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9. Real time clock version available
10. PC host software communicates via serial port

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5. Upload/download INTEL hex files
6. Assign memory and SFR's
7. Break points
8. PC driver available
9. PC host software communicates via serial port

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OTHER PRODUCTS  
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1. 8051 BOOK - The 8051 Architecture, Programming and Applications (£49.95).
   - This book includes a free assembler and simulator for personal or educational use.
2. PEB552 - The Philips evaluation board for the 80C552 processor variant, a monitor and programming adapter are available for this product.
3. MACH I - An RTX2000/1 PC based evaluation board.
4. ICC2000 - An 8 channel 10MTPS PC based intelligent communications card using the RTX2001 processor.
5. FORTH ++ - A low cost RTX2000/1 compiler.
### CONTENTS

In next month’s issue (among others):
- More than 50 construction projects
- RS232 tester
- 23 cm transceiver
- DC-to-AC inverter
- Audio DAC
- Fuzzy logic
- Mark 2 QTC 8040 loop
- Dealing with noise and interference
- Opto-card for multi-purpose bus

It is regretted that, owing to circumstances beyond our control, this article had to be postponed to the July issue.

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**AUDIO & HI-FI**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Audio-video processor – Part 2</td>
<td>an ELV design</td>
</tr>
</tbody>
</table>

**COMPONENTS**

<table>
<thead>
<tr>
<th>Page</th>
<th>Elements of passive electronic components – Part 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>56</td>
<td>by Steve Knight, B.Sc.</td>
</tr>
</tbody>
</table>

**COMPUTERS & MICROPROCESSORS**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>4 Megabyte printer buffer</td>
<td>Design by R. Degen</td>
</tr>
<tr>
<td>41</td>
<td>Multi-purpose Z80 card – Part 2</td>
<td>Design by A. Rietjens</td>
</tr>
<tr>
<td>50</td>
<td>8051/8032 assembler – Part 4</td>
<td>Design by M. Ohsmann</td>
</tr>
</tbody>
</table>

**DESIGN IDEAS**

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Plant warmer</td>
</tr>
<tr>
<td></td>
<td>By Samuel Dick</td>
</tr>
</tbody>
</table>

**ELECTROPHONICS**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Guitar tuner</td>
<td>Design by W. Herrmann</td>
</tr>
</tbody>
</table>

**GENERAL INTEREST**

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>Analyser III: a review</td>
</tr>
<tr>
<td></td>
<td>by Mike Wooding, G6IQM</td>
</tr>
</tbody>
</table>

**POWER SUPPLIES & BATTERY CHARGERS**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>MAX660 inverter/doubler</td>
<td>Design by J. Ruiters</td>
</tr>
</tbody>
</table>

**RADIO, TELEVISION & COMMUNICATIONS**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Audio-video processor – Part 2</td>
<td>an ELV design</td>
</tr>
<tr>
<td>27</td>
<td>FM tuner – Part 4</td>
<td>Design by H. Reelsen</td>
</tr>
<tr>
<td>62</td>
<td>Cellphones explained</td>
<td>by Bill Higgins</td>
</tr>
</tbody>
</table>

**SCIENCE & TECHNOLOGY**

<table>
<thead>
<tr>
<th>Page</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>Medical laser technology</td>
</tr>
<tr>
<td></td>
<td>by Douglas Clarkson</td>
</tr>
</tbody>
</table>

**TEST & MEASUREMENT**

<table>
<thead>
<tr>
<th>Page</th>
<th>PROJECT</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>PC LED display</td>
<td>Design by J. Ruffell</td>
</tr>
</tbody>
</table>

**MISCELLANEOUS INFORMATION**

- Electronics scene 11–13: Events 13: Readers’ corner 64; Letters 64: Switchboard 65; Product Overview 66; Readers’ services 68; Terms of Business 70; Index of advertisers 74
**Take the Sensible Route!**

**BoardMaker** is a powerful software tool which provides a convenient and fast method of designing printed circuit boards. Engineers worldwide have discovered that it provides an unparalleled price performance advantage over other PC-based and dedicated design systems by integrating sophisticated graphical editors and CAM outputs at an affordable price.

**NEW VERSION**

In the new version V2.40, full consideration has been given to allow designers to continue using their existing schematic capture package as a front end to BoardMaker. Even powerful facilities such as Top Down Modification, Component renumber and Back Annotation have been accommodated to provide overall design integrity between your schematic package and BoardMaker. Equally, powerful features are included to ensure that users who do not have schematic capture software can still take full advantage of BoardMaker's net capabilities.

**BoardMaker V2.40 is a remarkable £295.00 (ex. carriage & VAT) and includes 3 months FREE software updates and full telephone technical support.**

**AUTOROUTER**

BoardRouter is a new integrated gridless autoroute module which overcomes the limitations normally associated with autorouting. YOU specify the track width, via size and design rules for individual nets, BoardRouter then routes the board based on these settings in the same way you would route it yourself manually.

This ability allows you to autoroute mixed technology designs (SMD, analogue, digital, power switching etc)in ONE PASS while respecting ALL design rules.

**GRIDLESS ROUTING**

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**FULLY RE-ENTRANT**

You can freely pre-route any tracks manually using BoardMaker prior to autorouting. Whilst autorouting you can pan and zoom to inspect the routes placed, interrupt it, manually modify the layout and resume autorouting.

**BoardRouter is priced at £295.00, which includes 3 months FREE software updates and full telephone technical support. BoardMaker and BoardRouter can be bought together for only £495.00. (ex. carriage & VAT)**

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Don't just take our word for it. Call us today for a FREE Evaluation Pack and judge for yourself.
HELMET-HUNG SYSTEM WILL HELP DANISH RESCUE Missions

Heliocopter pilots on rescue missions in Danish waters will soon be guided by a British electronic mapping system that gives instant indication of the aircraft's position.

The new system, developed by GEC Ferranti, replaces roller map navigation display systems and overlays the helicopter's position on an electronic map. Area search patterns, obstacles, and other relevant information can be instantly recalled from a computer data base and overlaid on the map.

Survivor, wreckage positions and surveillance points can be entered into the system by any crew member and then called up by the pilot to easily relocate the point of sighting. The new system can also present the pilot with homing and glidepath steering information.

GEC Ferranti Defence Systems Ltd, Ferry Road, Edinburgh, Scotland EH5 2XS.

TAPE RECORDING PROBLEM FOR VISUALLY IMPAIRED SOLVED

A device to help blind and visually impaired people make good quality tape recordings has won its inventor an award in a UK national engineering design competition.

With most recording systems, recording levels are marked by a moving needle or a digital display. If the volume of the material being recorded is too high for the sort of tape that is being used—some tapes can take a higher recording level than others—the needle jumps into the red zone and adjustment to the volume is necessary.

Visually impaired people need to make use of audio material and be able to record such material, but they have no way of knowing when recording thresholds are being exceeded. This results in a loss of independence because they must get a sighted person to make the recording. If the volume of sound pending on the type of tape being used to low-speakers. A knob on the box allows the system to be adjusted manually depending on the type of tape being used to make the recording. If the volume of sound from the source exceeds the level preser on the box, a loud "squawk" is emitted, alerting the user to the maladjustment.

Mr Nicholas Malyon, Electronics Dept., University of York, York, England Y01 5DD.

ERROR CORRECTOR FOR MODEMS

A technique for correcting data transmitted between multi-standard modems in adverse conditions has been developed by GPT Data Systems.

The technique, called Sequence Estimation, is a digital signal processing technique for providing forward error correction—a way of avoiding errors by adding redundant bits to transmitted data. It does not compromise compatibility and provides improvements even when working with dissimilar modems.

GPT Sequence Estimation modems are already in use by the Greater Manchester Police force, where they serve remote traffic monitoring stations over notoriously poor-quality dial-up conditions. The force's modems are subject to close-range interference from VHF mobile radio transmission, but still provide solid, reliable connections unlike other modems tried.

The modem is also being used by the British Antarctic Survey to satellite links between the Antarctic and the UK that modems without Sequence Estimation found difficult to handle.

The GPT 3220 modem conforms with the

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Plessey Telecommunications Ltd. P.O. Box 53, Coventry, England CV3 1HH.

BUOYANT FUTURE FOR CELLULAR COMMUNICATIONS

According to a Frost & Sullivan report*, only a severe worsening of the European recession could dent the rapid growth expected for cellular telecommunications equipment and services. It is set to be one of the fastest-growing telecommunications markets up to the end of the century.

Cellular communications is a terrestrial switched radio-frequency mobile voice and non-voice service that provides a two-way link with the public switched telephone network—PSTN.

The number of cellular subscribers in Europe at the end of 1991 was 4.52 million and the report forecasts that by 1996 this will have topped 10 million. Fastest growth last year was in Italy as the new TACS analogue network was installed, making it the fourth largest market in Europe, behind the UK, Germany and Sweden.

Cellular communications continues to be one of the fastest moving of all telecommunications markets, not only in terms of subscriber numbers and service revenue growth, but also in the pace of liberalization, advances in the technological base and the development of distribution systems. Its long-term competitive battle will not be with analogue cellular markets, but with other mobile technologies, such as digital European cordless telephony (DECT), public access mobile radio (PAMR) and personal communications networks (PCN).


EUTELSAT AND ASTRA:
PEACEFUL COEXISTENCE

EUTELSAT and Société européenne des Satellites (SES) met recently at the ITU in Geneva to discuss the issue of potential interference between EUTELSAT satellites at 16° E and 21.5° E and Astra 1B at 19.2° E.

The two satellite operators were invited to Geneva by the International Frequency Registration Board (IFRB), the ITU body that deals with registering frequencies and use of positions in geostationary orbit.

Both operators have agreed to conduct together a series of tests on the real impact of transmission from EUTELSAT II-F3 at 16° E and EUTELSAT I-F5 at 21.5° E on Astra 1B reception via 60 cm antennas. EUTELSAT hopes that these tests will bring to a close recent debate on the issue of mutual harmful interference between the three

*The European Market for Cellular Communications Services and Terminals—Report E1586

ELEKTOR ELECTRONICS JUNE 1992
According to initial tests already conducted by EUTELSAT in France, Germany, Switzerland and the UK, as well as by a number of TVRO manufacturers, transmissions from its satellites are not causing any noticeable interference to Astra 1B reception via 60 cm antennas, provided these are pointed with reasonable accuracy.

Nevertheless, because of their narrower beamwidth, 80 cm antennas obviously enable more accurate pointing and thereby provide greater protection against interference from a neighbouring satellite, in addition to guaranteeing better quality. Moreover, 80 cm antennas will enable viewers to benefit fully from enhanced television reception offered by 16:9 aspect ratio TV.

European Telecommunications Satellite Organization, Tour Muine-Montparnasse, 33, avenue du Maine, 75755 Paris Cedex 15, France.

NEW FROM MAPLIN

Maplin Electronics, one of Europe’s major component suppliers, has introduced a number of new ideas and projects.

There is ‘Funtronics’, a series of easy-to-build electronics projects for complete beginners who require a simple and fun starter to electronics project building. Projects include a transistor tester, a water indicator (for thirsty plants) and a bulb and fuse tester.

A new, high-quality, low-priced 40 MHz delayed sweep oscilloscope Type 7046. This offers increased magnification, while its bandwidth enables it to display complex signals with precision and accuracy.

A tiny CCD video camera capable of producing a black-and-white picture from normal as well as infra-red illumination. Good resolution is achieved by the 8 mm (1/3 in) CCD element that has 80 000 pixels. The support circuitry ensures a video bandwidth of around 4 MHz.

A portable, pocket-sized test set that provides access to all 25 conductors of the RS232/V-24 interface between the data terminal and the data modem.

Further information from Claude Salmon at CNES, Telephone +33 61 27 34 72.

The Small Satellites Systems and Services Exhibition and Conference will be held at the National Exhibition Centre, Birmingham from 23 to 25 June.

Further information from Lynne Davey at Blenheim Online on Telephone 081 742 2828 or from Lynne Davey at Maplin Electronics, P.O. Box 3, Rayleigh, England SS6 8L.R.

SPECTRUM ANALYSER ADAPTOR FROM BK ELECTRONICS

The TSA250 adapts a low-cost oscilloscope into a cost-effective 250 MHz spectrum analyser. It will be particularly attractive to users who are involved with EMC investigation and education, as well as in traditional spectrum analysis applications. Priced at £345.00 plus VAT, the adaptor is available from B.K. Electronics, Units 1 & 5, Comet Way, Southend-on-Sea SS2 6TR, England.

Further information from Spearhead Exhibition, Rowe House, S5/59 Fife Road, Kingston upon Thames KT1 1TA: Telephone 081 549 5831; Fax 081 541 5637/5016.

EUROPEAN SEMICONDUCTOR

The European Semiconductor Exhibition and Conference will be held in Dublin on 3-5 June. Further information from Datask at (0893) 835 050.

SMALL SATELLITES

The Small Satellites Systems and Services Exhibition and Conference will be held at Cannes, France, from 29 June till 2 July. Further in formation from Claude Salmon at CNES, Telephone +33 61 27 34 72.
Our earlier publications on I²C-compatible circuits having met with a great deal of interest, we now move on to a four-digit seven-segment LED display unit that can be used in many applications as a bright and easy to drive readout.

**Design by J. Ruffell**

So far it has appeared a matter of course that the readout function in a computerized measurement system is invariably provided by the screen of the PC. The present 4-digit LED display unit may, however, prove an attractive alternative in many cases. It allows a PC fitted with an I'C controller card (Ref. 1), or any other I'C controller, to indicate, for instance, measured data in bright green, red or yellow numbers on an LED display. In other words, it is no longer necessary to reserve a part of the PC's screen for displaying measured values. This means that the PC can continue to run its main program, while a background program takes care of outputting measurement data to the LED display at regular intervals.

Another possibility is to use the display as a time and/or date indication. In a PC, the parameters needed for this application are easily copied from the system software or the PC's internal real-time clock. Another possible application that comes to mind is to use the display to bring to your attention the status of a certain measurement program that runs in the background.

The present display is, of course, software-compatible with the I'C device driver published earlier (Ref. 2), and its control is, therefore, 'food for programmers'. Those of you who work with microcontrollers will also find that the I'C display unit is readily used and fairly simple to control. Today, an increasing number of microcontrollers is available with an on-chip I'C interface, which makes connecting the present display unit a piece of cake.

The circuit shown in Fig. 1 is best described with three words: compact, simple and inexpensive. Apart from one IC, two transistors and, of course, four 7-segment LED displays, only a handful of passive parts is required to complete the circuit. As with the other circuits in our I'C series, the communication with the outside world is via two miniature 6-way DIN sockets. A length of 6-way cable is all that is required to convey the two serial signals, ground, the supply voltage and an interrupt signal (the +5 V supply voltage is carried via two wires).

The heart of the circuit is formed by a four-digit I'C-compatible LED driver Type SAA1064 from Philips Components. This IC is manufactured in 11 technology, and is capable of driving four 7-segment LED displays including decimal points as four multiplexed blocks. The block diagram of the SAA1064 (Fig. 2) shows that the IC contains an I'C transceiver that can be located at any of four I'C bus addresses, a power-reset flag, 16 outputs that operate under software control (each capable of sinking up to 21 mA), two multiplexed outputs, and oscillator, a bit that selects between static and dynamic mode, and, finally, a bit for test purposes.

As could be expected of an I'C application circuit, the control of the display driver is a matter of sending the right command to a previously determined address, which is the 'location' of the IC in the I'C network. Here, the address of the SAA1064 can be set with the aid of jumpers. Remarkably, only one IC pin is used to select one of four possible addresses in the system. Resistors Rs, R4 and R5 form a voltage divider which supplies the address selection voltage to the ADR pin of the SAA1064. The voltage level, i.e., the IC address, is determined by resistors R3, R4 and R5 formed by a voltage divider which supplies the address selection voltage to the ADR pin of the SAA1064. The voltage level, i.e., the IC address, is determined by resistors Rs, R4 and R5.

