICATION WITH CONTROLLER

Figure 3 shows a typical application of the sensor in combination with an adder. This amplifier not only raises the signal x10, but also removes the centre voltage from the signal. To ensure optimal operation of the analogue-to-digital converter (ADC), variable amplification is indispensable. This is provided by a preset in the feedback loop.

A load current of up to 4 mA may be drawn from the outputs of the sensor, which means that a wide variety of operational amplifiers may be used.

Finally, the two processed analogue signals are digitized as shown in the block diagram of a complete compass in Figure 4. This may be effected by an ADC and multiplexer or by two discrete 8-bit ADCs, such as the Type 0804. Another possibility is using a microcontroller with integral ADC, such as the 68HC11, the 80C55, one of the ST6xx series, or a Type 16C71 or 16C74 peripheral interface controller (PIC). When choosing a controller, make sure that it has an adequate number of port lines to enable an LED display or liquid crystal display (LCD) to be driven.

TIPS ON USE

The sensor is highly sensitive to external magnetic parts. It is, therefore, advisable when building a compass to check that components used are not magnetized, since this will almost certainly cause the compass reading to have an error. Nevertheless, the effect of the earth’s magnetic field is not limited in any sense. Also, the sensor is not damaged by other extraneous magnetic fields.

Note that the IC in the sensor can be damaged by sustained (>4 s) heat from a soldering iron, which should have a temperature not exceeding 360 °C. If in doubt about the temperature, it is advisable to use a heat deflector such as a pair of flat-nose pliers around the wire being soldered.
Elektor Electronics in digital form? Yes! From now on you will be able to inspect and study all articles that appear in the eleven annual issues on your computer screen. The 1995 content is now available on disk in four languages: Dutch, English, French and German. These languages are used because they are the main languages in which the magazine is published (although there are also issues in Greek, Hebrew, Italian, Polish, Portuguese, Spanish and Swedish).

The first CD-ROM - the guinea pig - contained the 1994 annual content in Dutch, purely because the Netherlands is a fairly easy testing ground. The response was good enough to convince us that there should be a disk for subsequent years and then in the four main languages used in our company. Moreover, CD-ROM drives are now available for such low prices, that we feel that almost any reader of our magazines has access to one.

Facilities

Needed for using the disk is an IBM (compatible) PC with a 386 or higher, not less than 4 MB RAM, a VGA screen, and a CD-ROM drive. The program on the disk runs under Windows 3.1, 3.11 and 95.

The program is designed so that you need not install anything on your hard disk. After it has been started, a box appears in which one of the four languages can be selected. Once this has been done, the program remembers it and next time your start, it will automatically open in the selected language.

Next appears a complete overview of all articles published during 1995 (but not news, new products, new books and similar columns). You may also select an overview of a particular month, whereupon the cover of that month is shown.

After an article has been opened, first the text and all photographs (if any) are shown. All circuit diagrams, printed-circuit board layouts, other drawings and tables, which can be selected individually, are shown in the text in colour. When you can click on one of them, it appears on the screen in a separate window.

In the case of circuit diagrams and board layouts, the left-hand and right-hand mouse keys enable zooming in and out.

Board layouts are shown in 600 dpi to enable you to make good-quality copies for producing and etching the board yourself.

The text, or part of it, may be copied and modified without any problems, for instance, for reviewing purposes (do not forget to mention the source in that case). There are many more facilities built in, too many to mention in this short note. Suffice it to say that the design differs considerably from that used by many other magazines. These normally convert existing DTP (desktop publishing) files into so-called HTML or PDF files. These files do not have a sufficiently high resolution as far as circuit diagrams and board layouts are concerned (or they are so large that they make the computer very slow), and we feel that just these are of particular importance to our readers. Our disk has the great advantage that the text as a whole remains perfectly legible and that only those illustrations are shown that you select. Text and illustrations may be said to be independent of one another.

A final point: if you buy the CD-ROM, please let us know of any constructive criticism you may have; this will only make next year's disk better.

The recommended retail price of the CD-ROM is £41.00 or $65.00, but subscribers to the magazine qualify for a 10 per cent discount.
Safety Guidelines

Safety requirements refer mainly to the 240 V mains voltage, but also to the temperature of touchable parts and fire protection. Most problems connected with a mains power supply can be prevented by the use of approved and correctly rated mains adaptors. As regards mains-operated equipment, there are two classes of insulation: Class I: single insulation, which always requires a three-core supply cable with earth, and Class II: double insulation, which requires no earth and only a two-core supply cable. Thus, the requirement is always for double protection. With the enclosure shut, all touchable, conductive parts must be at earth potential.

Class I requires isolation between the mains voltage and earth, and every touchable part that withstands a flashover voltage of 2120 V. To prevent flash-over, the distance between mains voltage carrying parts and touchable parts must be ≥ 3 mm. All touchable, conducting parts must be properly earthed.

Class II

The requirements of Class II are identical to those of Class I except that the test voltage is 4240 V and the flashover distance is ≥ 6 mm.

Practical considerations

A safe rule of thumb is to keep the distance between mains voltage carrying parts and touchable parts as far as possible. Use an approved mains entry with integrated fuseholder and on/off switch. Note that the manufacturer's statement "suitable for 250 V" does not mean that insulation of the switch is approved, merely that it does not break down at 250 V. If you do not use an integrated entry, use a strain relief on the mains cable at point of entry.

1. A single-pole mains on/off switch is allowed on equipment that is powered by transformers with isolated primary and secondary windings.

2. An on/off switch not in the mains circuit is allowed if the transformer has isolated primary and secondary windings, and the power consumption in the "off" position is not more than 10 W. There must be a visible indication that the equipment is plugged into the mains.

3. An on/off switch is not required if the power consumption of the equipment is ≤ 10 W or if the equipment is intended for continuous use, such as an antenna amplifier.

Equipment not meeting these three conditions must have a double-pole on/off switch.

Fuses, inductors, capacitors and resistors for interference suppression need not be switched off. It is advisable, though not mandatory, to precede the switch by a fuse.

Never solder mains carrying wires directly to a printed-circuit board: use solder tags. The use of clip-on tags is also good practice.

The mains earth must be connected to other parts that need to be grounded by a yellow/green wire. Pay particular attention to the metal spindles of other components.

The earth of the circuit may be touched because the mains transformer is double insulated. The earth of the mains power supply and each and every fuse, even if fused on a fuse, must be a label stating its rating and type. One of the side panels, or the rear panel, must have a label stating the identity of the equipment, for instance, EE power supply from no. 213, the mains voltage, and mains frequency. If operation from a.c. only is possible, the label must carry the symbol - . In case of a failure, there should not be any danger to the user.

The temperature of touchable parts must not be so high as to cause injury or create a fire risk. All risks can be eliminated by the use of correct fuses, a sufficient firm construction, correct choice and use of insulating materials and adequate cooling through heat sinks and by extractor fans. The rating of a slow fuse should be no greater than 1.25 times the normal operating current, whereas that of a fast fuse should be equal to the normal operating current. Fast fuses are used, for instance, in case of secondary windings. If there is an electrolytic capacitor behind the secondary, a slow fuse must be used to allow for surges in the charging current. The equipment must be sturdy: repetitively dropping it onto a hard surface from a height of 50 mm must not damage. Greater impacts must not loosen the mains transformer, electrolytic capacitors and other important components.

Do not use dubious or flammable materials that may emit poisonous gases.

Shorten screws that come too close to other components.

Keep mains-carrying parts and wires well away from ventilation holes, so that an intrusion screwdriver or inward falling metal object cannot touch such parts.