The base address of the SAA1064 is 0 1 1 1 1 0 A0 A1 A0 x.

To select an address, fit the jumpers as shown in Table 1. All other address bits in the I'C address are set.

<table>
<thead>
<tr>
<th>Table 1.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
</tr>
<tr>
<td>0 0</td>
</tr>
<tr>
<td>0 1</td>
</tr>
<tr>
<td>1 1</td>
</tr>
<tr>
<td>0 = open</td>
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<tr>
<td>1 = jumper fitted</td>
</tr>
</tbody>
</table>
address are 'burnt' in the IC hardware, and cannot be changed. As usual with I²C compatible ICs, the 'x' at the end of the address is a bit that selects between a read (x=1) or a write (x=0) operation. The 'read' addresses are 70H, 72H, 74H and 76H. The 'write' addresses are 71H, 73H, 75H and 77H.

Transistors T1 and T2 are required to multiplex the four common-anode displays pair-wise. They function as switches, with the hardware in the SAA1064 determining the current flow through the display segments. Software control allows the segment current to be set between 3 mA and 21 mA in steps of 3 mA. In dynamic mode, the segments light about half the time (48.2% typ. min.). The circuit configuration used here results in a multiplex frequency of about 150 Hz, which can be increased to about 800 Hz or 1,500 Hz by reducing C5 to 820 pF or 390 pF respectively.

The multiplex duty factor results in an average segment current that is about half the programmed current. Since the brightness of the Type HD11050 LED displays (manufacturer: Siemens) is sufficient at a segment current of 4.5 mA, a segment current of 9 mA is programmed.

Jumper JP4 allows the display to be powered by a separate supply, which may be required when more than one display is used. The external voltage is applied via PCB terminal 'V+', and may be up to 15 V, pro-

Fig. 1. The circuit for driving four 7-segment displays is very compact thanks to the power of the I²C protocol.

Fig. 2. Internal diagram of the SAA1064 LED display controller (courtesy Philips Components).
Fig. 3. Track layout (mirror image) and component mounting plan of the printed circuit board designed for the I2C display module.

Provided the total dissipation in the SAA1064 does not exceed 1 W.

Resistors R1 and R2, finally, ensure that the I2C bus is correctly terminated.

Construction

The printed circuit board for the I2C compatible display unit is compact — see Fig. 3 and the photographs. One of the mini-DIN sockets may be omitted if the unit is the last (or the only) device on the I2C bus. Since the two sockets are connected in parallel, it makes no difference which of them is omitted. If you cannot get hold of the special DIN sockets, or wish to reduce the cost of building the unit, use separate wires and the PCB terminals marked +5 V, 0 V, SDA, SCL and INT instead.

Start the construction by fitting the wire links. Next, mount the passive components, followed by the IC and the two transistors. If you solder the displays directly on to the board, make sure that they are not overheated — in general, it is better to fit the displays in IC sockets.

Set the jumpers as follows:

JP1 and JP3 open;
JP2 closed;
JP4 position ‘B’,

and connect the display unit to the I2C bus.

We built a few prototypes of the unit with different display colours. The suffix of the display type number indicates the colour: HD11050: orange; HD1105G: green; HD1105R: red; HD1105Y: yellow.

Software control

As already mentioned, the display is controlled by an I2C controller board described in Ref. 1. The control software has been described in Ref. 1, and is available on disk, under order number ESS 1671.
Figure 4 shows how the controller communicates with the SAA1064. Writing results in a status byte, which, among others, shows the state of the power-reset flag. This flag is set by the SAA1064 when power is applied, after which all registers contain zeros, and the display is blank.

There are a number of ways in which we can write to the SAA1064. Writing to the device requires the relevant control register to be set to the right mode, and data to be sent to the display digits. After addressing the SAA1064, an instruction byte is sent that selects one of the eight internal registers. Which register is selected first is determined by the level of bits SA, SB, and SC. The auto-increment function of the IC ensures that the next register is automatically selected for writing. The pointer of the auto-increment data is then automatically selected for writing to the SAA1064.

After addressing the SAA1064, an instruction byte is sent that selects one of the eight internal registers. Which register is selected first is determined by the level of bits SA, SB, and SC. The auto-increment function of the IC ensures that the next register is automatically selected for writing. The pointer of the auto-increment function is cyclic, and changes to '0' again after '7'. The three least-significant bits of the instruction byte select the registers as follows:

\[
\begin{align*}
\text{b7} &= 1: \text{increase segment current by 6 mA} \\
\text{b6} &= 1: \text{increase segment current by 3 mA} \\
\text{b5} &= 1: \text{segment test, all outputs active} \\
\text{b4} &= 1: \text{increase segment current by 12 mA} \\
\text{b3} &= 1: \text{enable digits 2 and 4} \\
\text{b2} &= 1: \text{enable digits 1 and 3} \\
\text{b1} &= 1: \text{dynamic mode (multiplex digits)} \\
\text{b0} &= 1: \text{enable digits 1 and 3} \\
\end{align*}
\]

The structure of the control byte is as follows:

- \text{b7} \text{reserved}
- \text{b6} \text{free}
- \text{b5} \text{free}
- \text{b4} \text{free}
- \text{b3} \text{free}
- \text{b2} \text{control register}
- \text{b1} \text{LD2 register}
- \text{b0} \text{LD1 register}

A segment is actuated (switched on) by making the associated bit '1'; a '0' switches it off again. This means that we are not limited to just displaying numbers 0 through 9: characters A through F are also possible, which is useful for making a hexadecimal readout.

Diskette ESS 1671 contains a demonstration file, LDIS.PAS, which contains the \text{I}^2\text{C} driver as well as the routines for controlling the A-D/D-A converter and the I/O port. LDIS.PAS is written in Turbo Pascal. Figure 4 shows the main procedure, which starts with moving the decimal point of the most significant digit to the least significant digit. Next, the program counts up to 0 from 9999, and starts again. The counter values appear on the display as well as on the PC screen.

References:
This GUITAR TUNER was designed because many commercial (analogue) models were found not robust enough for the practical, hard use required of them. After all, a guitar is an instrument that needs to be tuned daily.

In the design of the tuner, hands-off operation was a prime requirement. Consequently, all functions are either automatic or foot-operated. The input is connected to the output as long as the tuner is not in use. That means that it can remain in the signal path between the guitar and the amplifier system.

When the 'on' button is pressed (by foot), the unit is switched on, provided a plug is inserted into the input socket. At the same time, the output of the unit is removed from the amplifier, so that no tuning signals are output over the speakers.

When the unit is on, the LED associated with the high E string (fE = 329.63 Hz - equal temperament tuning) lights. When the high-E string is plucked, several LEDs light. If the band of light appears to move to the left, the played tone is too low; if it moves to the right, the played tone is too high. There is a period of 20 seconds to tune the string; correct tuning is indicated by the band of light standing still.

Each subsequent pressing of the 'on' button switches the tone to the next lower note, B1, G1, ... E2, indicated by the lighting of the associated LED. In each case, there is a period of 20 seconds to tune the relevant string. At the seventh pressing of the button, the LED associated with the high E lights again.

Tuning may be ended with the second footswitch, which switches the tone to stand-by, whereupon the guitar signal is reconnected automatically to the amplifier.

If the 20-second period is not long enough to tune a string, the unit must be returned to operation at the relevant frequency by repeatedly (six times) pressing the 'on' button. Neither on-switching nor off-switching causes any audible noise or contact bounce.

Crystal control

The circuit in Fig. 1 depends for its correct operation on a crystal-controlled oscillator, IC9a-ICN,-IC9d, and a divider, IC5a-IC8-IC9, associated with the high E string frequency because of the reset provided by RN-C13.

In the standby mode, battery power is available but the tuning mode is disabled. In this state, only three ICs are powered: quadruple or octuple analogue switch IC4; bistable IC6, and inverter IC10a-j. In this mode, the current drain is a mere 1.5 µA.

When, in the standby mode, S1 is pressed, bistable IC6 is reset, whereupon S1 is switched on to provide power to the remaining ICs. At the same time, analogue switch IC4b connects the guitar output to the amplifier, IC6 becomes high-impedance, and IC4d short-circuits the output of the tuner.

Capacitor C12 is charged slowly via R16. After about 20 seconds, the voltage across it has reached the threshold level of IC10b, and this inverter then switches off the tuner via gate IC10c. If, before the 20-second period has elapsed, the 'on' button is pressed, for instance, to allow the next string to be tuned, C12 discharges via IC11b-D16 and R35, whereupon there is a further delay of 20 seconds before the tuner is switched off.

Stop button S2 can, of course, reset bistable IC6, at any moment if required. In practice, a period of 20 seconds has been found just right for tuning a string. The period may, however, be made longer by increasing the value of C12.

The battery voltage is monitored by IC10c.
which has a threshold voltage of about $U/2$. Diodes $D_{28}$ and $D_{29}$ provide a reference voltage of 2.8 V. Therefore, if the battery voltage drops below $2 \times 2.8 = 5.2$ V, the logic level at pin 10 of $IC_{10}$ changes from 1 to 0, whereupon oscillator $IC_{10}$ is enabled, which causes the relevant string LED to blink.

**Setting up**

The scale factors for the six reference frequencies are calculated from:

\[
\text{scale factor} = \frac{f_c}{f_r} - 1,
\]

where $f_c$ is the crystal frequency and $f_r$ is the reference frequency, which is

\[
f_r = f_c \times 4, \quad \text{or} \quad f_r = f_c \times 8,
\]
where \( f_s \) is the fundamental frequency of the relevant string—see Table 1. Once the scale factor has been determined, it has to be incorporated into the diode matrix.

For instance, the scale factor for the E string (equal temperament tuning) is calculated as follows.

\[
f_c = 2.4576 \text{ MHz};
\]
\[
f_a = 329.63 \text{ Hz};
\]
\[
f_r = 8 \times 329.63 = 2637.04 \text{ Hz}.
\]

Scale factor = \( \frac{2.4576 \times 10^6}{2637.04} - 1 = 931 \text{ sec} \)

The outputs of IC6 have been given binary values as shown in Fig. 1. The diodes in the matrix must be connected in such a manner that the sum of six of the outputs is equal to the scale factor. How this is done for the E string is shown in Table 2. The string, its fundamental frequency (equal temperament tuning), the reference frequency and the resulting scale factor are tabulated in Table 3. The maximum tolerance on the tuned frequency is <0.05 Hz.

**Construction**

Building the tuner on the ready-made printed-

---

### Table 1

<table>
<thead>
<tr>
<th>string</th>
<th>harmonic tuning</th>
<th>equal temp. tuning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_E )</td>
<td>82.50 Hz</td>
<td>82.41 Hz</td>
</tr>
<tr>
<td>( f_A )</td>
<td>110.00 Hz</td>
<td>110.00 Hz</td>
</tr>
<tr>
<td>( f_D_1 )</td>
<td>146.83 Hz</td>
<td>146.83 Hz</td>
</tr>
<tr>
<td>( f_G_1 )</td>
<td>195.56 Hz</td>
<td>196.00 Hz</td>
</tr>
<tr>
<td>( f_B_1 )</td>
<td>247.50 Hz</td>
<td>246.94 Hz</td>
</tr>
<tr>
<td>( f_E )</td>
<td>330.00 Hz</td>
<td>329.63 Hz</td>
</tr>
</tbody>
</table>

### Table 2

| Q0 | 1 |
| Q1 | 2 |
| Q3 | 4 |
| Q4 | 8 |
| Q5 | 32 |
| Q6 | 64 |
| Q7 | 128 |
| Q7 | 256 |
| Q8 | 512 |

Total = 931

### Table 3

<table>
<thead>
<tr>
<th>string</th>
<th>( f_r )</th>
<th>( f_r )</th>
<th>scale factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E )</td>
<td>329.628 Hz</td>
<td>2637.02 Hz</td>
<td>931</td>
</tr>
<tr>
<td>( A )</td>
<td>110.000 Hz</td>
<td>880.00 Hz</td>
<td>2792</td>
</tr>
<tr>
<td>( D_1 )</td>
<td>146.832 Hz</td>
<td>1174.65 Hz</td>
<td>1566</td>
</tr>
<tr>
<td>( G_1 )</td>
<td>195.998 Hz</td>
<td>1567.98 Hz</td>
<td>1243</td>
</tr>
<tr>
<td>( B_1 )</td>
<td>246.942 Hz</td>
<td>1975.83 Hz</td>
<td>1243</td>
</tr>
<tr>
<td>( E )</td>
<td>329.628 Hz</td>
<td>2637.02 Hz</td>
<td>931</td>
</tr>
</tbody>
</table>

---

Fig. 2. Printed-circuit board for the guitar tuner.
circuit board—see Fig. 2—should not present any problems. Mount the LEDs on the board without soldering, insert the board into the prepared enclosure and turn the enclosure over. The LEDs can then be correctly accommodated into previously drilled and squared (filed) holes in the front panel, after which they can be soldered on to the board.

A ready-made front panel foil is available—see Fig. 3.

Switches $S_1$ and $S_2$ can be linked to the board with normal circuit wire: because of the short length of these connections, screened cable was not found necessary.

The negative terminal of the battery must be connected to the contact on the stereo input socket to ensure that the tuner is switched on only when the cable from the guitar is inserted into the tuner.

It should be noted that this article assumes equal temperament tuning throughout. In this, each semitone is made an equal interval, which has the advantage that the instrument may be played in virtually any key. The disadvantage, however, is that the tones do not sound 'natural', which is why many guitarists prefer to tune their instruments to harmonics. (Ed).

**PARTS LIST**

- **Resistors:**
  - $R_1 = 47 \text{ k}\Omega$
  - $R_2, R_3, R_{17}, R_{18}, R_{21}, R_{22}, R_{24} = 10 \text{ k}\Omega$
  - $R_4, R_8, R_9, R_{19} = 1 \text{ M}\Omega$
  - $R_5 = 4.7 \text{ k}\Omega$
  - $R_6 = 820 \text{ k}\Omega$
  - $R_7 = 680 \text{ k}\Omega$
  - $R_{10}, R_{11} = 2.7 \text{ k}\Omega$
  - $R_{12}, R_{25} = 1.2 \text{ k}\Omega$
  - $R_{13}, R_{15} = 100 \text{ k}\Omega$
  - $R_{16} = 33 \text{ M}\Omega$
  - $R_{20} = 2.2 \text{ k}\Omega$
  - $R_{23} = 5.6 \text{ M}\Omega$

- **Capacitors:**
  - $C_1 = 1 \text{ nF}$
  - $C_2 = 1 \mu\text{F}, 16 \text{ V}$
  - $C_3, C_8, C_9, C_{13}, C_{22} = 100 \text{ nF}$
  - $C_4, C_5, C_{12} = 10 \mu\text{F}, 16 \text{ V}$
  - $C_6 = 40 \mu\text{F}$, trimmer
  - $C_7 = 33 \mu\text{F}$
  - $C_{10}, C_{11} = 4.7 \mu\text{F}, 16 \text{ V}$

- **Miscellaneous:**
  - $D_1-D_{16} =$ rectangular LED, green
  - $D_{17}-D_{22}, D_{28}, D_{29} =$ rectangular LED, red
  - $D_{23}-D_{27} =$ 1N4148
  - $D_{30}-D_{xx} =$ 1N4148 (for matrix—see text)
  - $T_1 =$ BC327
  - $IC_1 = 4067$
  - $IC_2, IC_{11} = 4024$
  - $IC_3 = TLC272$
  - $IC_4 = 4066$
  - $IC_5 = 4049$
  - $IC_6 = 4040$
  - $IC_7, IC_8 = 4051$
  - $IC_9 = 4013$
  - $IC_{10} = 40106$
  - $K_1 = 6.35 \text{ mm}$ stereo audio socket with switch for PCB mounting
  - $K_2 = 6.35 \text{ mm}$ mono audio socket for PCB mounting
  - $B_{11} =$ PP3/6F22 (9 V)
  - $X_1 =$ quartz crystal 2.4576 MHz
  - $PCB = 920033$
  - $Front panel foil 920033F$

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**DESIGN IDEAS**

The contents of this column are based solely on information supplied by the author and do not imply practical experience by *Elektor Electronics*

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**PLANT WARMER**

by Samuel Dick

Frost is a gardener’s nightmare. It is especially damaging in the late autumn when plants may not (yet) have been moved to their winter site or during the spring when growing conditions are normally favourable but a sudden, unexpected frost can kill many young plants.