Transformers

Figure 1 shows how a transformer should be connected in line with safety requirements. Although double-pole on/off switches are shown, these may be single-pole since in both cases the transformer is a double-insulated type. It is assumed that the transformers are short-circuit-proof, where the absence of primary fuses. If the assumption is not true, a primary fuse must be used. The figures 1 and 2 indicate, respectively, whether single or double insulation is required.

Working in safety

As soon as you open an equipment, there are many more potential dangers. Most of these can be eliminated by unplugging the equipment from the mains before the unit is opened. But, since testing requires that it is plugged in, it is good practice (and safe) to fit an earth leakage switch rated at not more than 30 mA to the mains system (this may be fitted inside the outlet box or multiple socket). Earth leakage switches more sensitive than 30 mA need to be used only if the leakage current is expected to remain below 30 mA, which is rarely the case.

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With the electric-bulb tester you cannot only verify whether a bulb is still in working order, but, if so, also find its wattage. True, this power rating is normally stated on the bulb, but it happens frequently that, after a time, this is no longer legible. The tester indicates whether the bulb in question is rated at 15, 25, 40, 60, 75 or 100 watt. Now, isn't that handy?

If all that needs to be ascertained of a bulb is whether it is still usable, a special tester is not really required. It is quite easy to substitute it for a known working bulb in a standard or desk light. However, a tester that works without the need of mains voltage is, of course, always safer.

A different situation arises when you often have to deal with suspect bulbs. Also, if a defect bulb is to be replaced by one from an assortment of spare bulbs whose wattage is undecipherable, a simple tester like the one described here becomes indispensable.

An ohmmeter is all that's required to check the continuity of the filament of the bulb. If the filament is broken, it has a very high resistance, but if it is all right, the resistance is low. Moreover, the value of the resistance is a (rough) measure of the wattage of the bulb, as is shown in the two right-hand columns of Table 1. These columns give the filament resistance (when the filament is cold) of the most common bulbs.

So, Table 1 and an ohmmeter (or multimeter) make it possible to find out the most important aspects of a bulb. This method is not very convenient, however, and this article, therefore, describes a rather more user-friendly way.

DISPLAY DRIVER

It is not necessary to measure and interpret resistance values. The cold resistance of most bulbs may be converted into a voltage with the aid of an auxiliary (test) current. This voltage may be used to actuate a circuit, which is kept simple by the use of a display driver Type LM3915. This device makes displaying the voltage very simple indeed.

The driver, whose block diagram is shown in Figure 1, is specially designed to display analogue voltages on an LED scale. For this, the IC needs an internal reference voltage, a multi-section precision potential divider, and a number of comparators, the output of each of which can drive an LED.

The potential divider is arranged so that the LED display forms a logarithmic scale in steps of 3 dB. This means that each comparator threshold is higher by a factor 1.414 than its predecessor.

The measurand (that is, the quantity – here voltage – to be measured) is applied to pin 5. The input voltage range may conveniently be set by adapting the reference potential. The internal voltage reference provides a potential of 1.25 V across pins 7 and 8. It is thus a simple matter of setting a given voltage between pin 7 and earth with an external potential divider. Note, however, that this has its limits, since the resistance between pin 7 and earth determines the brightness of the LEDs. The current through the LEDs is about ten times as high as that through this resistance.

CURRENT SOURCE

All that is needed additionally to turn the display driver, IC4, into a bulb tester is a constant-current source. When this sends a current through the bulb on test, a potential difference ensues across the filament. This voltage is...
applied to pin 5 of IC₁. Depending on the level of this voltage (which is directly proportional to the wattage of the bulb), one of the LEDs lights. Since the IC works very well with low voltages, the current from the source need not be large. A current of 5 mA was decided upon, which helps to extend the life of battery B₁. Table 1 gives the correlation between the test current and the resulting voltages.

In the design of the current source, the internal voltage reference of IC₁ was used—see the circuit diagram in Figure 2. As already stated, the 1.25 V reference potential is available between pins 7 and 8. This means that the voltage drop, \( U_{\text{ref}} \), across \( R₁ + R₂ \) is 2.2 V. This potential is the upper limit of the measuring range, since pin 7 is linked to the upper terminal of the internal potential divider, that is, pin 6. Therefore, \( D₁ \) will light only when the input voltage applied to pin 5 exceeds 2.2 V. All other threshold voltages are derived from this and are given in Table 1.

The voltage drop across \( R₁ + R₂ \) is applied to the base of transistor \( T₁ \). This means that the voltage drop across \( R₃ \) is 2.2-0.6 = 1.6 V. With the specified value of \( R₃ \), this results in an emitter current of about 4.8 mA. Since the collector current is virtually identical to the emitter current, the current through \( P₁ + R₄ \) is also 4.8 mA. This makes it possible for \( P₁ \) to adjust the base voltage of \( T₂ \) to a level that results in a potential difference of exactly 1.1 V across emitter resistor \( R₅ \). This means that a stable current of exactly 5 mA flows through \( R₅ \) and the filament of the bulb on test which is connected in series with the collector circuit of \( T₂ \).

The voltage drop across the filament resistance, \( R₅ \), is applied to pin 5 of IC₁. Table 1 shows which diode will light at what voltage. Laboratory tests with a variety of electric bulbs showed that the voltages resulting from the 5 mA test current neatly fell between successive switching thresholds of IC₁. Only the test voltage for 25 W bulbs (0.750 V) may give difficulties as this is very close to the next highest threshold of 0.7980 V.

Depending on the tolerances of the components used and the accuracy with which \( P₁ \) is adjusted, it may be desirable to link \( D₂ \) to pin 11 instead of to pin 13. This can be done conveniently with jumper \( J P₁ \).

CONSTRUCTION

The electric-bulb tester is best built on the printed-circuit board shown in Figure 3, which is available ready-made through our Readers services (towards the end of this issue).

It is advisable to use a suitable socket for IC₁.

Mind the polarity of the LEDs: almost invariably, the shorter terminal is the cathode. How these diodes are best mounted depends to a large extent on the enclosure used. In most cases, it will be found best not to solder them directly to the board, but to mount them in the lid of the enclosure and link them to the board with insulated flexible circuit wire.

A photograph of the completed prototype board is shown in Figure 4. Power for the tester is best supplied from a 9 V battery. Since the circuit draws a current of only 15 mA and only then when the test button, \( S₁ \), is pressed, the battery will have a long life.

Even including the battery, the volume of the tester is small, so that finding a suitable plastic enclosure should not prove difficult. It is, of course, important that the LEDs are clearly visible, that \( S₁ \) is easy to operate, and that robust, high-conductive (copper) strips are used for attaching the bulb on test. The distance between the strips may be slightly less than that between the contacts on the bayonet fitting of the bulb. If continental, screw-type bulbs are to be tested, the strips should be arranged with one horizontal and the other so that it connects readily with the screw thread of the bulb.

See also the wiring diagram in Figure 5.

SETTING UP

After the board has been completed, check it thoroughly with reference to Figure 3 and the parts list. Make sure that the IC is slotted correctly into its socket. When everything appears to be in order, connect the battery and, using a multimeter set to the 5/10 V d.c. range, check the voltage between pins 2 and 7 of the IC, which should be about 2.2 V—do not forget to press \( S₁ \). Any variations of this voltage should be cor-

Elektor Electronics 10/96
Figure 3. The printed-circuit board for the bulb tester is easily completed.