The classic solution to the problem of frost for small gardens is a coldframe. It occupies less space than a greenhouse, while still providing storage for many plants or seed trays. But during cold weather, the temperature in a coldframe may still drop below freezing and, during the spring, the temperature may not rise high enough to significantly boost the growth of seeds and young plants. The 'plant warmer' offers a solution to these problems. By placing a sensor and two heating elements in the coldframe, a simple heating system may be constructed. In this design, the two heating elements are controlled independently; one heater is set for a higher temper...
perature than the other, so that maximum heat is supplied only during the coldest weather.

By altering both trigger points, the temperature in the coldframe may be raised by 10–15 °C to allow the coldframe to be used as a propagator during the spring.

Circuit description

The temperature in the coldframe is sensed by an LM335Z chip, D1. This is used as a temperature-dependent zener diode, R1 is chosen to pass a current of roughly 1 mA through the device. The voltage drop across the chip is 10 mV K⁻¹. At freezing point (0 °C=273 K), this would be 2.73 V, rising to 2.98 V at 25 °C. The voltage from the sensor is compared with two other potentials by IC1. The two potentials are set with preset potentiometers P1 and P2, both of these are multiturn types to make the process of setting accurate values as easy as possible. They, and the rest of the circuit, are supplied with a regulated voltage derived from zener diode D2 and filtered by C2 and C3. A current of around 20 mA is required by the control circuit. Capacitors C1, C4 and C5 filter noise on the inputs to IC1.

When the voltage from the sensor drops below one of the comparison potentials, IC1 detects this and switches on the appropriate output. The output signal is fed to the gate of the SCR to around 0.7 V. This ensures that the heating element is on only when the temperature is below the comparison potential set by the user.

Voltage comparators have a very high gain so that the transition voltage range (between on and off) is very small. This would mean that the circuit would for ever be switching on and off, since even a small temperature change (perhaps only 0.01 °C) would result in the controller changing state. As this could happen twice every a.c. cycle, that is, 100 Hz since rectified a.c. is used, a lot of switching noise might possibly be created. To prevent this happening, some hysteresis has been designed into the circuit. When the temperature has dropped below one of the trigger points, it must rise above the original trigger temperature by about 2 °C before the controller will switch the heater off. This prevents rapid switching and consequent noise.

The hysteresis is built in as follows. The actual circuit may be converted into a simpler form to ease understanding of its operation —see Fig. 2. In this simplified circuit, V4 represents the supply voltage, Vb, the output voltage of IC1a or IC1b, and Ra, Rb one of the preset potentiometers (its wiper represented by the junction Ra-Rb). When the heater is off, the output voltage of IC1a or IC1b is around 0.2 V. The voltage at junction Ra-Rb is lowered because Rb drains current from R1p thus, since the voltage across a resistor is proportional to the current flowing in it, the voltage across Rb is smaller than it would if Rb were not connected. When the temperature falls, the voltage on the inverting (-) input of IC1a or IC1b drops below that on the non-inverting (+) input and the output of the comparator goes high. In practice, this is limited by the gate of the SCR to around 0.7 V.

Since Rb now has 0.7 V rather than 0.2 V at its right end, the current flowing through it is reduced, so more current flows through R1p and the voltage at junction Rb-R1p rises. By representing the voltages by voltage sources, the rule may be applied that the sum of voltages around a loop in a circuit must equal zero. In Fig. 2, there are two loops: loop 1 contains V4, Ra and Rb, while loop 2 contains V4, Rb and Rb. The current flowing through Rb may be defined as i1 and that through Rb as i2:

\[ V_4-R_b(i_1+i_2)-R_b i_1=0 \]

and

\[ V_4-R_b i_1+R_b i_2=0. \]

Since the value of Rb should cause a change of at least 20 mV (equal to 2°C) in the voltage across Rb, when V4 changes from 0.2 V to 0.7 V, these equations may be rewritten in a form to enable it to be calculated as a function of V4 and Rb. Since Rb is about 1.2 kΩ for a trigger voltage of 2.5 V (equal to 7°C), Rb is 3.8 kΩ (as the potentiometer is 5 kΩ). Therefore,

\[ i_1=(V_4-R_b V_b/R_b)/(R_b+R_b+R_a+R_b/R_b). \]

For V4=12 V and the values of Rb, Rb and Vb as given, with Rb=33 kΩ, the required 20 mV change will take place when the output of IC1a (IC1b) goes from low to high, so providing the desired hysteresis.

To provide the higher temperature option for when the coldframe is used as a propagator, Rb is shorted by closing S2. The value of R12 for different higher temperatures may

![Fig. 1. Circuit diagram of the plant warmer.](image-url)
be calculated as follows—see Fig. 3. The voltage with $R_{12}$ in circuit is $V_{ol} = V_s R_2/(R_3 + R_4 + R_5)$, where $V_s$ is the supply voltage (12 V). With $R_{12}$ ($R_2$ in these equations) is shorted, the negative output voltage, $V_{ol} = V_s R_2/(R_3 + R_4)$. Note that $R_5 = P_1$ in the circuit.

$$R_{12} = P_1^2 \Delta V/(V_s R_2 - AV P_1),$$

where $\Delta V$ is the voltage increase required (say, 0.15 V corresponding to 15 °C higher than the frost protection set point). When the propagator mode is required, $R_3$ is given by $V_{set} P_1/V_s$.

### In use

The heating elements and sensor should operate in the coldframe and the sensor mounted near the bottom, too, but clear of either element. Some attention should be paid to the thermal insulation of the coldframe. If at all possible, an insulating layer should be placed between the ground and the elements and plant pots. This prevents the heat from being absorbed by the ground. Similarly, insulation over the top of the coldframe will help contain heat—most suitable form of insulation is transparent plastic sheets of air-filled bubbles, like those used for packing delicate items.

The values of $P_1$ and $P_2$ should be set, with the heating off, with the aid of a digital multimeter to give voltages of 2.80 V and 2.76 V respectively.

### Construction

The plant warmer was constructed on the printed-circuit board shown in Fig. 4 and fitted into a suitable box.

The two heating elements, $R_3$ and $R_7$, may be made as follows. The lower-powered heater, $R_7$, is made from thirty 1.0 Ω resistors, soldered together in series and then inserted into heatshrink sleeving for protection. The higher-powered heater, $R_5$, is made from two resistor chains, identical to $R_7$, connected in parallel. The values of the resistors and the number used have been calculated so that each resistor runs within its rated power dissipation. There is no need to shrink the sleeving after construction—indeed, this is undesirable since it makes the element less easy to bend, which could make fitting it to the coldframe difficult.

As the heating elements and sensor have to operate in damp conditions, care should be taken to cover the connections with an epoxy potting compound to prevent ingress of dampness.

### Parts List

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Value</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>R1</td>
<td>8.2 kΩ</td>
<td></td>
</tr>
<tr>
<td>R2, R3</td>
<td>33 kΩ</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>290 kΩ</td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>see text</td>
<td></td>
</tr>
<tr>
<td>R6, R8</td>
<td>2.2 kΩ</td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td>2.7 kΩ</td>
<td></td>
</tr>
<tr>
<td>R10, R11</td>
<td>6.8 kΩ</td>
<td></td>
</tr>
<tr>
<td>R12</td>
<td>150 kΩ</td>
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<tr>
<td>P1, P2</td>
<td>5 kΩ</td>
<td>preset, multturn</td>
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<thead>
<tr>
<th>Capacitor</th>
<th>Value</th>
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<td>C1</td>
<td>6.8 μF</td>
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<td>C2, C4, C5</td>
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<td>C3</td>
<td>47 μF</td>
<td>25 V</td>
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<table>
<thead>
<tr>
<th>Semiconductor</th>
<th>Description</th>
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<tr>
<td>D1</td>
<td>LM335Z (temperature sensor)</td>
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</tr>
<tr>
<td>D2</td>
<td>BZY88C, 12 V, 500 mW zener</td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>1N4002</td>
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<tr>
<td>D4, D6, D8</td>
<td>LED, green</td>
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<tr>
<td>IC1</td>
<td>LM3319 (voltage comparator)</td>
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<tr>
<td>N1</td>
<td>mains voltage neon, green, with integral resistor</td>
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<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>BR1</td>
<td>100 V, 6 A bridge rectifier</td>
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</tr>
<tr>
<td>T1</td>
<td>0–15 V, 2 A secondary mains transformer</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>DPDT, 250 VAC, 2 A</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>SPST, low voltage</td>
<td></td>
</tr>
<tr>
<td>Case</td>
<td>with feet</td>
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</tr>
<tr>
<td>Grommets</td>
<td>(2)</td>
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</tr>
<tr>
<td>4-core cable</td>
<td>for heater wires</td>
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<tr>
<td>Audio-quality coax cable for temperature sensor</td>
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<td></td>
</tr>
<tr>
<td>Heatshrink sleeving to cover R5</td>
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</tr>
</tbody>
</table>

**Fig. 4.** Printed-circuit board for the plant warmer.
Input circuits and chroma-VBS separation filter

The circuit in Fig. 3 serves to select one of the inputs and to separate the chroma and VBS signals. Note that, in spite of the English-language front panel, some rear panels have the annotation 'FBAS' instead of CVBS. FBAS is the acronym of the German Farbbild Austast Synchronsignal = chroma, video, blanking, synchronization signal.

The input signals may be divided into two groups: CVBS and S-VHS signals. In case of the former, the chroma and the VBS signals must be separated; with S-VHS signals that has already been done.

The CVBS signals are applied from the input selector circuit to two filters via S201. Both these filters, L203-C227 and I-202-C112, are tuned to the colour subcarrier. Filter L203-C227 is a band-stop filter that passes only the VBS signal to the output. The other filter passes only the subcarrier, and thus the colour signal, to the chroma output.

Filter L203-C227 operates in conjunction with four transistors, T207-T212, that share a common emitter resistance, R260. The d.c. operating points of the transistors ensure that at any one time only one of them is switched on: the others are off. Which one is switched on depends on the selected input and the colour standard identified by the

Fig. 3. Circuit diagram of the input stages and the chroma-VBS separation filter.
multi-standard decoder elsewhere in the processor.

Assuming that an input with a CVBS signal has been selected, a potential of about 2.5 V will be put on to the switching lines of the multi-standard decoder. Only T211 is then switched on, resulting in the complete CVBS signal being applied to terminal K. This has the additional advantage that in case of a black-and-white signal (when the decoder cannot identify a colour standard) no filters are switched into circuit, which is beneficial to the picture quality.

If a colour standard has been identified, the potential on one of the switching lines, B-E, becomes 5.5–6 V. That voltage is used, via D214–D217, to set the d.c. operating point of T212. The drop across R260 then rises to a value that causes T211 to switch off. The CVBS signal is then forced to pass through band-stop filter L203–C75 before it becomes available, via K5, at T212.

If the multi-standard decoder has also recognized that the signal is an NTSC signal with a 3.58 MHz subcarrier, diode D211 is switched on. This causes C233 to be connected in parallel with the band-stop filter so that the resonance frequency is shifted appropriately. Although the band-stop frequency for all other signals is 4.434 MHz, it should be noted that the SECAM subcarrier of 4.286 MHz is also suppressed adequately.

If no CVBS signal has been selected, the control logic ensures that T239 and T210 are switched on. The VBS signal of one of the S-VHS inputs is then passed directly to terminal K. At the same time, the drop across R260 then rises to a value that causes T210 to switch off. The CVBS signal is then forced to pass through bandstop filter L203–C237 before it becomes available, via K5, at T212.

The control signals for the multiplexer are provided by counter IC202, which is operated by switch TA301. The selected signal is applied to buffer/inverter TA20–TA25. The processor may be set for positively or negatively modulated signals by switch S201. From that switch, the signal is split into two: one part to the chroma filter and the other to the VBS band-stop filter.

Since SCART connector BL/201 also serves as an S-VHS input, the signal at pin 20 is passed not only to the multiplexer, but also directly to the VBS band-stop filter. S-VHS signals are not switched by the multiplexer, but by transistor stages in the filter sections: T265–T266 and T219–T210. The necessary switching signals are derived from the state of counter IC209 by IC201.

The switching of input signals is effected by IC201–IC203. Video signals (audio signals will be reverted to later) are present at one of the four input connectors. The standard value of their signal strength is 1 Vpp. All inputs are terminated into a 75 ohm resistor, R205–R208. The signals are passed to analogue multiplexer IC201 (2x4 positions) via coupling capacitors C203–C206. The multiplexer selects one of the signals, which is indicated by the associated LEDs.

The circuit associated with the chroma filter operates in a manner similar to that of the VBS band-stop filter. Here, the common emitter resistance of transistors T207–T206 is R216. The resonant frequency and Q of the filter are chosen for the SECAM signal (4.286 MHz). To enable the filter to handle the greater bandwidth of PAL and NTSC 4.434 MHz signals, it is shunted by R221 via T236 and decoupling capacitor C224. The Q of the network will then drop, while the bandwidth increases. The small difference with the required bandwidth is negligible, so that the filter does not need retuning. To enable the filter to handle NTSC 3.58 MHz signals, it is shunted by capacitor C223 via T205, while at the same time the bandwidth is increased because the Q factor is lowered by R221.

The chroma filter selects between CVBS and S-VHS signals with the aid of T203. In contrast to the VBS band-stop filter, the chroma filter is always in circuit. This does not affect the quality of the output signal.

When T203 is switched on (by its base voltage), one of the two S-VHS signals is passed to the chroma output, depending on the base potential of T202. When that transistor is on, T201 is off and the VBS signal at input Video 5 is passed. When T201 is on and T202 is off, the signal at Video 1/6 is selected.

The circuit diagram of the multi-standard decoder and the video colour controller.

ELEKTOR ELECTRONICS JUNE 1992
Multi-standard decoder and video colour controller

The circuit of the multi-standard decoder and video colour controller, shown in Fig. 4, carries out the decoding and processing of all video signals.

The actual decoding is effected by IC101. The standard of the incoming signal is determined by IC101 on the basis of the chroma signal at pin 15. The chroma filter is set up (wide band) to enable any chroma signal to be passed correctly. The standard is translated into appropriate voltage levels at input/output pins 25–28. Four levels are recognized: 0.5 V – standard out; 2.5 V – search mode; 6 V – standard on; 9 V – forced acceptance of a standard.

Although the multi-standard decoder is a fairly complex circuit, it has only three calibration points, which, by the way, have nothing to do with the internal of the IC, but are merely intended for adjusting some external components. These are (1) the SECAM reference circuit, L110–C114, (2) Q110 and (3) Q111. Because NTSC signals lack a colour burst, there is no reference for the chroma signals. R111 is provided to make sure that the reference of the decoder is, nevertheless, the same as that of the transmitter. Maladjustment of this potentiometer results in unnatural colouring of the picture.

The output of IC101 consists of two colour-difference signals that are applied to delay line IC103. The output of this line is also two colour-difference signals but with corrected transit times. These signals are then ready for the final stage in the decoding and for being processed into a picture signal. Those tasks are performed by IC104, the video colour controller.

In addition to the colour-difference signals, the inputs to IC104 consist of the VBS signal that is provided via delay line VZ101, or the RGB signals that are input via Video 2 and terminals H–J.

Circuit IC104 synthesizes the colour-difference and VBS signals to an RGB signal. This synthesis may be affected by the setting of R111 (colour saturation control). Apart from its white-point adjustment, the RGB signal can be modified in respect of brightness and contrast. The final RGB signal is applied to the PAL/NTSC encoder via pins 1, 3 and 5.