**PARTS LIST**

**Resistors:**
- R₁ = 2.7 kΩ
- R₂ = 1.8 kΩ
- R₅, R₆ = 220 Ω
- R₄ = 330 Ω
- P₁ = 250 Ω preset

**Capacitors:**
- C₁ = 100 nF
- C₂ = 100 μF, 16 V, radial

**Semiconductors:**
- D₁ = LED, red, low current
- D₂ = LED, green, low current
- T₁ = BC550C
- T₂ = BC557B

**Integrated circuits:**
- IC₁ = LM3915 (National Semiconductor)

**Miscellaneous:**
- JP₁ = 3-way header and jumper
- S₁ = single-pole press button switch
- B₁ = 9 V battery (PP3, 6F22P, 6LR61)

Table 1.

<table>
<thead>
<tr>
<th>Switching threshold (volt)</th>
<th>LED</th>
<th>test voltage (volt)</th>
<th>bulb wattage (watt)</th>
<th>filament resistance (Ω) (cold)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2000</td>
<td>D₁</td>
<td>&gt; 2.200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.9550</td>
<td>D₂</td>
<td>1.880</td>
<td>15</td>
<td>336</td>
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<td>1.1025</td>
<td></td>
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<td></td>
<td></td>
</tr>
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<td>0.7880</td>
<td>D₃</td>
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<td>0.5525</td>
<td>D₄</td>
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<td>95</td>
</tr>
<tr>
<td>0.3209</td>
<td>D₅</td>
<td>0.2925</td>
<td>60</td>
<td>58.5</td>
</tr>
<tr>
<td>0.2765</td>
<td>D₆</td>
<td>0.245</td>
<td>75</td>
<td>49</td>
</tr>
<tr>
<td>0.1961</td>
<td>D₇</td>
<td>0.180</td>
<td>100</td>
<td>36</td>
</tr>
<tr>
<td>0.1321</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0980</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. The completed prototype board.

Figure 5. The wiring diagram enables all connections to be checked thoroughly.

Table 1. Switching threshold, LED, test voltage, bulb wattage, and filament resistance.

rected by altering the value of R₅: a higher resistance results in a higher voltage.

When all is right, connect a multimeter set to the 10 mA d.c. range to terminals R₂ and adjust P₁ until the meter reading is exactly 5 mA.

It is advisable to check the tester with a variety of known working electric bulbs and check that all relevant LEDs light as required. This is also the time to see what is the better position for JP₁. If the results are slightly adrift, they can almost certainly be corrected by adapting the test current slightly through a small readjustment of P₁.

Finally, although the test current is not large, it does heat up the filament of small-wattage bulbs quite quickly. It is, therefore, necessary to keep the test short to prevent a fault indication (red LED lights).
 Computers are increasingly used to analyse electronic circuits. Today's simulation programs are so good that electronics designers can be 95% sure about the behaviour of almost any circuit, without having to make a single solder joint. Moreover, simulation is not limited to just the circuit diagram. Having designed the printed circuit board, for example, you may even run a simulation to check the effect of copper tracks on the board. Simulating electronic circuits is not easy. Not surprisingly, it was just not practical before the arrival of large and (then) powerful computer systems. The first simulator to be developed in the sixties was called CANCER. It was soon followed by SPICE, designed at Berkeley University in the late sixties. SPICE2, a further development of SPICE, is generally considered to have caused a breakthrough in electronic circuit simulation. SPICE is an acronym for Simulation Program with Integrated Circuit Emphasis. The original SPICE programs have always been available free of charge for anyone. For an overview, see, among others, the Internet page www.paranola.com/~filip/g/html/free_s_pice4.html. SPICE2, in turn, was used by a number of software companies as a basis for their own simulation programs. These were generally intended to be run on mainframes and, at a later stage, workstations. However, thanks to the growing popularity and computing power of the IBM-compatible PC, simulation programs started to appear for that platform, too, in the early 1980s. Meanwhile, these DOS programs (primitive as regards user interface) have been largely superseded by modern Windows versions, which has helped a lot as far as user friendliness is concerned. Moreover, the simulation abilities have been extended considerably, and the results are much more realistic than before.

Initially, electronics simulation programs were limited to simple components. Today, however, the models are very realistic indeed, while almost any step from design to production may be simulated.

**Models and Netlists**

In principle, not much is required to simulate an electronic circuit. Essentially, all components are represented by resistors, inductors, capacitors, (driven) voltage and current sources, or combinations of these. Each junction in the circuit is numbered. Next, all this data is stored in a so-called netlist (Figure 1). This list indicates which component is connected between which junctions. In addition, the list also informs the system about the specific characteristics of the relevant component. The software then processes the list to set
up a number of current equations for these junctions. After solving the resulting equation matrix, the program knows all currents. Consequently, it is able to compute the voltages across all components in the design.

All this may look fairly easy, but a good simulation requires models which come as close as possible to the real-life behaviour of a component. Figure 2, for example, shows a simulation model of a diode (source: Interactive Image Technologies). In many cases, different models and modified or entirely different calculations are necessary for the direct voltage settings of the circuit, the alternating voltage response and the transient behaviour. This is illustrated in the example with the diode.

**PSpice and Co.**
The simulation algorithms and models applied in PSpice2 have been used as starting points by various software manufacturers for their own products. One of the best known programs in this area is PSpice from Microsim, which appeared on the market in 1984. Many other, competitive, programs will have some indication or other reading 'PSpice compatible' or similar, which tells you that they are capable of processing or importing PSpice netlists.

Most simulation programs consist of a number of modules, each of which having a specific task. For example, there is usually an input model which allows the user to enter a circuit diagram (graphically, or as text), a calculation module which solves the network equations, and an oscilloscope program which presents the results graphically. In a program like PSpice, these modules are clearly separated, but there are also products like MicroCap which combine all these modules within a single shell.

**Simulation Options**
The simulation options are usually:

- **DC analysis.** This tells you how a circuit settles electrically after the power supply is switched on. In other words, you then know whether or not all active components are biased such that they function properly. The results enable you to draw conclusions about, say, the drive margin of a transistor stage or an opamp output.

- **AC analysis.** The alternating voltage behaviour of a circuit (in response to a sine wave) is computed at a number of frequencies to enable a Bode plot to be generated. The Bode plot shows the frequency and phase response, and, based on this data, the propagation delay of the hypothetical circuit. In many cases, a distinction is made between the a.c. response of a circuit to large and small signals.

- **Transient analysis.** This examines the way the circuit responds to certain signals the user is allowed to select (for example, a triangle waveform, a square wave, a staircase voltage). This method allows the response of the circuit to be traced in the time domain. With this type of analysis, the starting point is important: the user is allowed to select between a situation in which all d.c. settings are already present (steady-state), or a situation in which the power supply is not switched on until the starting instant. The latter option is particularly valuable to examine, for instance, the initial behaviour of an oscillator voltage after the supply is switched on.

- **Mixed-mode analysis.** Simulating digital and analogue components in a single circuit. Until a few years ago, separate programs existed to simulate analogue and digital circuits. With many up-to-date programs, these modes have been merged, which ensures greater flexibility as far as entering circuit diagrams is concerned. It is possible to go further than just looking at the logic behaviour of a circuit. Because the models of digital components often include analogue properties, it becomes possible to examine timing errors and pulse rise times.

- **Fourier analysis.** Every waveform you can think of may be dissected into the sine wave components (basic frequencies) it consists of, which are presented along with their associated levels.

- **Monte Carlo analysis.** This is a statistical test in which a circuit is simulated many times in succession, while the component properties are modified in a random manner within tolerance bounds defined by the user. This test is particularly useful if you want to know how a circuit responds to tolerances which inevitably apply to the components used during the assembly phase. Usually, a Monte Carlo test may be run for d.c. as well as a.c. behaviour.