PAL/NTSC encoder

The diagram of the circuit that reconverts the RGB signal into a CVBS signal, PAL or NTSC standard, is shown in Fig. 5. Apart from the RGB signal, the Type TPE1378A encoder, IC301, requires a number of other signals. The first of these is the synchronization signal at pin 15, which is provided by the synchronization circuit to be discussed in Part 3 of this article.

Generation of the colour subcarrier requires a generator: since NTSC 4.43 MHz as well as NTSC 3.56 MHz signals can be handled, two generators are needed. When either of these is energized, the relevant bandpass filter, BPF301 or BPF302, is also actuated. To compensate for the delay of the chroma signal in the filter, the VBS signal is also delayed: in VZ301.

The RGB input signal is also available as a buffered output of IC301. The RGB lines are connected to the relevant pins of connector BU301 (Video 4 output) via coupling capacitors and terminating resistors. A voltage can be applied to this connector by S304 to force the equipment connected to the processor to use the RGB signals instead of the CVBS signal on pin 19 as input.

The CVBS signal is available at pin 5 of IC301. It is applied to S304 via a coupling capacitor and a terminating resistor, and to electronic switch IC302. That switch ensures that, if Video 4 is used as input and as output, for instance, during format conversion, the CVBS signal is replaced by a composite sync (DS or Blanking/Synchronization) signal. This arrangement prevents the arising of noise and interference between the colour subcarriers of the input and output signals in the connecting cable. This means, of course, that in the final analysis only the RGB signal can be used as an output signal.

The remaining signals provided by IC301 are the VBS and chroma signals for the S-VHS outputs. These signals are applied to the relevant connectors, BU301 and BU302, via a buffer stage. To ensure that the terminating impedance of the VBS or chroma signal is correct, connectors BU301 and BU302 must not be used simultaneously, unless S304 is in position CVBS and no S-VHS equipment is connected to BU301.

The instalment in the July issue will describe the audio, power supply and synchronization circuits, while that in the September issue will deal with the construction and setting up.

Fig. 5. Circuit diagram of the PAL/NTSC encoder
In this instalment we deal with the construction of the synthesizer board, and the operation of the combined keyboard/display/controls unit.

**Design by H. Reelsen**

The introductory photograph shows the completed FM tuner in a 19-inch rack style enclosure, which follows the line of other high-end audio equipment published over the past year or so in this magazine. Inside the enclosure are six printed circuit boards:

1. Main tuner board (PCB no. 920005) which combines all RF and audio electronics; described in Elektor Electronics March 1992.
2. Power supply (PCB no. 920005-2) described in Elektor Electronics April and May 1992.
3. Mode control board (PCB no. 920005-3) described in this instalment.
4. Keyboard and display board (PCB no. 920005-4) also described in this instalment.
5. Synthesizer board (920005-5); circuit diagram described in Elektor Electronics May 1992, construction in this instalment.
6. Field strength indicator (PCB no. 920005-6), to be described in next month's instalment, together with the construction of the keyboard/display unit, and, possibly, details on wiring.

**Audio mode and mono/stereo control unit**

While the large keyboard and display keyboard control and indicate all synthesizer functions, a smaller board, described here, arranges the audio mode switching of the main tuner board. The circuit shown in Fig. 12 operates independently of the microprocessor on the synthesizer board, so that it is also useful if the synthesizer is omitted, and 'replaced' by manual tuning (by a precision multiturn potentiometer). The printed circuit board for the mode control unit (Fig. 13) is designed such that it can be fitted at the inside of the receiver's front panel. The PCB accommodates five push-buttons, of which four have a built-in LED. Starting at the left, the first three keys are used to select different modes of the TDA3810 audio IC, while the remaining two serve to control the mono/stereo switching of the TDA1578 stereo decoder IC. Both the TDA3810 and the TDA1578 are located on the main tuner board.

The function of the push-buttons is as follows (left to right):

- S203: NORMAL audio mode (audio processor TDA3810).
- S204: WIDE audio mode (audio processor TDA3810). The stereo image is widened, and LED D203 lights.

**Fig. 12. Circuit diagram of the audio mode and mono/stereo control unit.**
- S205: PSEUDO STEREO mode (audio processor TDA3810). This effect can be switched on with the stereo decoder in mono as well as stereo mode. When selected, LED D202 lights.

- S201: STEREO mode (stereo decoder TDA1578).

- S202: MONO mode (stereo decoder TDA1578). Mono/stereo mode is indicated by LED D205.

Since push-buttons are used to select the different modes, bistables are required to set the logic levels of the control lines to the main tuner board. The mono/stereo selection requires only one bistable, which consists of NOR gates IC20a and IC20b. When the 'stereo' key, S201, is pressed, the bistable output (terminal 'G' of the board) goes to 0 V. Terminal 'G' is connected to terminal 'MONO' on the main tuner board. When a stereo broadcast is received, the 'stereo' indicator, LED D202, lights. Terminal 'D' is connected to the terminal marked 'STEREO LED' on the main tuner board. When the 'mono' key is pressed, the bistable is reset, and terminal 'G' goes to +5 V. This causes the stereo decoder to switch to mono, and the 'stereo' LED to go out. Components C201 - R201 form a power-up network that sets the bistable at power-on. This means that 'stereo' reception is selected automatically when the receiver is switched on.

The switching between the three audio modes offered by the TDA3810 works in a manner similar to that of the TDA1578 described above. Three of the four D-type bistables contained in the 74HC175 package are used. The three bistable inputs are connected to ground via 22-kΩ resistors. Push buttons S203, S204 and S205 at these inputs have toggle (change-over) contacts. They are normally closed (as indicated by the circuit symbol), so that the bistable inputs are held at +5 V. When one of these push-buttons is pressed, its contact switches to the other position, so that the corresponding bistable
input goes low. At the same time, the level at the clock input (pin 9) changes from low to high. When this positive transition occurs, the logic level at the D (data) input of the bistable is transferred to the Q output, where it remains stable until the next positive edge at the clock input. This basic operation results in the following switching behaviour:

- When the 'NORMAL' key (S04) is pressed, the output of the first bistable (terminal 'E') goes low, and that of the third bistable (terminal 'F'), high.
- When the 'WIDE' key (S04) is pressed, both 'E' and 'F' go logic high.
- When the 'PSEUDO' key (S08) is pressed, 'E' goes high, and 'F' low.

The two outputs 'E' and 'F' are connected to the MODE SELECT A and MODE SELECT B terminals on the main board, where the logic levels result in the following modes:

<table>
<thead>
<tr>
<th>Mode</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereo</td>
<td>L</td>
<td>X</td>
</tr>
<tr>
<td>Wide image</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Pseudo stereo</td>
<td>H</td>
<td>L</td>
</tr>
</tbody>
</table>

The associated indicators, LEDs D202 and D203, are driven by the main board. The connections are as follows: terminal 'A' goes to 'BASIS B LED' on the tuner board, and terminal 'B' to 'P-STEREO' on the tuner board.

The UNLOCKED (out of lock) signal supplied by the synthesizer requires to be inverted before it can be used. This is achieved with gate IC201D, whose output is fed to the 'MUTE' input of the tuner board via terminal 'H'. The mute indication is also driven by circuitry on the main board: the 'MUTE LED' output (at R46) is connected to terminal 'C' (at D204) on the small controls board.

**Keyboard and display**

The circuit diagram of the keyboard/display unit is given in Fig. 14. This unit is constructed on a separate printed circuit board, where the logic levels result in the following modes:

The readout consists of seven 7-segment LED displays.

Only a single 8-bit bidirectional port is required to drive the displays and read the keys. However, this port must be capable of sinking as well as sourcing a current of 5 mA per line. This requirement is met by IC108 on the synthesizer board. The outputs of IC108 are connected to inputs D0 to D6 on the display board.

Data lines D0 to D3 are connected to all inputs of display drivers IC1 to IC7, which are Type 4511 7-segment LED display latches/decoders/drivers. A 'low' level at the LE (latch enable) input of a 4511 clocks the data into the display decoder. Address decoder IC1 determines which display driver accepts the data. The selection is made with the aid of the logic levels on the D4, D5 and D6 lines that exist when IORW is actuated. This forms the strobe signal that indicates that the data on D0-D6 are stable and valid.

The keyboard is encoded with the aid of diodes, which also serve as straight connections. This method is traditional as well as economic, since it enables the use of single
Fig. 15. Track layout (mirror image) and component mounting plan of the synthesizer board.

**COMPONENTS LIST**

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Value/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 1kΩ</td>
<td>R401;R403;R405</td>
<td></td>
</tr>
<tr>
<td>3 2kΩ</td>
<td>R402;R413;R414</td>
<td></td>
</tr>
<tr>
<td>1 33kΩ</td>
<td>R404</td>
<td></td>
</tr>
<tr>
<td>2 56Ω</td>
<td>R406;R415</td>
<td></td>
</tr>
<tr>
<td>1 68Ω</td>
<td>R407</td>
<td></td>
</tr>
<tr>
<td>2 10kΩ</td>
<td>R408;R416</td>
<td></td>
</tr>
<tr>
<td>1 270Ω</td>
<td>R409</td>
<td></td>
</tr>
<tr>
<td>1 2kΩΩ</td>
<td>R410</td>
<td></td>
</tr>
<tr>
<td>1 237kΩ 1%</td>
<td>R411</td>
<td></td>
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<tr>
<td>1 18kΩ</td>
<td>R412</td>
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</tr>
<tr>
<td>1 4kΩΩ</td>
<td>R417</td>
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<tr>
<td>1 1MΩ</td>
<td>R418</td>
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</tr>
<tr>
<td>1 8-way 10kΩ S/IL array</td>
<td>R419</td>
<td></td>
</tr>
<tr>
<td>1 4-way 2kΩΩ S/IL array</td>
<td>R420</td>
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<td>Capacitors:</td>
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<td>1 220nF</td>
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<tr>
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<td>C405</td>
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<tr>
<td>3 4nF</td>
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<td>C406;C412;C415</td>
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<tr>
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<td>C414</td>
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<td>C416-C421</td>
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<td>Semiconductors:</td>
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<tr>
<td>2 1N4148</td>
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<tr>
<td>1 BC547B</td>
<td>T401</td>
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</tr>
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<td>1 6264LP-15 RAM</td>
<td>IC401</td>
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</tr>
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<td>1 27C256 (ESS6101)</td>
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<td>1 74HC573</td>
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<td>1 74HC245</td>
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<td>1 74HC02</td>
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<td>1 SP8795 (GEC-Plessey)</td>
<td>IC410</td>
<td></td>
</tr>
<tr>
<td>1 74HC00</td>
<td>IC411</td>
<td></td>
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<tr>
<td>1 TL081</td>
<td>IC412</td>
<td></td>
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<tr>
<td>Miscellaneous:</td>
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<tr>
<td>1 Lithium battery CR2032</td>
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<tr>
<td>with PCB-mount holder</td>
<td>B41</td>
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</tr>
<tr>
<td>1 Quartz crystal 2MHz</td>
<td>X402</td>
<td></td>
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<tr>
<td>1 Quartz crystal 16MHz</td>
<td>X401</td>
<td></td>
</tr>
<tr>
<td>1 Printed circuit board</td>
<td>920005-5</td>
<td></td>
</tr>
</tbody>
</table>
FM TUNER - 4

sided PCB.

Pressing a key on the tuning keyboard causes a high level on one or more datalines, but only when the driver on the synthesizer board is switched to 'receive'. When this is so, the key code is applied to ICtos via R51 - R54 and datalines D0-D3. When it happens that a key is pressed while the driver 'transmits', no bus conflict occurs because the driver 'overcomes' the keyboard lines with their 1-kΩ resistors. Resistors Rs1-Rs4 then function as pull-ups only.

Push-button S15, which is connected to the 'F' and 'E' terminals via 1-kΩ resistors, has a special function. We are talking about the reset key. When S15 is pressed, the reset input line of the synthesizer tuning system is pulled to ground. As described last month, the synthesizer is switched off during normal operation of the receiver. The push-button that causes the reset action is labelled 'ENER' because it restarts the microcontroller, and needs to be pressed before every new entry.

A further novelty of the circuit is the 'EXECUTE' key, S11, which is used to terminate entries. The parallel R-C network RsCs ensures that an 'execute' key action is simulated at power on.

The tuning functions

The upper part of the keyboard has the number keys 0 to 9 to enter frequencies and station presets. The receive frequency is shown on the five LED displays to the right of the readout, while the first two digits show the preset number. This means that a total of 99 presets is available.

In addition to the 9 numerical keys there are 5 function keys:
- ENTER to start every entry;
- STORE to store a frequency entered or displayed;
- EXECUTE to close off any entry (except when STORE is used);
- UP to increase the tuning frequency;
- DOWN to decrease the tuning frequency in steps of 50 kHz.

The operation of the keyboard is simplicity itself. When power is applied, the receiver is automatically tuned to the station it was last tuned to, and the display shows the station frequency. The following keys have to be pressed to select another station from the memory:
- ENTER — Station number (1-99) — EXECUTE

Alternatively, you may want to enter the station frequency, e.g. 96.50 MHz:
- ENTER — 9650 — EXECUTE

When it is desired to store the displayed frequency as preset (station number) 15, press
- ENTER — 15 — STORE

To tune the receiver up or down press
- ENTER — UP

The frequency changes as long as you hold the UP or DOWN key pressed. When the key is released, the frequency remains static for about 3 seconds, after which the microcontroller switches itself off. In the other entry modes, the microcontroller is switched off when the 'EXECUTE' or 'STORE' key is pressed, and 'woken up' again when the 'ENTER' key is pressed.

The lithium battery on the synthesizer board ensures that stored frequencies and station preset numbers remain intact for at least ten years. All entry errors, for instance, an out-of-band frequency (lower than 87.50 or higher than 108.00), are signalled by the display clearing to all zeroes, and flashing five times. After this error indication, you can attempt a new entry.

The frequency raster is 50 kHz in direct frequency entry mode. This means that the last digit can only be '0' or '5'. When another value is entered, the tuning program automatically rounds it to the nearest raster value.

Synthesizer board

Although the synthesizer is a fairly complex circuit, its construction is entirely straightforward. Start your work by fitting the 27 wire links on the board (see the component overlay in Fig. 15). The rest of the work is mostly positioning components, and bending, soldering and cutting component wires. It is recommended to use sockets for all ICs.

Finally, note a small error in the circuit diagram of the synthesizer (Fig. 11): the 4.7-nF capacitor at the OSC input should be labelled C15, not C407.

A further error has been made with the electrolytic capacitor C70 on the main tuner board: C70 is shown with the wrong polarity both in the circuit diagram, Fig. 4, and on the component overlay of the tuner board (also Fig. 5b).

The construction of the readout/keyboard unit will be discussed in next month's installment.
A small circuit is described that inverts a positive voltage into a negative one or doubles its level. It does not use inductors and is based on a single Type MAX660 chip.

The power supply for a battery-operated design can often cause a few headaches as regards the level of the voltage or whether asymmetrical supply should be used. The latter, for instance, normally means a doubling of the number of batteries, which take twice the space originally allowed for and increase the weight: two undesirable factors. The obvious solution is a switch-mode supply, but the construction and/or dimensions of the inductor required for that is another unwelcome element.

There is, however, another solution, provided the output current is not required to be larger than 100 mA: the Type MAX660 integrated circuit. This IC needs only a few capacitors and a diode to provide, from a positive supply, a negative voltage at the same level or double the voltage. It is, of course, possible to use a number of these ICs to increase the output current or voltage, but the proposed design is based on just one.

The circuit

The internal of the MAX660 circuit is shown in Fig. 1; Fig. 1a is a design for a voltage inverter and Fig. 1b, for a voltage doubler. Within the IC, one of two pairs of CMOS switches is opened or closed by the internal

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**Fig. 1.** Basic circuit of a voltage inverter (a) and a voltage doubler (b) based on a Type MAX660 integrated circuit.