- **Parameter modifications, worst-case analysis, etc.** Basically, these are all related tests in which a com-
ponent value is 'shifted' step-by-step through its tolerance range (alternatively, only the tolerance bounds may be used). The analysis is started over again after any change in tolerance.

Although the options mentioned above may have different names in simulation programs, they do cover most, if not all, functions which are usually available.

Further important points for the user to concentrate on are: what is the size of the library which comes with the program; is it possible to add components easily, or modify the drawing symbols? Evidently, these points are more important to the professional user than to the hobbyist.

**From Large to Small**

Broadly speaking, the simulation programs available today may be divided into three categories.

**Semi professional programs**

A range of programs is available for accurate simulation of extensive analogue/digital circuits. Here, we limit ourselves to versions which are intended to run on a PC. Well-known programs include PSpice A/13 from NHCrossim, ICAP/4 from Intusoft, Smash Wizard from Dolphin Integration, MicroCap from Spectrum, and SpiceAge from Those Engineers. Complete versions of these programs may be expected to cost between £0,000 and £10,000. Auxiliary programs may often be obtained separately with these (semi) professional programs, for example, filter design tools, magnetic field simulators, and others.

**Educational programs**

Although educational programs are also complete simulation programs, it is still worthwhile to note that they differ from professional programs because of their structure or possibilities. Students in particular make frequent use of simulation programs. The marketing aim is clear: many students of course start using professional programs once they have found employment.

The greatest simulation program we know for educational purposes is Electronics Workbench (v.1.1) from Interactive Image Technologies (UK representative: Robinson Marshall). Using this program you have available a virtual multimeter, a signal generator, an oscilloscope, etc. These instruments appear on the screen, and may be hooked up to the circuit, just as in a 'real' lab, once the circuit diagram is complete. Beginners, too, will be able to use this program which is employed in many schools and educational institutions. Electronics Workbench, too, has been expanded and enhanced many times. As we write this, a mixed-mode 32-bit version is offered for which additional modules are available for Spice importing and exporting, model libraries and export facilities for printed circuit board layout programs. Recently, a competitive product appeared on the market: CircuitMaker from LabVolt. More details on this interesting new software product may be found on page 9 of the September 1996 issue of Elektor Electronics.

Not educational in the strict sense of the word, but also fitting in this category as far as price and potential buyers are concerned, are the so-called student versions of 'big programs offered by various companies (including Intusoft and Spectrum). Usually, the maximum number of components and component junctions (nodes) is limited in the student versions. Normally, student packages are offered at reduced prices of between £40 and £80. For many electronics enthusiasts, such a student version is a good choice to become acquainted with electronic circuit simulation, and, of course, for actual work on those smaller circuits.

**Hobby programs**

Meanwhile, simulation programs have popped up in the shareware circuit, too. Such programs may be tried out during a limited period before you pay...
the author for his product. Simulation programs from the shareware circuit usually have a less professional look and feel than the ones mentioned so far, and also offer fewer simulation options. None the less, they are interesting enough to obtain some experience in this area. Moreover, the limited possibilities of the typical shareware program are a blessing for those who are easily confused by a multitude of options, preferences, file formats, etc. More is not always better!

Demonstration versions of a number of 'big-gun' programs are also available from their manufacturers. These versions are often free of charge, and for evaluation purposes. Some are available on the Internet, for example, via www.intusoft.com and www.microsim.com. The demo version of PSpice, for instance (current version: 6.3), enables small circuits to be simulated and stored. In most demo versions, including that of MicroCap V, the 'save' and 'print' options are disabled, so that the user has to draw the circuit diagram from scratch every time the program is used. Be that as it may, such a simulation program is, of course, fine if you want to do a quick test on a small circuit, or just satisfy your curiosity.

FURTHER OUTLOOK

Future releases of the programs mentioned in this article will no doubt contain even better models, while the simulation methods will be improved. More important, however, is the trend which can be seen with EDA software (Electronic Design Automation), which aims at condensing the complete design process from circuit diagram to layout into one, continuous, operation. A few years ago we witnessed the amalgamation, so to speak, of analogue and digital simulation into a single program. Now, the software industry looks poised to include even the PCB layout phase in the design process. Not surprisingly, suppliers of simulation-only software, like Microsim, extend their product range in the direction of PCB design programs. Likewise, established makers of PCB design and schematic drawing programs are beginning to add simulation programs. OrCAD, for example, offers a simulation program for digital circuits, called OrCAD Simulate. Still others already supply a complete electronics design system, for example, the Proteus bundle from Labcenter Electronics. Note, however, that this package still consists of three modules.

There are even programs around which are capable of simulating the effect of printed circuit board tracks. An example is the relatively new LAYAN software from Number One Systems. In the near future, simulation programs will be so powerful and intelligent that users are able to see exactly how a circuit behaves on a certain board, check its unwanted emissions, and make sure that it complies with EMC directives.

Manufacturer, Importers and Distributors of the programs mentioned in this article:

Electronics Workbench: Robinson Marshall (Europe) plc, Nadella Buildings, Progress Close, Lotech Business Park, Coventry, Warwickshire CV3 2TF. Tel. (01203) 233-216, fax (01203) 233-210. Email: rmme@cityscape.co.uk.

Smash: Dolphin Integration, 8 Chemin des Clos, F-38242 Meylan, France. Tel. (+33) 76411096, fax (+33) 76902965.

ICAP/4: Intusoft, Technology Sources Ltd., Dr Graham Plows, Grove House Lodge, Falmouth Ave, Newmarket, Suffolk CB8 0LZ. Tel. (01638) 561460, fax (01638) 561721.

Pspice: MicroSim Corp., 20 Fairbanks, Irvine, CA 92718, USA. Tel. (+1) 714 770-3022, fax (+1) 714 455-0554.

MicroCap: Spectrum Software, 1021 S. Wolfe Road, Sunnyvale, CA 94086, USA. Tel. (+1) 408 738-4387, fax (+1) 408 738-4702.

OrCAD Simulate: OrCAD, 9300 S.W. Nimbus Avenue, Beaverton, OR 97008, USA. Tel. (+1) 503 671-9500, fax (+1) 503 671-9501.

SpiceAge: Those Engineers Ltd., 31 Birbeck Road, London NW7 4BP. Tel. (0181) 9060155, fax (0181) 9060969. Email: 100550.2455@compuserve.com.

LAYAN: Number One Systems, Harding Way, St. Ives, Cambes PE17 4WR. Tel. (01480) 461778, fax (01480) 494042.

CircuitMaker: Lab-Volt (UK) Ltd., 28 Stephenson Road, Industrial Estate, St. Ives, Cambes PE17 4WJ. Tel. (01480) 300695, fax (01480) 451654.

Proteus: Labcenter Electronics, 53-55 Main St., Grassington BD23 5AA. Tel. (01756) 753440, fax (01756) 752587.

Next month we start a short course on simulation of analogue circuits called Hand On Electronics by Owen Bishop. The cases and examples discussed in this course may be applied in practice with the aid of a demonstration version of MicroCap V which may be obtained through your local distributor or the Elektor Electronics Readers Service. Alternatively, you may use a similar Spice compatible simulation program.
Although we would not denigrate the many photographic development and printing services (which vary from poor to fairly good), it is a fact that many serious amateur photographers would not dream of sending their carefully taken and exposed films to one of these bureaux. Many others are hesitant to do so. This article is aimed at all these photographers. It describes a darkroom timer that is calibrated in f numbers. This kind of calibration makes the timer much easier to use than the traditional ones that have a linear scale.

**The 555**

The 555 can in truth be called the workhorse of electronics. It can be used in almost any case where an RC timer is required.