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**Fig. 2.** The two circuits of Fig. 1 can be combined into one that can serve either as an inverter or as a doubler.
oscillator that operates at 10 kHz.

If, in Fig. 1a, S1 and S3 are closed (S2 and S4 are then open), C1 will be charged. When these switches change over, C1 and C3 are in parallel, whereupon charge is transferred from C1 to C3. Also, the polarity of C1 with respect to earth is reversed (pin 2 was connected to UUb and is now connected to earth, while pin 4 was connected to earth and is now connected to pin 5). The voltage across C3 will thus be negative with respect to earth. In the absence of a load, a negative voltage will arise across C3, whose level is equal to that of UUb. When the circuit is loaded, that negative voltage will not only decrease, but will also have a ripple. This is, of course, because C1 can transfer only a limited charge, smaller than the one required, per unit time. On average, there will remain a smaller charge in C3, so that the voltage across this capacitor will drop.

When the switches are connected as in Fig. 1b, and a diode, D1, is added, the IC will double the input voltage. When the supply is switched on, C3 is charged immediately to the supply voltage (less the forward voltage of the diode) via D1. This is necessary to ensure a supply to the oscillator. Furthermore, the charge need not be transferred via the IC. Here again, C1 is the reservoir. Its charged when the switches are in the position shown. When the position of the switches is reversed, C1 is in series with the supply voltage, UUb, so that the potential across it is 2UUb. At the same time, C3 is connected, so that charge is transferred from C1 to C3. In that way, and provided the circuit is not loaded, a voltage arises across C2 that is twice UUb. As in Fig. 1a, when a load is connected to the circuit, the output voltage, 2UUb, will decrease in proportion to the load (see Table 3). Bear in mind that the input current will be twice as large as the output: the energy has to come from somewhere.

The circuits in Fig. 1a and Fig. 1b can be combined as shown in Fig. 2. The position of the jumper JP1 and the connections to X, Y and Z are given in Table 1. Table 2 shows the function of each of the external components. When the circuit serves as voltage inverter, D1 is not really required, but, together with a 160 mA fuse, it serves as protection against polarity reversal. Should the supply voltage be connected with incorrect polarity, it will be short-circuited by D1, whereupon the fuse blows.

The minimum input voltage to the doubler circuit cannot be as low as to the inverter circuit, because, in that configuration, the oscillator has difficulty in starting at too low a voltage. This happens particularly at input voltages below 3.5 V, above that level, the oscillator starts readily at all times.

Although the circuit is perfect for building into an existing design, there may be applications where it is used by itself and for those a printed circuit board—see Fig. 3—is provided.

### TABLE 1

<table>
<thead>
<tr>
<th>Connections</th>
<th>Inverter</th>
<th>Doubler</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP1</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>X</td>
<td>ground</td>
<td>in (2.5–5.5 V)</td>
</tr>
<tr>
<td>Y</td>
<td>in (1.5–5.5 V)</td>
<td>out</td>
</tr>
<tr>
<td>Z</td>
<td>out</td>
<td>ground</td>
</tr>
</tbody>
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### TABLE 2

<table>
<thead>
<tr>
<th>Component</th>
<th>Inverter</th>
<th>Doubler</th>
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<tbody>
<tr>
<td>C1</td>
<td>pump</td>
<td>pump</td>
</tr>
<tr>
<td>C2</td>
<td>input buffer</td>
<td>output reservoir</td>
</tr>
<tr>
<td>C3</td>
<td>output reservoir</td>
<td>input buffer</td>
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<tr>
<td>D1</td>
<td>polarity protection</td>
<td>startup</td>
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### TABLE 3

<table>
<thead>
<tr>
<th>$U_{in}$ (V)</th>
<th>$R_L$ (Ω)</th>
<th>$I_{in}$ (mA)</th>
<th>$U_{out}$ (V)</th>
<th>$U_{ripple}$ (mVpp)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverter</td>
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<td></td>
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<td>-2.8</td>
<td>5</td>
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<td>80</td>
<td>-1.8</td>
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<td>5.0</td>
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<td>22</td>
<td>80</td>
<td>4.1</td>
<td>100</td>
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<tr>
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<td>100</td>
<td>0.2</td>
<td>10.0</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td>5.0</td>
<td>47</td>
<td>97</td>
<td>9.5</td>
<td>100</td>
<td>95</td>
</tr>
</tbody>
</table>

Maximum output current = 100 mA.

### PARTS LIST

**Capacitors:**
C1–C3 = 220 μF, 16 V, radial

**Semiconductors:**
D1 = BAT85
IC1 = MAX660
Print files, whether they contain text, graphics or both, seem to become larger and larger as the programs that output them, and the printers that produce the 'hard copy', become smarter every day. That is all very well, but we do not want to see our ever so fast PC being held up by a simple task such as printing. The solution to this well-known bottleneck is to use a fast intermediate storage device with a large memory to capture the printer data supplied by the computer. Such a buffer is described here: it is Centronics-compatible, and offers a memory size of 1 MByte or 4 MByte.

**Main Specifications**
- Simple to use
- Compact design
- Uses industry-standard DRAMs or single SIP/SIM DRAM module
- One or four megabyte DRAM
- Power supply: internal or via printer
- Microprocessor-controlled (80C31)

Print files and the display. Address decoding and register selection is arranged by IC12, a 74HC138.

The circuit in detail
The control of the DRAM is fairly complex, and will therefore be looked at in some detail. Since an 8-bit microcontroller can address a RAM of 64 Kbyte only, some additional logic is needed if we want it to deal with a RAM of 4 MByte. Here, this additional logic consists of 2 bistables, four NAND gates and a little software.

DRAM refresh circuitry has to be added also, because it is not provided by the 8031 microcontroller. Although this would appear to call for a refresh counter implemented in software, a counting routine for 512 or 1,024 refresh cycles would, unfortunately, take too much valuable processor time. A different approach is, therefore, used.

To keep the refresh time as short as possible, the microcontroller's 'external memory access' signal is used. Since the PSEN output of the 8031 is actuated twice during every processor cycle (16 MHz/12 = 750 ns), it can be used to derive the RAS (row address strobe) signal needed for the DRAMs. Address information being available during the PSEN pulse, all that is needed further is ensuring that the correct addresses are applied to the RAMs. To arrange this, the processor jumps to a subroutine that starts at address 10001, where a sequence of 512-byte instructions is started. The only function of this part of the program is to enable the controller to increase the value on address lines A0 - A9 sequentially. This type of refresh control is usually referred to as RAS-only-refresh.

The control of the read and write functions of the DRAMs is arranged via the WR line of the microcontroller. To address a DRAM IC, the column address must be supplied before the row address. This is achieved by actuating the output of the controller's RAS-enable function (pin 15). Next,
the row address is put on to the databus with the aid of a MOVX instruction. At the same time, the controller’s WR line is pulled low, which causes the output of the bistable (pin 6 of IC18) to go low also. The signal arrives at the RAS connections of the DRAMs via NAND gate IC17 and Bistable IC18. In this way, the row addresses are conveyed to the DRAMs.

Next, the column addresses have to be supplied. To begin with, the controller’s CAS (column address strobe) enable function (pin 14) is actuated. Next, the column address is placed on to the databus with the aid of a MOVX instruction, while the microcontroller’s WR line is pulled low. This signal arrives at the CAS inputs of the RAMs via NAND gate IC17, and at the clock input of bistable IC18. In this way, the column addresses are conveyed to the DRAMs.

When the output of IC18 is actuated on the positive edge of the WR signal, this bistable resets the RAS line to its normal level. An R-C network ensures that IC18 is reset immediately after the RAS line. From then on, the microcontroller can write data into the DRAMs.

A further interesting section of the circuit is the Centronics input. To enable this to respond sufficiently fast to the computer’s strobe signal, a bistable circuit was designed that pulls the BUSY line high the instant the strobe pulse appears. At the same time, data is stored in a register. The microcontroller resets the bistable after reading the register. The fast operation of this circuit prevents data loss.

The printer buffer may be powered in two ways: by its own, internal, supply, or by the printer it is connected to. The selection between these two possibilities is made with switch S3 on the board. If CMOS components are used, the current consumption of the buffer lies between 150 mA and 200 mA.

Control software

After powering up, the internal memory of the buffer is tested. When the test is finished, the memory size is briefly shown on the 3-digit LED readout. The indication ‘1.02’ stands for 1 MByte, and ‘4.09’ for 4 MByte. By the way, these figures do not indicate that all bits in the memory function correctly; the basic memory test is too simple for that, and, based on a few random tests, serves only to determine the memory size.

As soon as the memory size has been determined, the size indication is replaced by ‘000’. At the same time, the INT line on the Centronics bus is pulled low to reset the printer to its default mode. Next, the controller waits for the strobe line of the computer to go high. When this happens, the buffer is switched to receive mode. The advantage of this sequence is that the buffer can not be loaded with incorrect data when the computer is not yet switched on, while the buffer is on.

RAM test

If it is possible to test every bit in the buffer
Fig. 3. Circuit diagram of the printer buffer. Remarkably, the microcontroller needs very little external hardware to perform a not so simple...
Fig. 4. On previous page: Track layouts (mirror images) of the component side and the solder side of the double-sided through-plated PCB. Above: component overlay.

**COMPONENTS LIST**

**Resistors:**
- 1 47kΩ
- 2 10kΩ
- 1 8-way 10kΩ SMD array
- 2 220Ω
- 8 150Ω
- 3 2kΩ

**Capacitors:**
- 21 100nF
- 2 22μF 16V
- 1 47μF 16V
- 1 220pF
- 1 330nF
- 1 100μF 16V radial

**Semiconductors:**
- 2 LED, red, 3mm
- 1 1N4001
- 3 BC557B
- HYB519000 (1MByte)

**Miscellaneous:**
- 2 36-way female Centronics connector for PCB mounting
- 2 8-way PCB terminal block (pitch 5mm)
- 2 20-way box header

**Miscellaneous:**
- 2 Digitast push-button
- 1 Change-over slide switch
- 1 Quartz crystal 16MHz:
- 1 Printed circuit board
- 1 Front panel foil
- 1 Enclosure 75-1410J (Vero)
- 1 SIMM adapter (if required)

**SMD:**
- S1/S2
- S3
- X1
- 910110
- 910110-F

**ELEKTOR ELECTRONICS JUNE 1992**
Computers and Microprocessors

Centronics connector pinning

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>DATA STROBE</td>
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<td>DATA 1</td>
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<td>3</td>
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<td>9</td>
<td>DATA 8</td>
</tr>
<tr>
<td>10</td>
<td>ACKNLG</td>
</tr>
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<td>11</td>
<td>BUSY</td>
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<td>15</td>
<td>IS</td>
</tr>
<tr>
<td>16</td>
<td>OV</td>
</tr>
<tr>
<td>17</td>
<td>OV</td>
</tr>
<tr>
<td>18</td>
<td>+5V, 50mA</td>
</tr>
<tr>
<td>19-29</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>GND</td>
</tr>
</tbody>
</table>

Fig. 5. Centronics connector pinning. Check this against the data given in the manual that came with your printer.

Construction

The PCB section that forms the keyboard/display (controls) unit is cut off from the board supplied through the Readers Services. The artwork for the double-sided, through-plated board is given in Fig. 4. The completed controls board is fitted behind the front panel of the Vero enclosure. When the LED displays are fitted in IC sockets, they are at about the same height as the key caps of the push-buttons.

There are several options in regard of the buffer RAM. One is to use so-called SIM modules (SIMMs), which are commonly used in PCs. These are available as 1-MByte or 4-MByte modules with a ‘width’ of 8 or 9 bits. SIMMs have PCB edge connectors like PC extension cards, and require a special adapter with snap-in side latches (Fig. 6) to enable them to be mounted on to the main printer buffer board.

SIP modules are equally suitable, and also come in 1-MByte or 4-MByte, and 8- or 9-bit, versions. Having pin connections, they do not require adaptors to be fitted on to the board.

The last memory option is to use eight 1-Mbit or 4-Mbit RAM ICs in DIL packages. Unfortunately 4-Mbit ICs like the MT4C1004 are still pretty expensive and difficult to obtain. If you can get them, make sure that they are 18-pin DIL types — it appears that the enclosure is not the same with all manufacturers. Finally, it is not possible to fit both a module and discrete RAMs at the same time, for instance, to create a RAM of 2 MByte.

Practical use

Connect the input of the printer buffer (K1) to the Centronics output of the computer, and the output of the printer buffer (K2) to the input of the printer. These connections are made with standard Centronics printer cables.

The amount of data sent to the printer buffer is shown on the display, rounded to whole kilobytes. The printer buffer starts to feed out data immediately if it finds that the printer is 'on line'. This may be stopped by pressing the CLR key, whereupon the display reads 'Cir'. Next, the data in the buffer is cleared, and the display indicates '000' again.

The copy function of the printer buffer may be used to produce copies of the print file. This function is available only when the computer is not sending data any more, and the printer has read all data from the buffer. The copy function is automatically disabled when a memory overflow occurs, so that only files that fit in the buffer memory can be printed more than once (i.e., copied). The copy function is started by pressing the 'COPY' key, whereupon the associated LED will start to flash. Copying can be terminated at any time by pressing the 'CLR' key, and started again by pressing 'COPY'. If, however, the 'CLR' key is pressed a second time, the buffer memory is cleared, and the printer is initialised. Since it is required for the copy function that the last received file is duplicated (rather than the complete contents of the buffer memory), the control software contains a strobe-timeout routine that marks the start and end addresses of a file, about 40 s after the last strobe signal received from the computer.

Fig. 6. A bracket-style adaptor as shown here is required if you want to use a SIM module.
MULTI-PURPOSE Z80 CARD

PART 2: CONSTRUCTION AND TEST

Following last month's description of the system structure and the circuit diagram, this second and last instalment looks at building and testing the card.

Design by A. Rietjens

Test routines in BIOS

The card can be tested with the aid of a number of routines contained in the BIOS. These test routines are called automatically when only the BIOS is present. However, they may also be run when an application program is executed that starts up the card. All that is required to call the tests is to keep a key pressed while the system starts. The way in which the application is called offers the possibility to change the I/O routines (to a certain extent) for your own use. This is so because two routines contained in the application EPROM are called when the system starts: the first before, and the second, after, the test routines. For example, the first routine may set up a key code translation table for the IR receiver, which may be verified via the keyboard test routine. The second routine then contains the application proper.

Software support

The diskette available for this project (MSDOS 360 KByte 5¼-inch; order code 771) contains examples that demonstrate the practical use of some of the software features discussed earlier. Among the examples are the things you have to put in an EPROM to enable it to be identified by the BIOS, and a software 'hook' that adds a routine to the 10-ms interrupt of Timer 3.

Also contained on the disk are the Turbo Pascal procedures used to produce the basic functions of the RS232 interface. After switching on the card, the baud rate and transmission format are automatically set to 2400 bit/s, 8 data bits, no parity, 1 stop bit.

The disk contains a file that enables owners of an EPROM programmer to burn their own BIOS EPROM. Those of you who do not have an EPROM programmer may obtain the BIOS EPROM through our Readers' Services as item 6121. The BIOS file is also required when you wish to use 64 KBytes of RAM, since in that case the BIOS and the application are both contained in a single 27256 EPROM. How the two are combined is explained on the diskette.

The source code (assembler file) of the BIOS is not contained on the diskette; only a list with call addresses is provided, and instructions for use.

Connections to the outside world

Your own hardware experiments may be connected to the Z80 card via flatcables. Care should be taken to observe the polarity of the IDC headers on the cables, and the box.

Fig. 7. There is nothing mysterious about fitting an IDC connector on to a flatcable. As shown here, a small wise does the trick. For IDC plugs, make sure that the pins are temporarily inserted into a few pieces of stripboard.

SOFTWARE SUPPORT

The multi-purpose Z80 is supported by the following software:
- ESS 6111: a set of two GALs for address decoding and memory decoding;
- ESS 6121: one programmed 27128 EPROM containing the BIOS;
- ESS 1711: one 5¼-inch 360-KByte MSDOS diskette containing the following files:
  - description of BIOS calls with examples (if necessary depending on the routine's level of complexity);
  - example of how the BIOS file can be incorporated in your own source code file;
  - description of the system variables;
  - EPROM listing of the BIOS in hexadecimal and binary format;
  - assembly programming examples of (1) a 'hook' and (2) an EPROM definition for your own application;
  - description of how to put the contents of two EPROMs into a single 27256, so that 64 KByte RAM may be used;
- ESS 1711: one 5¼-inch 360-KByte MSDOS diskette containing the following files:
  - description of BIOS calls with examples (if necessary depending on the routine's level of complexity);
  - example of how the BIOS file can be incorporated in your own source code file;
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  - example of how the BIOS file can be incorporated in your own source code file;
  - description of the system variables;
  - EPROM listing of the BIOS in hexadecimal and binary format;
  - assembly programming examples of (1) a 'hook' and (2) an EPROM definition for your own application;
  - description of how to put the contents of two EPROMs into a single 27256, so that 64 KByte RAM may be used;
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COMPUTERS AND MICROPROCESSORS

RS232 CONNECTIONS

<table>
<thead>
<tr>
<th>K11</th>
<th>D9-Connector (female)</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
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<td>6</td>
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<td>9</td>
<td>6</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 8. The Hitachi LM092LN LCD is simple to connect via a 16-way flatcable with an IDC plug at one side, and an IDC socket at the other.

Fig. 9. Pinning of K10 (Z80 card) and the LCD. If necessary, the LCD backlight may be powered separately via flatcable wires 15 and 16 (see text).

Fig. 10. Refer to this pinning overview in case you are forced to use a solder type 9-way sub-D connector for the RS232 link.

Fig. 11. A standard 9-to-9 male-to-female RS232 cable is not difficult to make from a length of flatcable and two IDC connectors.

Liquid crystal display
The PCB connector for the LCD also provides the supply voltage for back-lighted displays. The LCD type given in the parts list is the easiest to use since it may be connected via a 'straight-through' 16-way cable. One end of a piece of 16-way flatcable is fitted with a normal IDC socket, and the other end with an IDC plug for PCB mounting (see Fig. 8). As already mentioned in last month's instalment, almost any LCD with one or two lines of up to 40 characters, with or without back-lighting, may be used. Although the pin functions of the LCDs seem to be standardised, the actual positions of the pins may differ. The back light must be an LED (there are also LCDs around that use a higher voltage for the back light). Depending on whether current drive or voltage drive is required, resistor Rz1 is calculated to pass the required current, or it is short-circuited. If the back light is powered via two separate connections instead of two wires in the flatcable, it is best to split wires 15 and 16 from the flatcable, and solder these directly (wire 15 = BL = anode; wire 16 = ground = cathode). The LCD connections are given in.

The components list contains all connectors and flatcables necessary for the applications implemented on the Z80 card. The cables required are described below.

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Fig. 8. The Hitachi LM092LN LCD is simple to connect via a 16-way flatcable with an IDC plug at one side, and an IDC socket at the other.
In this section, we will discuss various components and their fitting. Before populating the board, take a look at the photographs in this and last month’s instalment. If the LCD module may be fitted on a front panel, together with the LCD. It is then best mounted on a small aluminium plate, which is secured to the rear side of the LCD. This requires the connections to the LED and the photodiode to be extended with wires to enable these components to be fitted on the front panel (see Fig. 13).

Printer connections

There are two printer connections: a standard one, PRN, and another, PRN’, for specific applications. Figures 14 and 15 illustrate how the PRN connector is wired to a 25-way female D connector, to which a standard Centronics printer cable may be connected.

Battery backup

The memory backup battery may be either a dry cell, a rechargeable battery, or a lithium battery. Depending on the battery type used, one or two jumpers have to be fitted (Fig. 16).

Make sure that the jumpers are correctly fitted, because dry cells and lithium batteries must never be charged. When a lithium cell is used, this must be shunted by a 3.3-MΩ resistor to compensate the leakage currents that would otherwise cause the battery to be charged. Although we could not measure the charge current even at a resolution of 0.1 µA, it could be shown that the lithium battery on our prototype board was being charged, hence the use of the shunt resistor to prevent problems. The 3.3-MΩ resistor is best fitted at the solder side of the PCB.

The minimum and maximum battery voltages are 2 V and 4 V respectively. When the system is switched on, the current consumption of the RAM ICs is between 2 µA and 4 µA.

Construction and test

The PCB designed for this project is remarkably compact, and fits in a Retex Type RE.4 enclosure. Although the track layouts of both sides of the PCB are given in Fig. 17, along with the component mounting plan, it is not recommended to make this PCB yourself, mainly because of the high track density and the large number of through contacts.

Before you start populating the board, file away a small piece of PCB material near connector K2. This allows the supply wires to be bent away more easily later.

The ICs are best fitted last. It is recommended to use boxheaders in the connector positions on the board. A boxheader is a pin header with a plastic enclosure around it. It has a polarizing hole that prevents an IDC socket being inserted the wrong way around. If you have never seen a box header before, look at the photographs in this and last month’s instalment. If the LCD mentioned in the parts list is used, fit a wire jumper in position R21.

First, connect the Z80 card to a suitable power supply, and check that the current consumption is normal, i.e., a few milli-amps (the ICs are not fitted as yet). Next, perform the step-by-step test procedure given below.

Each time you switch on the card, keep an eye on the current consumption, which is a good indicator when something is amiss. The typical current consumption of the Z80 card with all IC fitted will be around 100 mA; about 150 mA with the PC-XT keyboard connected, and about 300 mA with the keyboard and the back-lighted LCD connected.

Do not forget to switch off the power supply in between the steps. If the circuit does not behave as described, check for errors in the component(s) last fitted.

1. Fit IC16, and use an oscilloscope to check that the oscillator works (pin 6).

2. Fit the following ICs and jumpers: IC1 (Z8000-CPU); ICs and IC9 (Z80 decoder 1 and Z80 decoder 2; GALs; order code 6111). IC9 (bankswitching); JPi to JPs at the ROM-select side. Set the memory configuration to '0' by fitting the 'con-0' jumper in position '0', and the 'con-1' jumper in position '0' also.

3. Fit IC1 (EPROM ESS 6121, a type 27128), and the LCD. Before re-applying power, temporarily connect the cathode of D5 to ground, and set PI to mid-travel.

When power is applied, the Z80 runs a RAM test. Since there is no RAM as yet, the result is negative, and the processor is switched to the 'halt' status, which is retained because no interrupts have been initialized as yet. Thus, if the card works correctly so far, the 'halt' LED must light.

The LCD is not yet initialized, but will indicate an empty line and a black line when...
correctly connected. If nothing shows on the LCD, try to adjust the contrast by turning preset Pi. If this does not work, review the LCD connections. If you are using a back-lit LCD, concentrate on the LED current. Measure the current consumption via the jumper marked 'LCD' — typical values are of the order of 120 mA to 150 mA. When current drive is used, the value of R21 must be determined by experiment. Fit jumper ‘LCD’ if you wish to have the back light on permanently.

4. Fit IC1 (a 43256 32-KByte RAM), IC7 (Z80B-PIO), IC5 (Z80B-CTC), jumper BZ, IC10 (MAX690), a jumper on pins 4 and 5 of K14; IR receiver and/or keyboard. After applying power, the 'halt' LED will not light permanently any more, which indicates that the upper addresses (08000H to 0FFFFH) in the RAM are 'good.' (by the way, the RAM test is non-destructive, i.e., any data that was present before running the test remains intact and at the original location).

When this part of the RAM test is successfully completed, a copyright message is output to LCD, informing you that 32 KBytes of memory have been found. Also, a beep sounds to indicate that the I/O has been initialised. Next, a second RAM test is run to check for the presence of RAM in parallel with the EPROM (10000H to 17FFFH). After this test, a memory overview is shown. If no additional memory is found, the 'halt' LED lights briefly. If additional memory is found, a second beep sounds. The parallel RAM

<table>
<thead>
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<th>Pin number (K14)</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
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</table>

Fig. 16. Battery options and jumper settings.

Fig. 15. Centronics printer cable details.

Fig. 17a. Component side track layout (mirror image).
configuration is allowed in memory configurations 1, 2 and 3 only. Since we have set configuration '0' for the moment, no parallel RAM will be found, so that the RAM test will indicate 32 KByte, and only one beep sounds.

At this point, the Z80 card is in a wait cycle, which is left when a key is pressed on the keyboard. Next, the screen is cleared, and the system is in the display and keyboard test procedure.

The system tests the LC display as follows. Characters typed on the keyboard are displayed in the top line of the LCD. Next, the character is read back from the LCD, and copied to the same position in line 2. When a line is full, it is cleared for a short period, which results in the display flashing on and off while all positions show the last typed character. In this way, the system tests the read and write functions of the display.

When the ESC key is pressed, or the channel '1' key on the IR transmitter, the system switches to the next test routine. The system now responds to keyboard entries by beeping when a key is pressed, and displaying the character on the LCD. This test allows you to check that the keys work and produce the right codes.

5. Fit IC12 (COM81C17), and IC13 (MAX232). Before applying power, remove the wire between the cathode of D5 and ground, and set Pt to mid-travel. The RS232 interface is tested by connecting it to itself: connect RxD to TxD, and CTS to RTS. This is readily done by fitting two jumpers on the 10-way box header: link pin 3 to 5, and pin 4 to pin 6.

After powering up, readjust Pt. Skip the first two tests by pressing the ESC key three times. In this way, you enter the RS232 test routine, which is basically the same as the LCD test. Typed characters are sent and received (echoed) via the RS232 interface. If the jumpers are not fitted, you will only hear beeps, and no characters will appear on the LCD.

6. Fit IC11 (AD7569), and connect a 100-kΩ potentiometer and a multimeter to K1, as shown in Fig. 18.

After powering up, step through the test routines by pressing the ESC key until the A/D/D-A test routine is reached. The voltage reading on the multimeter must change proportionally as you turn the potentiometer. The voltage range is 0 V to 2.5 V when no jumper is fitted on pins 1 and 3. If the jumper is fitted, the range is 0 V to 1.25 V (in which case half of the travel of the potentiometer 'does nothing').

7. Fit IC16 (74HCT574) and IC17 (74HCT541). Press the ESC key as many times as necessary to arrive at the printer test routine. The message 'Test printer Y/N' appears. If you type 'Y', the Z80 card transmits three lines of text to the printer. An error message is produced when the printer is not connected. If everything is all right so far, the system prints the text shown in Fig. 19. When the system has finished printing the text, you are
If you expect to exchange EPROMs frequently, it is worthwhile to invest in a ZIF socket. Do not solder this straight on to the board, but use two or three stacked, normal, sockets in between. This has the advantage of being able to unplug the ZIF socket later, and use it in another circuit (removing an IC socket from a double-sided board is fairly difficult).

The description of the BIOS on the disk supplied for this project is sufficiently detailed to use the file, or parts of it, in your own source code. In many cases, the infor-
### COMPONENTS LIST

#### Resistors:
- 5-way 10kΩ SIL array: R1
- 12 10kΩ: R2, R3, R4, R10
- 10kΩ: R11, R12, R14
- 10kΩ: R18, R20, R23, R24
- 3kΩ: R31
- 1kΩ: R1, R2, R3, R4
- 47kΩ: R5, R6, R9
- 100kΩ: R7
- 1kΩ: R12, R13
- 2kΩ: R15, R16
- 10kΩ: R21
- 10kΩ: R22
- 10kΩ preset V

#### Capacitors:
- 68pF: C1, C2
- 10μF 16V radial: C3, C7
- 100μF 16V radial: C10, C13, C15, C27
- 220μF 16V radial: C14
- 50μF: C16

#### Semiconductors:
- LED red 3mm: D1
- BAT85
- 1N4001
- BC557B
- BC5478
- 27128 EPROM (Bios): IC1
- 27256 EPROM: IC2
- 43256 RAM: IC3
- Z80B-CPU: IC4
- Z80B-CTC: IC5
- Z80B/P/O: IC6, IC7
- 16V GAL: IC8
- 18V GAL: IC9
- MAX690: IC10
- AD7569: IC11
- COMB1C10: IC12
- MAX232: IC13
- 74HCT245: IC14, IC15
- 74HCT574: IC16
- 74HCT414: IC17
- 74HCT404: IC18
- 74HCT774: IC19
- 74905: IC20, IC21
- 7474: IC22

#### Miscellaneous:
- 6-way PCB-mount DIN socket: K1
- 10-way boxheader: J1
- 16-way boxheader: J2
- 20-way boxheader: J3
- 20-way boxheader: J4
- 20-way boxheader: J5
- 5-way PCB mount DIN socket: K1
- 5-way PCB mount DIN socket: K10
- 5-way PCB mount DIN socket: K11
- 5-way PCB mount DIN socket: K12
- 5-way PCB mount DIN socket: K13
- 5-way PCB mount DIN socket: K14

#### Options:
- RC-5 infra-red receiver (Ref. 2; 910137)
- Infra-red transmitter Policom IRC301
- PC-X1 keyboard
- mains adapter 9-15V 3.1A

---

**Fig. 19.** Printer test text.

**Fig. 20.** Folded flatcables give a neat impression and add considerably to a 'professional look'.

**Fig. 21.** Holes in the side panel give ready access to sockets K1 and K12, and preset P1

Information contained on the disk, together with the variables and the associated addresses set up by the BIOS, will prove extremely useful to write a program quickly and efficiently.

Talking of future applications, the present Z80 card will form the 'brains' of an advanced photographic slide control system to be described in a forthcoming issue of *Elektor Electronics*. The system, called DiAV (for Digital Audio/Visual), is capable of controlling up to 16 slide projectors. Note that the GALs and the EPROM required for the DiAV controller are not the same as the ones used here, and order codes will be published in due course. The DiAV requires a 32-KByte RAM (43256) to be fitted on the Z80 card.
ANALOGUE circuit design is traditionally difficult because all designs have to be tested to confirm that they work as desired. Even more difficult is the ability to conduct the sheer infinite number of tests over the full frequency spectrum that the design is intended to work over. Furthermore, the time spent on building breadboarded prototypes to conduct the tests on is pretty expensive in most cases. One way to cut on development costs is to use a computer simulation of the design and analyse its performance in theory before anything is built. Fortunately, computer programs to do this have descended from ‘higher spheres’ to a level where one encounters the intrepid hobbyist.

Analyser III is a fast, advanced and easy to use Linear Analogue Circuit Analysis program. The package allows electronic designs to be tested without soldering a single component and, often more important, without the need for expensive test equipment. The circuit design can be tested on a PC and modifications made until the circuit functions as required all without using a soldering iron in anger, or blowing up any expensive devices.

The system is ideal for the analysis of filters, amplifiers, cross-over networks, wideband amplifiers, aerial matching networks, radio and TV IF amplifiers, chr-monotone filters, linear integrated circuits, etc. Analyser III also has advantages over physical test equipment in that it allows analysis over a frequency range from 0.001 Hz to 999 GHz, showing gain, phase, group delay, and input and output impedances.

The system is designed to be basically a menu-driven program, where the user can easily access any menu of items via a mouse or keyboard. The 'Grand Tour' comprises the greater part of the user manual and gives an outline of the screen presentations and some of the basic commands used to manipulate these screens and move around in them. Once the user is familiar with these basic commands, it's on to the next section, 'The Grand Tour'.

The user manual

The comprehensive user manual is packaged in an A5 ring binder, which allows the easy insertion of upgrade instructions, personal notes, etc., and follows the established pattern of Number One Systems' program documentation (see photograph). The first few pages of the manual deal with an overview of Analyser III, the installation and running of the program.