The IC can be used for building monostable as well as astable multivibrators for operation over a frequency range of 0-500 kHz.

There are other versions of the IC: the 7555 or the newer TLC555.

Basically, the IC consists of a potential divider composed of three identical resistors, two comparators, a bistable (multivibrator), and an output buffer—see the block diagram.

When a negative trigger pulse of $<V_{CE}$ is applied to pin 2, timer capacitor C is discharged via an internal resistor. Subsequently, the capacitor is recharged via $R_2$. As soon as the potential across C has reach a value of $2V_{CE}$, the bistable is reset to its original state.

The width of the output pulse, $t$, is computed from

$$t = 1.1R_2C.$$

When the RC time has elapsed, the 555 is back in its original state, and the next period may begin.
Circuit description

The circuit of the timer is shown in the diagram of Figure 1. In essence, it is based on the well-known Type NE555 chip. A section of the circuit provides the interface with the mains supply.

Most timers based on an NE555 use an RC network as the timing element. A detailed description of the operation of a monostable timer is given in the box on page 62.

As stated previously, the timer has 12 basic settings separated by a half stop. Switch S1, resistors R7-R12, and capacitors C1-C2 form the timing element. Note that capacitor C1 is the normally capacitance; C2 only comes into operation when switch S2 is closed. The additional capacitance enables the gradation to be refined by an extra quarter of a stop. That is, when S2 is closed, the exposure time is lengthened by a quarter of a stop. Users who see no need for this enhanced resolution may omit S2 and C2. Bear in mind that the basic range of 12 half-stop steps is more than adequate for virtually all applications.

The timer is actuated with switch S3. As soon as this switch is closed, a negative trigger pulse appears at pin 3 of IC1. The design of the input circuit ensures that the time the switch remains pressed does not affect the exposure time.

The output level at pin 3 (Q) goes high at the start of the mono time.

The LED in solid-state relay IC2 is powered via D3 and R11, as a result, the bulb in the magnifier is switched on. At the end of the mono time, the level at pin 3 goes low and the solid-state relay is deenergized. Consequently, the bulb in the magnifier is switched off.

Switch S4 enables the bulb in the magnifier to be switched on and off independently of the timer circuit. When this switch is closed, the bulb is on so that the desired image can be assessed. The enlarger may be focused at the same time. When the switch is opened, the timer resumes control of the bulb in the enlarger.

The enlarger is connected to K2, while the mains supply is linked to K1.

The supply for the timer is perfectly straightforward: diode D1 rectifies the secondary voltage of the transformer and the resulting pulsating voltage is smoothed by capacitor...
The consequent direct voltage is about 8 V.

**DETERMINING THE TIMER STEPS**

The value of the resistors in the timing element is calculated on the basis that the twelve timer steps differ by half a stop. Fortunately, the tolerance of the values is not very important: even when the optional facility of½ stops is used, it may be as high as 19 per cent without affecting the performance. The mono time, \( \tau \), is calculated from

\[ T = 1.1RC \]

so that

\[ R = \frac{T}{1.1C}. \]

Lengthening the exposure time by a ½ stop means that the time constant must be increased by \( \sqrt{2} = 1.414 \). Since the capacitor has a fixed value, all changes are brought about by selecting different value resistors. The resistors are combined into a series network, that is, every time a different resistor is selected, it changes the value of the resistor chain by \( \sqrt{2} \). All resistors are from the E-96 series, not because of their low tolerance, but because the requisite values are best approached in this series. The correlation between the resistors is given in Table 1.

**CONSTRUCTION**

The timer is best built on the printed-circuit board shown in Figure 2. This is a very simple board that should not present any undue difficulties even to beginners in electronic construction. However, it is important to bear in mind that the timer is to be connected to the mains supply; this should be done only when the board is safely fitted in a plastic enclosure.

Rotary switch \( S_1 \) is fitted in the centre of the board. Make sure that its stop is set so that all 12 positions can really be used. If this is not so, the stop should be undone and reset as appropriate.

Switches \( S_2 - S_4 \) are linked to the

---

### Parts list

**Resistors:**
- \( R_1 = 511 \, k\Omega \)
- \( R_2 = 200 \, k\Omega \)
- \( R_3 = 301 \, k\Omega \)
- \( R_4 = 422 \, k\Omega \)
- \( R_5 = 590 \, k\Omega \)
- \( R_6 = 845 \, k\Omega \)
- \( R_7 = 1.18 \, M\Omega \)
- \( R_8 = 1.69 \, M\Omega \)
- \( R_9 = 2.37 \, M\Omega \)
- \( R_{10} = 3.32 \, M\Omega \)
- \( R_{11} = 4.75 \, M\Omega \)
- \( R_{12} = 6.65 \, M\Omega \)
- \( R_{13}, R_{14} = 100 \, k\Omega \)
- \( R_{15} = 300 \, \Omega \)

**Capacitors:**
- \( C_1 = 1 \, \mu F, 65 \, V, \) polystyrene (ma)
- \( C_2, C_3 = 330 \, nF \)
- \( C_4 = 100 \, nF \)
- \( C_5 = 100 \, pF, 25 \, V \)

**Semiconductors:**
- \( D_1 = 1N4002 \)
- \( D_2 = 1N4148 \)

**Integrated circuits:**
- \( I_{C1} = NE555 \) or TLC555
- \( I_{C2} = S202S02 \) or S201SO4

**Miscellaneous:**
- \( K_1, K_2 = 3 \)-way terminal block, pitch 5 mm
- \( S_1 = \) single-pole, 12-position rotary switch
- \( S_2, S_3 = \) change-over switch for board mounting
- \( S_4 = \) press-button switch with make contact
- \( T_r = \) mains transformer, 6 V, 350 mA
- PCB Order no 960086-1
- Enclosure

---

**Figure 2. The printed-circuit board for the dark-room timer.**
board via a number of solder pins that are mounted on the board first.

Mind the polarity of diode D_1 and capacitor C_5.

After the passive components, resistors, capacitors, connectors, and a socket for IC_1 have been put into place, fit IC_1 into its socket.

Next, fit IC_2 and transformer Tr_1 into place. Make sure that the terminals of IC_2 go as far as possible into the holes on the board, this ensures that the pins at which later the mains voltage is present cannot be touched.

Note that there are two versions of IC_2: the S201S02 and the S201S04. Only if the first is used, is series resistor R_15 required. The optoisolator in the second version has this resistor already on board. In this case, R_15 must be replaced by a wire bridge.

Finally

When the board has been completed, it should be tested. Since mains voltage will be present at several locations, it is absolutely essential that the board is fitted securely in a plastic enclosure.

Link the mains to K_1 via an appropriate length of mains cable, but do not switch the mains on yet. At the same time, connect a similar length of cable, terminated into an in-line socket, to K_2. Connect, say, a table lamp or similar to the in-line socket. A completed board is shown in Figure 3. Set S_1 to an exposure time of, say, 2 seconds.

Switch on the mains and check (with a stop watch, if possible; otherwise with a good standard watch) that the table lamp can be switched on for 2 seconds with S_2. Check all other settings one by one in a similar manner.

In the unlikely case that the circuit does not work properly, the cause for this can normally be found quite quickly with a multimeter.

First, make sure that a direct voltage of 8-10 V is present across C_5, and between pins 1 and 8 of IC_1. If this voltage is not present, the mains cable is faulty, the transformer does not work, or diode D_1 is faulty.

If the voltage across C_5 is correct, close S_4. If the table lamp does not come on, R_15 or IC_2 is faulty.