The section in the manual is called 'First Impressions' and gives an outline of the screen presentations and some of the basic commands used to manipulate these screens and move around in them. Once the user is familiar with these basic commands, it's on to the next section, 'The Grand Tour'.

'The Grand Tour' comprises the greater part of the user manual and takes the user through a step-by-step simulation: from entering the initial design netlist to the final proven circuit. To assist with the instruction, a predesigned simple passive twin 'T' notch filter circuit is used as a practical example, from which a netlist is composed.

A netlist is a file of connections between the various components within the circuit, their values and any other associated parameters, such as small-signal gain (life) or transition frequency (ft), for example, for a bipolar transistor. The libraries supplied within Analyser III contain ready-made netlist outlines for many basic circuit structures and various popular bipolar and Fet transistors, opamps, etc.

After the comprehensive chapter dealing with netlist editing and production, the next section in the manual tackles the actual operation of the analyser. To begin with, you need to select the input and output connections. Next, Analyser III calculates and displays the frequency and phase response curves of the circuit. Initially, the display defaults to a frequency range of 1 kHz to 1 MHz, but this range, and any other of the display parameters, can be changed simply by a few clicks of the mouse button or keyboard presses, which are explained in detail in the next section of the manual.

The 'Grand Tour' then continues with the various different displayed parameters available, such as group delay, vector selection, scaling the various plots, including offsets in the analysis, using the display grids and tabulating the results.

The remaining sections of the user manual deal with printing out the plots, converting circuits to single components for inclusion in more complex circuits (e.g., using the notch filter in the feedback loop of an amplifier) and adding them as library entries, using the libraries, customising Analyser III to your exact requirements, using the DOS browser and, finally, a list of the built-in library component entries is given.

The analyser

Once a circuit netlist has been created and the input, output and ground connections established, Analyser III simulates the circuit operation and displays on the screen a plot of the frequency and phase versus gain such as one would see displayed on a circuit analyser or spectrum analyser, but only after the circuit had been built.

The 'tilde' key (~) will trigger a printout of the current screen (including any menus, etc.) in 'extra' dot-matrix Laserjet
or GEM format, as defined in the Configuration menu.

The display screen is divided into three main areas. The top of the screen contains the main menu, showing Analyser III's top-level commands, with the currently active mode highlighted. The program defaults to the analyser mode on start-up. The other modes are:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Customises Analyser III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Libraries</td>
<td>Maintains Component libraries</td>
</tr>
<tr>
<td>DOS</td>
<td>Manipulates Files and Directories</td>
</tr>
<tr>
<td>F1</td>
<td>Help (on-line help information)</td>
</tr>
<tr>
<td>Quit</td>
<td>Leave Analyser III</td>
</tr>
</tbody>
</table>

Also shown in the menu area are the file name of the circuit currently being analysed, the frequency limits of the analysis, the number of steps in the analysis and whether the scales are logarithmic or linear.

**Configuration:**
This command selects a set of menus which allow the default parameters for Analyser III to be set according to the user's choice. The default search paths for files, the time and date format, etc., can all be preset by the user, and the configuration saved.

**Libraries:**
The library command allows the various libraries to be scanned and manipulated.

**DOS:**
Selecting this command displays a menu of basic DOS commands which are available for use without leaving Analyser III. Also selectable is a DOS Shell, which allows you to exit Analyser III to the DOS prompt, but without losing any data currently held in Analyser III. Quitting the DOS Shell returns you to Analyser III, exactly where you left it.

**F1 (HELP) and QUIT** are self-explanatory.

The main area of the screen is devoted to the analyser display with the moveable cursor.

At the bottom of the screen is a submenu of control commands for the different plots, a display of the relative level of the plot and the scaling factor for the Y axis.

With Analyser III the only limitation to the frequency range of the analysis is that it lies within the limits 0.001 Hz to 999 GHz! In other words, just about any circuit that you care to analyse can be accommodated within Analyser III's capabilities. Having spent most of my working life in electronic test laboratories, I think I can safely say that I do not know of any circuit or spectrum analysis equipment that will directly look at frequencies much above 100 GHz, let alone 999 GHz! The usual way to perform such tests is to down-convert the final signal before conventional display analysis, and that system has all sorts of inherent inaccuracies present. Also, it would have to be 'normalised' to eliminate the effects that the down-conversion has on the display. Finally, the circuit has to be prototyped and built before such analysis can take place.

**The libraries**
As I mentioned earlier, there are built-in libraries in Analyser III, which make the creation of netlists much quicker. The libraries are:

1. **PRIM.ALB:** a library of all the basic device models.
2. **DEVICE.ALB:** this library contains a selection of 'real' device models. All the components in this library are made up from the primitive elements in the PRIM.ALB library with the appropriate parameters set. As there are many thousands of different devices, and every engineer has his/her particular favourites, this library is really intended as a set of examples to help the user create his/her own personal set of libraries.

After building up netlists for a circuit, and subsequently naming the component type being used, Analyser III responds by reading the pin and parameter information from the library for the device. All you have to do is enter the various connection details.

Circuit blocks previously designed and tested can be added to the libraries, which is very useful if you require a particular circuit, or part of a circuit, more than once.

**Conclusions**
After having familiarised myself a little with the concept of a netlist, I successfully created the one for the example circuit. Following the instructions I then connected my inputs and outputs, and Analyser III analysed the circuit and presented the plots on the screen.

It soon became evident to me that the facilities available are quite extensive. Using conventional circuit and spectrum analysers often as I do, I can imagine that in a development environment Analyser III would be far more ideal. The fact that a design circuit does not actually have to be built would be one great advantage. That, coupled with the ability of Analyser III to analyse the circuit over as wide a frequency spectrum as you like, plus the ability to change devices in the circuit for re-analysis, could prove a great boon to circuit designers.

I can heartily recommend Analyser III to anyone engaged in linear circuit design and testing work. This software enables a designer to test a circuit ideally up to the production stage, without even raising a soldering iron in anger and committing any devices to the breadboard, or dustbin! I wish to thank Mr. Espin and the staff of Number One Systems Limited for their help and advice, and for the review software.

**ANALYSER III** is priced at £195.00 + VAT and is available from: Number One Systems, Harding Way, St. Ives, Huntingdon, Cambs PE17 4WR, England. Telephone: (0480) 61778. Fax: (0480) 494042.
In this instalment of the course we will deepen our knowledge of the 8051 instruction set, and also get to grips with the concept of bit addressing. The new instructions allow programs to be written with 'real world' applications such as the control of a small servo motor in a model boat, and outputting an analogue voltage. Both applications make use of the hardware extensions described in last month's instalment.

Flags and bit addressing

It is often required for a program to wait for a certain signal to change state, which is called a condition. Such a conditional signal may be supplied by an external source, for instance, the output of a comparator, which is connected to an input port line. It may, however, also be internal, i.e., a bit or a flag, for instance, bit 3 in the accumulator (written as ACC.3). The 8051 family of microcontrollers offer a number of instructions for bit addressing and logic bit manipulation (for instance, an OR function) that allow bit states (0 or 1) to be evaluated in a simple way.

The microcontrollers in the 8051 series can address 256 bits in the range 00H to 0FFF. As with direct addressing, the function of the addresses smaller than or equal to 127 is different from those greater than 127. The addresses from 0 to 127 are used to address bits in the internal RAM. Bit address 0 corresponds to bit 0 of the byte at address 20H in the internal RAM. Likewise, bit address 127 corresponds to bit 7 of the byte at address 2FH in the internal RAM. Hence, the 16 bytes 20H to 2FH of the internal RAM store bits 0 to 127 (see Fig. 5 in part 1 of the course).

Bit addresses 128 to 255 enable bits in the special function registers (SFRs) to be addressed. The effective bit address is the sum of the SFR address and the bit number to be addressed. Thus, bit address 0E3H is used to address bit 3 in the accumulator (SFR 0E0H). The assembler used during this course does all the adding automatically if you use the so-called point notation, which means that a point is inserted between the SFR and the bit number. For example:

```
JB ACC.3,THERE
```

Note, however, that this requires an EQU statement for the accumulator SFR address to be assigned to constant 'ACC'. Only those SFRs whose address ends with three '0' bits are bit addressable; these are the SFRs marked with an asterisk (*) in Fig. 8 (see part 2).

Instructions that change flags

```
MNEMONIC | C | OV AC
ADD        | x | x | 
ADD<3>     | x | x | 
SUBB       | x | x | 
MUL        | 0 | x | 
DIV        | 0 | x | 
DA         | x | 
RRC        | x | 
RLC        | x | 
SETB 0     | 1 | 
CLR 0      | 0 | 
CPL 0      | x | 
ANL 0,b    | x | 
ANL C,b    | x | 
ORL 0,b    | x | 
ORL C,b    | x | 
MOV C,b    | x | 
CMJE

x = flag changed
1 = flag set
0 = flag reset
/b = inverted bit combined
```

Note: flags also changed by writing to SFR address 0D0H.
### Program status word (PSW)

The program status word, PSW, is stored at SFR address ODOH in the 8051. The PSW contains bits (flags) that indicate, for instance, whether or not a carry has occurred as a result of a subtraction. This information is stored in bit 7, and can be accessed via bit address PSW.7. This bit, which is also called the C-Flag, can be addressed via many bit manipulation instructions. Since it contains the result of logic bit combination operations (OR, AND and NOT), the C-Flag thus forms a kind of one-bit accumulator for bit manipulation.

The parity bit, PSW.0, is set when the accumulator contains an odd number of ones. The flags OV (PSW.2) and AC (PSW.5) have checking functions when signed numbers (e.g., BCD numbers) are used. Bits 3 and 4 in the PSW allow the programmer to determine which register bank is addressed. Since only bank 0 is used during this course, these bits should not be changed. Bits 1 and 5 are free for general use and may be set and interrogated as required.

Figure 13 shows an overview of the bit functions and identifications, and Fig. 14 a list of instructions that change the flags in the PSW.

### Conditional jumps

Conditional jump instructions are used to perform certain functions in a program, depending on the state of certain external signals or occurrences. The conditional jump is made when the relevant condition set up by the instruction is fulfilled. If the condition is not fulfilled, the program simply continues with the next instruction. Practical examples of the use of conditional jumps may be found in XAMPLE06.A51 and XAMPLE07.A51 on your course disk.

The respective list files are given in Figs. 20 and 21. The microcontrollers in the MCS-51 series offer the following conditional jump instructions:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JZ addr</td>
<td>Jump to addr if ( \text{accu} = 0 )</td>
</tr>
<tr>
<td>JC addr</td>
<td>Jump to addr if carry flag (PSW.7) is set</td>
</tr>
<tr>
<td>JB bit,addr</td>
<td>Jump to addr if bit at bit address is 1</td>
</tr>
<tr>
<td>IBC bit,addr</td>
<td>Jump to addr if bit at bit address is 0 as JB, but clear bit</td>
</tr>
</tbody>
</table>

The first three of these instructions are also available in the form of a negative condition, marked by a preceding 'N'.

Conditional jumps are 'short' jumps, i.e., they can be used for an address difference within the range +127 to -128

### Compare instruction

The 'compare' instruction of the 8051 takes the form of a conditional jump:

\[
\text{CNJ} \text{op1,op2,addr} \quad \text{jump to address if op1 is not equal to op2}
\]

The operands that may be used are given in the instruction set overview. This instruction is particularly useful to direct the program flow depending on whether a certain

### Logic combinations

The MCS-51 microcontrollers offer the following instructions to perform logic combinations: OR, AND and XR (exclusive OR). The logic combination comprises all bits of both operands. They are:

- ANL target,source: target replaced by (target AND source)
- ORL target,source: target replaced by (target OR source)
- XRL target,source: target replaced by (target XOR source)

Again, the possible operands (source and target) are taken from the instruction set overview. Assuming, for instance, that the accumulator contains the value

\[10010111_2 = 97_{10} = 151_{H}\]

and register R0 the value

10010111_2 = 97_{10} = 151_{H}
1110010B = F2H = 242,

the logic operators give the following results:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>ANL A,R0</th>
<th>ORL A,R0</th>
<th>XRL A,R0</th>
</tr>
</thead>
<tbody>
<tr>
<td>A before:</td>
<td><code>10010111</code></td>
<td><code>10010111</code></td>
<td><code>10010111</code></td>
</tr>
<tr>
<td>R0 before:</td>
<td><code>1110010</code></td>
<td><code>1110010</code></td>
<td><code>1110010</code></td>
</tr>
<tr>
<td>A afterwards:</td>
<td><code>10010010</code></td>
<td><code>11110111</code></td>
<td><code>01100101</code></td>
</tr>
</tbody>
</table>

The ANL instruction may be used, for instance, to reset (clear) certain bits in a byte, without changing the others. Likewise, the ORL instruction is used to set certain bits. The setting or resetting of certain bits in a byte is called masking. This technique is used, for example, to check if one of the bits 0, 1, 2, or 7 in the accumulator is set, as shown in the programming example:

```
ANL A, #10000111
JNZ set
; mask bits 7, 2, 1 and 0
; A not 0 when one of these bits is set
```

The operation of the related instructions

- CLR A: clear accumulator
- CPL A: invert bits in accumulator

speaks for itself.

**Bit manipulation instructions**

The bit manipulation instructions

- CLR bit-operand: clear bit
- SETB bit-operand: set bit
- CPL bit-operand: invert bit
- ANL C, bit-operand: C replaced by (C AND bit)
- ORL C, bit-operand: C replaced by (C OR bit)
- MOV bit, operand: bit replaced by C
- MOV C, bit-operand: C replaced by bit

allow single-bit manipulations to be carried out on bytes. Their usage is similar to that of the logic manipulations. The C-bit (bit 7 in the PSW) is used as a result register. The bit manipulations are often used to set or reset single bits, for instance, of an output port, without affecting the state of the others.

**Testing a servo motor**

The function of the program given in the assembly file XAMPL06.A51 is to generate pulses to control a servo motor that operates the rudder in a remotely controlled model boat. Fig. 15 shows the timing of the pulses involved. As you can see, it is required that the program generates 'short' pulses of 800 µs when push-button 'A' is pressed, and 'long' pulses of 1600 µs when push-button 'B' is pressed. These pulse lengths result in the rudder being turned to the left and the right respectively. To keep the rudder fixed in the centre position (i.e., to make the boat sail straight on), the program generates pulses with a length of 1200 µs. The pulses are separated by 10-ms long pauses.

For this example application we make use of the hardware extensions described in last month's installment. Push-buttons 'A' and 'B' are realized with the aid of
of the push-buttons. If push-button 'A' is pressed, bit 7 in the accumulator has a '0', which sets up a condition evaluated by line 16.

Depending on which push-button is pressed, the value written into register Ri indicates the length of the individual pulse. In line 23, the output bit, P1.0, is set to '0'. This causes the MIDI output to go high (positive), and the pulse starts.

The subroutine 'WATT' called in line 24 provides the delay that determines the pulse length. When the required time has elapsed, the pulse is ended with the aid of the instruction in line 25. The previously discussed bit manipulation instructions are used to set and reset the output bits.

Next, a pause of about 10 ms is created by calling subroutine 'PAUSE'. When the pause has elapsed, the program jumps to 'NEW', and starts again.

The two timing loops in the program (one for the 'mark' time and one for the 'space' time) are implemented with the aid of the DJNZ instruction.

If you do not have a servo, it is, of course, possible to test the program by connecting pin 4 of K5 to an oscilloscope. A small modification will enable the program to be used as a simple sound generator. All that is required is to change line 36 into

```
MOV R2,#1
```

and change bit P1.0 into bit P1.1 in lines 23 and 25. This causes the loudspeaker (connected to P1.1) to produce a sound of which the frequency depends on the push-button pressed.

It goes without saying that the above changes to the program can be taken further by those of you who want to generate
signals with a specific pulse length or pulse order. The first step towards a programmable pulse generator has been taken.