If the lamp does light, check the timer circuit thoroughly. When S_3 is pressed, the level at pin 3 of IC_1 must be high for the time set. If this is so, and the table lamp still does not light, check diode D_2. If, however, the level at pin 3 does not go high, and the level at pin 2 of the IC is high in the quiescent state, it is almost certain that IC_1 is faulty and should be replaced.

When all is in working order, close the case. It is advisable to provide S_1 with a suitable scale such as, for instance, shown in Figure 5.

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test charts on the Internet

The publication of an advanced Video Test Chart Generator in this issue prompted us to search the Internet for test charts for TVs and computer monitors. Lo and behold, quite a few of these are easily found among the millions of web pages which are currently available on the net. Such test charts are ideal for adjusting and repairing computer monitors. By chance, we hit upon a virtual museum which shows a permanent collection of test charts from TV stations all over the world.

Although most of you will be totally aware of the fact that GIFF and TIFF pictures can not fully replace a real test chart, they are still useful for adjusting a computer monitor. One of the nicest programs around for testing your monitor is called MONTBTEXE from Nokia (file size: 1.2 MB). It may be found on the Nokia Internet web site at www.nokia.com/products/monitors/monitor_test.html. The program may be downloaded from that page. The test program runs exclusively under Windows, and provides a number of useful (and accurate) test charts which enable virtually all relevant monitor settings to be checked.

Those of you who are looking for more generally applicable test charts should have a go at Chris’ video test patterns page (address: www2.dgsys.com/~chillt/video). Chris has about ten test charts available in two resolutions: 640 x 480 pixels and 1024 x 768 pixels. On this page you find colour bars to the EIS and SMPTE standards, a number of screens, and an NTSC test chart. Any picture may be downloaded individually at the desired resolution.

Another address that provides you with free test patterns is the ‘Video Test Imagery’ from Charles Henrich at the Michigan State University. The address is: wxweb.msu.edu/~henrich/video. Charles has taken the trouble of composing three digital test charts which every web user is free to download from his site.

We close off this month’s Electronics On-line page by pointing the way to a very special address: the TV Test Chart Museum. The address, www.ping.at/users/stay-tuned/program.html takes you to the ‘Stay Tuned’ page which offers a number of test options ranging from sounds to short films. One of these, at the left-hand side of the page, leads you to the ‘testbild museum’ (test chart museum), a cluster of four virtual rooms (rooms 1, 2, 3 and 4) in which tens of test charts are on display from TV stations all over the world. Full-screen versions of most of these test charts are available. Looking around in these ‘rooms’ is certainly worthwhile.
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PIC POCKET New Product £89.95
The ultimate in convenient home D2MAC programming! This tiny unit can read, write and DEPROTECT 1,2,3 chip D2MAC + wafer cards. It is completely stand-alone - NO computer or PSU is needed. Power comes from a 9V battery. 16 predefined programs are built into the processor on board - simply select one with the switch and the unit is ready to go. The PICPOCKET contains memory for 2, 4, 8, 16, and 32 pin D2MACs.

PAC PROGRAMMER £69.95
Programs PIC16C54-55-56-57-58-582-61-64-65-71-75-84-620-621-622 and Memory Chips, 24LC01-02-16-32-65. Plugs into Centronics cable, works on IBM PCs and laptops. Requires 13-18V AC or DC supply. Supplied with powerful assembler/editor/software, sample files and other information. Code can be downloaded in Microchip, Intel Hex, or binary format. Comes with full instructions.

PIC ICE II In Circuit Emulator £99.95
Essential for the serious PIC developer! Emulates PICs 54/5/6/7/71/84 - on board A/D for PIC71. Powerful software includes Editor, Assembler, Emulator. For IBM PC, runs from Centronics cable. Single step through code, go with/without breakpoints. Change any register at any time. Now you can debug code before committing to a PIC. Save days - even weeks of development time with the lowest cost ICE on the market.

SERIAL EEPROMER £49.95
Serial EEPROM programmer plugs straight into IBM Centronics port. Programs 93xx and 24LCxx EEPROMS. These types are used in expensive cars and related equipment - dashboards, electronic milemeters, radios etc. Full editor software suitable for all IBM PCs and laptops. Fully cased.
The CXA1645P/M is an encoder IC that converts analogue RGB signals into a composite video signal. This IC has various pulse generators necessary for encoding. Composite video and Y/C outputs for the S terminal are obtained just by inputting composite sync, subcarrier and analogue RGB signals. It is best suited to image processing of personal computers and video games.

**Applications**

- Image processing of video games and personal computers.

**Application Example**

- Video Test Chart Generator, Elektor Electronics September and October 1995.

**Features**

- Single 5V power supply
- Compatible with both NTSC and PAL systems

**Absolute Maximum Ratings**

- Supply voltage, $V_{CC}$: 14V
- Operating temperature, $T_{OP}$: -20 to +75°C
- Storage temperature, $T_{STG}$: -65 to +150°C
- Allowable power dissipation, $P_{D}$: CXA1645P 1250mW, CXA1645M 700mW

**Recommended Operating Condition**

- Supply Voltage, $V_{CC}$: 5.0 ±0.25V

**Packages**

- CXA1645P: 24-pin DIP (plastic), 400 mil, 2.0g
- CXA1645M: 24-pin SOP (plastic), 300 mil, 0.3g

**Pin Descriptions**

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>Pin Voltage</th>
<th>Description, notes(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND1</td>
<td>0V</td>
<td>Ground for all circuits other than RGB, composite video and Y/C output circuits. The leads to GND1 should be as short and wide as possible.</td>
</tr>
<tr>
<td>2</td>
<td>PIN</td>
<td>Black level when clamped 2.0V</td>
<td>Analogue RGB input signals, input 100% = 1Vp-p (max.). To minimize clamp error, input as low impedance as possible.</td>
</tr>
<tr>
<td>3</td>
<td>GND2</td>
<td>0V</td>
<td>Ground for all circuits other than RGB, composite video and Y/C output circuits. The leads to GND2 should be as short and wide as possible.</td>
</tr>
<tr>
<td>4</td>
<td>BIN</td>
<td>1.7V</td>
<td>Pin for switching between NTSC and PAL modes. NTSC: Vcc; PAL: GND</td>
</tr>
<tr>
<td>5</td>
<td>NC</td>
<td>2.0V</td>
<td>No connection</td>
</tr>
<tr>
<td>6</td>
<td>SCIN</td>
<td>2.0V</td>
<td>Subcarrier input. Refer to Notes 3 and 5</td>
</tr>
<tr>
<td>7</td>
<td>NPN1</td>
<td>3.3V</td>
<td>Pin for reducing cross colour caused by the subcarrier frequency component in the Y signal. When the CVOUT pin is in use, connect a capacitor or an inductor in series between CVOUT and GND. Decide capacitance and inductance, giving consideration to cross colour and the required resolution. No influence on YOUT pin. Input resistance approx. 1.5kΩ. Refers to Notes 6 and 7.</td>
</tr>
<tr>
<td>8</td>
<td>IFOUT</td>
<td>2.0V</td>
<td>Y signal output. Capable of driving a 75Ω load. Refer to Notes 6 and 9.</td>
</tr>
<tr>
<td>9</td>
<td>YCLPC</td>
<td>2.0V</td>
<td>Pin to determine the Y signal clamp timing constant. Connect to GND via 0.1 µF capacitor.</td>
</tr>
<tr>
<td>10</td>
<td>SYNC IN</td>
<td>2.0V</td>
<td>Power supply for all circuits other than RGB, composite video and Y/C output circuits. Refer to Notes 4 and 10.</td>
</tr>
<tr>
<td>11</td>
<td>VREF</td>
<td>3.3V</td>
<td>Internal reference voltage. Connect a decoupling capacitor of approx. 10µF. Refer to Notes 4 and 7.</td>
</tr>
<tr>
<td>12</td>
<td>VCC1</td>
<td>3.3V</td>
<td>Internal reference voltage. Connect a decoupling capacitor of approx. 10µF. Refer to Notes 4 and 7.</td>
</tr>
<tr>
<td>13</td>
<td>YOUT</td>
<td>2.0V</td>
<td>Y signal output. Capable of driving a 75Ω load. Refer to Notes 6 and 9.</td>
</tr>
<tr>
<td>14</td>
<td>VCC2</td>
<td>3.3V</td>
<td>Power supply for RGB, composite video and Y/C output circuits. Refer to Notes 4 and 9.</td>
</tr>
<tr>
<td>15</td>
<td>CVOUT</td>
<td>2.0V</td>
<td>Composite video signal output. Capable of driving a 75Ω load. Refer to Notes 6 and 9.</td>
</tr>
<tr>
<td>16</td>
<td>BOUT</td>
<td>2.0V</td>
<td>Analogous RGB signal outputs. Capable of driving a 75Ω load. Refer to Notes 6 and 9.</td>
</tr>
<tr>
<td>17</td>
<td>YTRAP</td>
<td>2.0V</td>
<td>Ground for RGB, composite video and Y/C output circuits. The leads to GND1 should be as short and wide as possible.</td>
</tr>
</tbody>
</table>
**Electrical Characteristics**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>M</th>
<th>A</th>
<th>A</th>
<th>S</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vcc1</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
</tr>
<tr>
<td>Vcc2</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
</tr>
<tr>
<td>Vref</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
</tr>
<tr>
<td>Vrel</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
<td>0V</td>
</tr>
</tbody>
</table>

**Application Circuit (PAL mode)**

- **Clamp voltage**: voltage appearing at pin 9 when CSYNC is Input.
- **PAL burst phase**: 0.5Vpp to 1V.
- **PAL burst level ratio**: 1.1 to 0.9.
- **Carrier leak**: 20k.
- **SG3**: SIN wave, 3.58 MHz, 0.5Vpp to 1.0Vpp, 1-200 MHz.
- **SG4**: SIN wave, 3.58 MHz, 0.5Vpp to 1.0Vpp, 1-200 MHz.
- **SG1 to S03**: Nu sepia, 8/16:1.
- **CSYNC, TTL level**: 2.5V to 125V.
- **Vcc1, Ind, Vrel to ON01**: Vcc2 to OND2.
- **Each decoupling capacitor must be a wide frequency band type such as tantalum or ceramic. Each capacitor must be connect-
- **3. Pin 6 (SC input) accepts both sine wave and pulse which must be 0.4-0.5Vpp. However in some cases pulse Input may cause
- **4.1 PAL applications, extreme care is required for board layout, particularly around the GNI), Vol. tied, Ire! and Vrel areas.**
- **5. Additional R -C low-pass networks are required at the SC Input and CSYNC Input, as follows. SC: 2.2kΩ series R, 5pF C to
- **6.1 To prevent spurious oscillations, external series R -C networks should be connected to pins 15 and 16 as shown in the 603:
- **7. In 503: CSYNC: 2.2kΩ series R, 47pF C to ground, CSYNC: 2,2kΩ series R, 47pF C to ground, CSYNC: 2,2kΩ series R, 47pF C to
- **8. Pin 17 (YTRAP). II colour Is blurred, the chrome component, leaks Into the luminance signal, Connect an L -C trap tuned to the
- **9. Pin 19, Keep distance between pin 19 and capacitor to GND as short as possible.**
- **10/96**

**Integrated Circuits**

- **CX41645P/M**
- **Notes (English amended by Elukter)**

**Measurement conditions**

- **Ta = 25°C, VOC = 5V**
- **Input analogue ROB signal: 1.0Vpp. ROB Inputs must be driven by low impedance sources (approx. 200-300Ω). High Imp&
- **Current consumption 2Icet**
- **Current consumption 1Icet**
- **1. This IC Is designed for video signal processing in TV game anti home computers. If other applications are Intended, please
Embedded Control Computer Programs In-Target

Engineers can develop C-language programs on Z-World’s new Micro-G2TM ($119) embedded-control computer right in their target system without the aid of expensive and troublesome in-circuit emulators or logic analyzers. This small but powerful embedded computer measures only 3.2x2.3x0.5 in. (81x58x12 mm) yet its basic version provides 26 digital I/O channels, both RS-232 and RS-485 networking, as well as connections for an external backup battery.

✓ Programs in-circuit without in-circuit emulators or logic analyzers.
✓ 26 standard digital I/O channels.
✓ 4 optional analog-input channels.

Other single-board computers (SBCs) in the Micro-G2’s class execute slow, interpreted languages such as BASIC or FORTH. The Micro-G2 executes fast, compiled C programs. The single-chip microcontrollers of other SBCs can handle only very small programs. The Micro-G2 can accommodate real-time, multitasking programs having as many as 20,000 lines of C. The Micro-G2’s Z180 microprocessor (an enhanced Z80) runs at 9.216 MHz and can address as much as 1 MByte. Depending on options, data-memory capacity ranges from 32 kByte to 512 kByte of battery-backed SRAM. Either UV-erasable EPROM (32 kByte to 512 kByte) or flash EPROM (128 kByte to 256 kByte) is available for program storage. Optionally, a 12-bit A/D converter provides four 0-2.5 V analog-input channels, two having signal conditioning. A real-time-clock IC is also available. A standard on-board 5 V regulator accepts 9-12 V DC and the board draws 80 mA. For developing software, an interface cable connects the Micro-G2 to the serial port of a host PC running Z-World’s Dynamic C (tm). Dynamic C integrates an editor, compiler, and symbolic debugger. Other SBCs require engineers to integrate a hodgepodge of third-party tools. Dynamic C comes with two real-time multitasking facilities, hardware drivers, numerous function libraries, and sample programs, all in source code. Available for MS Windows and DOS, Dynamic C costs $195. Micro-G2 version A (32-kbyte SRAM. power-supervisor IC, RS232/485, digital I/O, on-board regulator) $119; Micro-G2 version B (adds 4-channel, 12-bit A/D converter) $159; Micro-G2 version C (adds real-time-clock IC, 128-kbyte SRAM) $199.

For additional information, or a free demo disk, contact ZWorld Engineering, 1724 Picasso Ave, Davis, CA 95616-0547, USA. Tel. (916) 757-3737. Fax (916) 753-5141. WWW: http://www.zworld.com/.

New Compact EMC Tester

The BEST96 from Schaffner is an entire EMC test system in a single, compact package. It is the first complete, self-contained solution to combine all the functions required for full EU compliance testing of residential, commercial and light-industrial electrical and electronic products. For the first time, manufacturers who need to CE mark their products can complete the entire pre-compliance and compliance test procedures in-house is easily, quickly, cheaply and reliably. Priced to fit the budget of small manufacturing companies, BEST96 cost around half as much as traditional test solutions. Schaffner EMC Ltd., Ashville Way, Molly Millar’s Lane, Wokingham RG41 2PL. Tel. (0118) 9770070, fax (0118) 9792969.

ICEPIC In-circuit PIC Emulator

New from Microchip is ICEPIC, a powerful low-cost development tool for the popular 8-bit PIC16C5x and 16Cx microcontrollers. Running under Microsoft Windows 3.1, ICEPIC provides complete source-level debugging in assembly or C languages. ICEPIC includes an easy-to-use toolbar, an unlimited number of breakpoints, single, multiple and procedure step, the ability to display and modify any register, user selectable processor speeds via an oscillator modulator, full context-sensitive help and an RS232 serial port. ICEPIC runs seamlessly with MPASM and Microchip’s MP-C Compiler. Arizona Microchip Technology Ltd., Unit 6, The Courtyard, Meadowbank, Furlong Road, Bourne End, Bucks SL8 5AD. Tel. (01628) 851077, fax (01628) 850259.
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LIMITED QUANTITY only of these 123Mb Hi GRADE 286 systems. Made to order & packed by us in the UK. Ideal for home or office. Designed for solid reliability. The complete case houses the mo- therboard, dual floppy drives plus 5.25" cartridge drive & Integral 40Gb hard disk drive to the front. Real time clock with stopwatch facility. Fully expandable with upgraded BIOS, 64k on board RAM, 2Mb of RAM upgradable, 16Mb of video RAM, and expandable hard disk. Order as HIGRADE 286 ONLY £129.00.
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Massive increase of products and 3" disk drives enables us to present prime product at amazing low prices! All units (unless stated) are IBM-PC compatible (3" supported) on your PC. ACPI IBM-PC compatible, 5.25" drive floppy, mini-SDRAM's, SmartDrive, 10Mb hard disks.

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32U - High Quality - All steel RackCab Made by Eurocast Enclosures Ltd to the highest possible spec, rack features all steel construction with high class fan mounts. Over 900 fans keeps the unit cool for easy access and all lockable for security. Only a few left! This 32 unit is constructed of double walled steel with a thick back plate. The unit is air tight and is fitted with many useful status indicators to be seen through the front door. Order as: E34 ATC £255.00 (E) + vat. A selection of features fully stocked reinforced vertical fixing members to take the heaviest of 19" rack equipment. The complete rack in one piece with a base, £255.00 + vat. Mounted to your bottom rail, provides 9 x E3 3U 6 u-sizes slots and 9 x E2 1U 3 u-sizes slots and an E1 4 u-sizes slot. £255.00 (E)

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A superb buy at only £195.00 (E)

Over 1000 racks 19" 22" & 24" wide 3 to 44 U high. Available from stock!!

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TOUCH SCREEN SYSTEM
The ultimate in 'Touch Screen Technology' made by the experts - MicrTouch - but sold at a price below cost. It Systems consists of a microcomputer card that plugs into a normal video card slot. When connected to an electronic controller: PCB, the controler produces a full colour video display directly from the I/O TF output which contains a full screen data set for the particular application. The unit is mounted on a touch-sensitive surface (e.g. a single sheet of glass or acrylic), allowing the user to interact with the system using simple gestural manipulation. The system is designed to respond to a single touch at a time, and can be used to control a wide range of applications, from simple data entry to complex graphical interfaces. The system is incredibly durable and can be used in a variety of environments, including industrial and commercial settings.

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MICROTOUCH TOUCH SCREEN SYSTEM
The ultimate in 'Touch Screen Technology' made by the experts - MicrTouch - but sold at a price below cost. It Systems consists of a microcomputer card that plugs into a normal video card slot. When connected to an electronic controller: PCB, the controler produces a full colour video display directly from the I/O TF output which contains a full screen data set for the particular application. The system is designed to respond to a single touch at a time, and can be used to control a wide range of applications, from simple data entry to complex graphical interfaces. The system is incredibly durable and can be used in a variety of environments, including industrial and commercial settings.

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Multi-purpose Pascal I/O unit

It's definitely rare for a PC not to have I/O ports, serial or parallel. As far as hardware is concerned, these ports are directly accessible for many control purposes. The relevant software, however, is often difficult to find. The multi-purpose I/O unit presented in this article is written in the Pascal programming language. It contains three functions and two procedures which may be used to run I/O activities using the existing serial and parallel ports.

The Pascal I/O unit described in this article may be found on a diskette with order code 966013-1 which is supplied through our Readers Services. The software may be used in combination with a Turbo Pascal compiler. Apart from the complete source code with associated comment, the disk also contains a compact test program for the I/O unit. The three functions and two procedures which make up the software allow your computer to measure frequencies, read or write hit combinations, and generate a pulse-shaped output signal. The aim of it all is to encourage programmers to use this library of functions and procedures in their own software.

The I/O ports which are supported by the software include COM1 through COM4, and printer ports LPT1, LPT2 and LPT4 (the latter may be available on a Hercules card). Any of these may be selected, if physically available, of course. Finally, it is often possible to specify a certain pin (or 'line') on a port when a function or procedure is called.

The use of this software is straightforward. The available functions and procedures are briefly described below.

**FUNCTION Frequency (I0Port, Channel)**
This function returns the frequency measured at a pin (channel) of the selected I/O port. The inset box in this article tells you which number has to be entered for 'Channel' to select a particular port pin. The highest frequency that can be read by this function is dependent on the computer you are using. In general, frequencies up to 10 kHz should not cause problems.

**FUNCTION Inport (I0Port, Channel)**
This function returns the logic level at the selected I/O line. A logic high level is indicated by True, a logic low level, by False.

**PROCEDURE Impulse (I0Port, Channel, ImpCount, ImpTimeH, ImpTimeL)**
This generates a pulse signal consisting of ImpCount pulses at the selected pin (Channel) on the selected I/O port (I0Port). The pulses have a length which equals (ImpTimeH+ImpTimeL)*2 centiseconds. ImpTimeH determines the high time of the pulse, ImpTimeL, the low time. In both cases, the unit which is used to count is 0.5 centisecond (5 ms).

**PROCEDURE Outport (I0Port, Channel, Level)**
This procedure may be used to control the level of a selected output line. The variable 'Level' may be False to define a logic low level, or True to set a logic high level.

**FUNCTION Convert (RNumber, Array)**
This converts a quantity with the aid of an array. Although not an I/O function, this little 'extra' may prove very useful when measured values have to be converted to an analogue scale, for example, the conversion of the digital values produced by an A/D converter into a centigrade temperature scale.

The demonstration program on the disk, Turbo.pas, provides a clear and structured guide to implementing the functions and routines into your own programs. Having studied the operation of this simple demo program, the software should not have secrets any more.

---

Supported I/O line:

<table>
<thead>
<tr>
<th>Parallel ports</th>
<th>Serial ports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>function</td>
</tr>
<tr>
<td>D0*</td>
<td>read/write</td>
</tr>
<tr>
<td>D1*</td>
<td>read/write</td>
</tr>
<tr>
<td>D2*</td>
<td>read/write</td>
</tr>
<tr>
<td>D3*</td>
<td>read/write</td>
</tr>
<tr>
<td>D4*</td>
<td>read/write</td>
</tr>
<tr>
<td>D5*</td>
<td>read/write</td>
</tr>
<tr>
<td>D6*</td>
<td>read/write</td>
</tr>
<tr>
<td>D7*</td>
<td>read/write</td>
</tr>
<tr>
<td>Strobe</td>
<td>read/write</td>
</tr>
<tr>
<td>AutoFeed</td>
<td>read/write</td>
</tr>
<tr>
<td>init</td>
<td>read/write</td>
</tr>
<tr>
<td>SLKT IN</td>
<td>read/write</td>
</tr>
<tr>
<td>Error</td>
<td>read</td>
</tr>
<tr>
<td>Select</td>
<td>read</td>
</tr>
<tr>
<td>PE</td>
<td>read</td>
</tr>
<tr>
<td>Ack</td>
<td>read</td>
</tr>
<tr>
<td>Busy</td>
<td>read</td>
</tr>
</tbody>
</table>

*not suitable for frequency measurements*
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