**Counting**

The following instructions are available to count within the range of one byte, i.e., from 0 to 255:

- **INC Byte-operand**: increment byte by 1
- **DEC Byte-operand**: decrease byte by 1
- **INC DPTR**: increase 16-bit DPTR by 1

As usual, the byte-operands that may be used are given in the instruction set overview in part 2. The INC and DEC instructions do not change any of the flags, including the carry flag. Increasing the value 255 results in 0, and decreasing 0 results in 255. A simple application of the DEC and INC instructions may be found in XAMPL07.

The INC DPTR instruction is often used to implement successive addressing of tables in the program or data memory.

**Testing the D-A converter**

Fig. 18 shows the functional diagram of the digital-to-analogue (D-A) converter on the extension board. The output voltage of the R-2R ladder network is buffered at the analogue output, and also fed to the input of three comparators (the diagram shows only one of these). This set-up allows the

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**Below:** One of our readers, Mr. W. Otten of Germany, sent us this photograph of his remote-controlled model truck 'loaded' with an 80C32 SBC, batteries and a number of home-made extension cards.
output voltage of the DAC to be compared to the voltage applied to inputs 1, 2 or 3. The function of program XAMPLE07 is as follows: generate an output voltage that can be increased or decreased by pressing push-button 'A' or 'B' respectively. In addition, show the status of the comparator outputs on the three LEDs.

Summarizing, the proposed system allows us to program an output voltage, and find out if this is greater or smaller than the voltages at the three comparator inputs.

The flow diagram of the program we have in mind is given in Fig. 19. The assembly language program (Fig. 21) has a couple of instructions that may be new to you. Also, internal RAM addressing is used for the first time. Let us have a look at the listing in Fig. 21. The current value of the voltage is stored at address 050H in the internal RAM. This address is assigned the label 'DA_VALU' in line 9. When the program starts, the voltage is set to 128 in line 12. In the loop that starts with the label 'NEW', DA_VALU, i.e. the value at 050H, is sent to the DAC (lines 14, 15 and 16).

Next, the program waits 5 ms before sending the comparator output signals to the LEDs (lines 19 to 22). Lines 23, 24 and 25 serve to check if a key is pressed. If so, the program jumps to the corresponding subroutine, which causes DA_VALU to be increased (lines 32 to 36) or decreased (lines 27 to 31). In each subroutine provision is made to prevent the minimum value being exceeded, and the maximum value being increased.

Assignment

On the basis of what you have learned so far, combine XAMPLE06 and XAMPLE07 in such a way that the position of the rudder (i.e., the length of the pulses generated by XAMPLE06) can be controlled with the push-buttons, just like the output voltages in XAMPLE07.

You may also have a go at outputting a sawtooth via the DAC, or any other waveform you find interesting. This will quickly take you to a level where you will start writing your own assembly language routines, however simple to start with.

Next time: the fifth instalment of the course will address the remaining arithmetical instructions. Based on that information, we will tackle methods of implementing simple calculations with the aid of the 8051 (calculations are often required to process measured values). Part 5 will also introduce some programming techniques, including those required for receiving and transmitting (MIDI) data via the serial interface.
Elements of Passive Electronic Components

Part 2: The Iron-Cored Transformer

by Steve Knight, B.Sc.

The iron-cored power transformer is usually looked on as simply a device for raising or lowering the voltage of an alternating supply, with a corresponding decrease or increase in the current, but there is more to its functions in life than this simplistic view suggests. The transformer is an electromagnetic energy converter, whose operation is explainable in terms of the behaviour of a magnetic circuit excited by an alternating or changing current. As such, a brief review of its operational behaviour as a passive electronic component, is justified.

Faraday, in his experiments into mutual induction, which were described in the first part of this short series, used an iron-cored transformer that differed in construction from the toroidal forms we have today in nothing but possibly the technology of the core material. Essentially, in the construction of any transformer, there are two insulated windings wound upon a closed magnetic circuit of low reluctance: one winding is referred to as the primary (or input) coil, and the other as the secondary (or output) coil. In practice, there may be a number of output coils, but this does not affect the basic operational principles of the transformer. For clarity, Fig. 1 illustrates the input and output windings as being on separate limbs of the magnetic circuit, but however they are disposed, both windings are assumed to be linked by the same magnetic flux.

There is no direct connection between input and output: the transformer isolates one circuit from the other while allowing an exchange of energy between them. In addition, the transformer may be used to transform not only voltage and current, but also impedance, transforming the input circuit from the other while allowing an exchange of energy between them. In addition, the transformer may be used to transform not only voltage and current, but also impedance, which enables the transfer of maximum power through impedance matching. Further, since only alternating or changing current are transformed, the output circuit can be isolated from direct-current components in the input signal. All of these functions can be performed, with high efficiency and precision.

For power applications, the frequency range of operation is in general 50–800 Hz, but special design refinements make the iron-cored transformer of value over the audio range of 20 Hz to 25 kHz.

Voltage transformation

Because of the relatively large number of primary turns and the presence of the closed magnetic circuit, the self-inductance of the primary coil of a commonplace power transformer is large; and because of the tightness of the coupling between primary and secondary, the coils have a high mutual inductance. When the primary coil is connected to an alternating supply, the transformer will simply exhibit the characteristics of an iron-cored inductor. A current will flow and an alternating flux will be established in the core, a high proportion of which will link with the turns of the secondary. An e.m.f. of mutual induction will be set up in the secondary and, if the secondary circuit is completed through an external load, a current will flow in the load. Energy is, therefore, transferred from the input to the output circuit entirely by way of the magnetic coupling.

Assuming for the moment that we have a near-ideal component, the levels of the primary and secondary induced voltages, and respectively, will be proportional to the number of turns in the respective windings, since all the flux set up by the primary can be assumed to link with the secondary and is changing at the same rate, for both windings.

For a sinusoidal variation in the core flux of the form \( \phi = \phi_0 \sin \omega t \), the induced e.m.f.s are, from Faraday's law:

\[
\phi_1 = T_1 (\phi_0 \omega dt) = T_1 \phi_0 \omega \cos \omega t = E_1 \cos \omega t
\]

and

\[
\phi_2 = T_2 (\phi_0 \omega dt) = T_2 \phi_0 \omega \cos \omega t = E_2 \cos \omega t,
\]

where \( T_1 \) and \( T_2 \) are the turns in the primary and secondary windings respectively, and \( E_1 \) and \( E_2 \) are the r.m.s. values of the sinusoidal e.m.f.s. Hence,

\[
ed_1 = E_1 = T_2 / T_1 = n
\]

demonstrates that the ratio of the induced e.m.f.s is equal to the turns ratio. For \( n > 1 \), the transformer is a step-up, for \( n < 1 \), it is a step-down. These terms are applied to the voltage transformation ratio.

In practical transformers, the terminal voltages, designated \( V_I \), differ slightly from the induced e.m.f.s owing to the presence of effective internal resistance in both the primary and the secondary coil: the terminal voltage ratio is, therefore, not the same as the turns ratio, but the difference can be considered as negligible for most applications.

The unloaded transformer

We have noted that when the secondary terminals of a transformer are open-circuit, the primary winding behaves as a large inductive impedance, through which a small no-load current, \( I_0 \), will flow that lags the applied voltage, \( V_I \), by an angle \( \theta_0 \), which will be close to 90°. A component of this current will set up an alternating in-phase flux \( \phi \) in the core that in turn produces primary and secondary e.m.f.s, \( E_1 \) and \( E_2 \). There will be a hysteresis loss in the core when the flux is established and this loss will appear as heat, unaffected by the laminations of the core, which is designed to reduce the other loss component, eddy currents. The no-load current, \( I_0 \), must, therefore, contain an iron-loss component in addition to the true magnetizing component, \( I_m \).

The phasor diagram for the unloaded transformer is shown in Fig. 2, where \( \phi \) is taken as the reference phasor since it is common to the primary and secondary circuits. Ignoring the small difference between the applied voltage, \( V_I \), and the primary induced e.m.f., \( E_1 \), the latter will be in anti-phase with the for...
Further, the alternating flux that links with the primary turns and induces a back-e.m.f. of \(-E_1\) volts also links with the secondary; consequently, there is induced in the secondary an e.m.f. \(E_2\) that is in phase with the primary back-e.m.f. For a transformation ratio of \(n\), therefore, \(E_2 = -E_1/n\).

The two components of \(I_0\) are \(I_0\sin \theta_0\) in phase with the flux, which is the magnetizing current \(I_m\), a purely reactive component that is just sufficient to establish the flux; and the loss component, \(I_0\cos \theta_0\), in phase with the applied voltage. This component supplies the iron losses.

Under no-load conditions, the \(I_R\) copper loss is very small and the overall losses are found in the iron circuit, so that \(I_0\) is almost equal to \(I_m\). Strictly, the magnetizing current is not sinusoidal for a sinusoidal input, since the \(B-H\) magnetizing curve for the core material is non-linear, but for small \(I_m\) the phasor representation is perfectly valid.

What is important to appreciate at this stage is that, since the induced primary e.m.f. must depend on the magnitude of the alternating flux, it follows that this magnitude is determined solely by the magnitude of the applied primary voltage. Therefore, if \(V_1\) is constant, \(\delta\) is constant. This has two important consequences: \(\delta\) must remain constant irrespective of any other currents that may be caused to flow in either the primary or the secondary winding when the transformer is loaded; and, on full load, the core flux is the same as on no load, so that the full-load iron losses are identical to the no-load iron losses.

What does increase with loading are the \(PR\) copper losses in both windings. It can be demonstrated that the efficiency of the transformer is a maximum when the copper losses are equal to the iron losses.

### The loaded conditions

In Fig. 3, the secondary terminals of the transformer are connected to a load that, as an example, is assumed to be a positive impedance (the most common circumstance). Ignoring the copper losses, the secondary terminal voltage, \(V_2\), will be identical to the secondary induced e.m.f., \(E_2\), and the primary applied voltage, \(V_1\), will be equal to, and in anti-phase with, the induced (back-)e.m.f. in the primary winding.

The induced secondary e.m.f., \(E_2\), will cause a current, \(I_2\), to flow through impedance \(Z_2\). This current will lag \(E_2\) by an angle \(\theta_2\).

\[
I_2 = E_2/Z_2
\]

\[
V_2 = -E_2 = E_1
\]

\[
I_2 \text{ lags by } \theta_1 \text{ on } E_2
\]

![Fig. 3. Transformer operation with a complex secondary load.](image)

Fig. 4. Phasor diagram of the loaded transformer, and will attempt to create a flux of its own in the transformer core. It is here that the constancy of the flux, \(\phi\), must be taken into account, since there has been no voltage change in \(V_1\). Some action must, therefore, take place to neutralize the effect of the secondary load current on the core flux; what happens is that a primary current flows of such magnitude and phasor the effect of the secondary current is nullified. The demagnetizing magnetomotive force, m.m.f., \(I_1^2 Z_1\) ampere-turns, is neutralized, in effect, by an additional primary current that increases the primary m.m.f. to \(I_1^2 T_1 + I_2^2 T_2\) ampere-turns. Current \(I_1\) is the balancing current and must, therefore, be \(180^\circ\) out of phase with \(I_2\) and of such a magnitude that the total effective resultant flux introduced by the two currents is zero. This implies that the new effective m.m.f. must equal the m.m.f. caused by \(I_m\) alone, or:

\[
I_m T_1 - I_2^2 T_2 + I_1 T_1 = I_m T_1
\]

so that:

\[
I_1 T_1 = I_2^2 T_2\]

or:

\[
I_1 = I_2^2 T_2/T_1
\]

Notice that the current ratio \(I_2/I_1 = 1/n\). This accords with the well-known fact that a transformer converts a high-voltage, small-current power into a low-voltage, high-current one, and vice versa.

The phasor diagram for the loaded transformer under discussion is given in Fig. 4. For convenience and clarity, it is taken as 1. The total primary current, \(I_1\), is the phasor sum of the no-load current, \(I_0\), and the balancing current, \(I_1\), lagging the primary voltage by an angle \(\theta_1\). In practice, \(I_1\) is much larger than \(I_0\) and \(I_1\) and \(I_1\) can be looked on as being equal in magnitude. Angle \(\theta_1\) by which the secondary current lags the secondary e.m.f. is then practically equal to \(\theta_2\). This means that the power factor is roughly the same for both the primary and the secondary winding and that the transformer does not to any great extent alter the phase relationship between current and voltage. Because, in practice, \(\theta_2\) is always slightly greater than \(\theta_1\), the use of a transformer tends to decrease the overall power factor of a system.

### Impedance transformation

When the primary current increases owing to the application of a secondary load, the primary impedance effectively falls. There is clearly a relationship between the load impedance and that seen at the primary terminals when such a load is connected.

In Fig. 5, suppose the secondary load impedance to be \(Z_2\); the secondary e.m.f. will then be \(E_2\) volts and the secondary current will be \(E_2/Z_2\). The primary balancing current will consequently be \(E_1 n/Z_2\). The primary balancing current will be \(E_1 n/Z_2\) and this will equal the primary current if the magnetizing current is small. Therefore, \(E_2 = E_1 n/Z_2\) and \(E_1 n = Z_2 h^2\). Thus, since \(E_2 = E_1 n = Z_2 h^2\), the impedance seen at the primary terminals is \(Z_2 = Z_2 h^2\).

For a step-up turns ratio, \(Z_1\) will be smaller than \(Z_2\); for a step-down ratio, \(Z_1\) will be larger than \(Z_2\). Impedance is, therefore, transferred across the transformer from secondary to primary and is increased or decreased (from the primary viewpoint) accordingly as the turns ratio \(n\) is (looking from the secondary side) up or down respectively.

The impedance matching abilities of a transformer have little relevance in power transformers, but are of importance in audio-frequency transformers.

### Audio-frequency transformers

When a transformer is designed for a range of frequencies, unlike power transformers that are made for a single frequency, the equivalent circuit that the transformer presents to the input system is often quite different at one end of the range from what it is at the other. If a reasonably uniform response over, say, the audio-frequency range is desired, the transformer, including interstage types, output types, input matching devices, and so on, requires careful design considerations. In a practical transformer, there are a number of losses that may be represented as...
extra components added to the external circuits of an otherwise 'ideal' transformer, as illustrated in Fig. 6. The copper losses are shown as external resistances, \( R_1 \) and \( R_2 \), in the primary and secondary circuits respectively; hysteresis and eddy current losses are represented by a parallel primary resistance, \( R_i \); flux leakages by series inductors \( L_1 \) and \( L_2 \); and the self-capacitances of the windings as parallel capacitors \( C_1 \) and \( C_2 \). At power frequencies, the self-capacitances and the leakage inductances are not particularly important.

By transferring the secondary loss components to the primary circuit, the equivalent model becomes as shown in Fig. 6(b), where \( R_c \), the total copper loss, \( = R_1 + R_2/n^2 \); the total leakage inductance, \( L = L_1 + L_2/n^2 \); and the total effective winding capacitance \( C_w = C_1 + C_2/n^2 \). There is also \( L \), the effective primary inductance with the secondary on open-circuit, such that \( V_i/2L \) gives the magnetizing current. The remaining ideal transformer is then a component without the imperfections of the real device.

What happens to this model when it is used over the audio-frequency range? At very low frequencies, the input impedance will approximate that shown in Fig. 7, where the series inductance \( L \) is neglected along with the shunt resistance and the winding capacitance, \( C_w \). Hence, the ratio of the terminal voltage, \( V_2 \), and the effective primary voltage \( V \) will be small, so the output voltage, \( V_2 \), will be small. At some mid-frequency in the range, the transferred load resistance, \( Z/n^2 \), will be very much larger than the resistance of \( L \) and there will be a tendency for \( C \) and \( L \) to resonate, so making the ratio \( 1/1/1 \) approach \( 1 \).

At high frequencies, the shunt capacitance, \( C_w \), has a low reactance relative to that of \( L \) and becomes dominant. This means that the response falls relatively rapidly. The high-frequency response can be extended by sectionalized windings to reduce the self-capacitances and by getting the resonant condition to fall in the upper third of the range. In the same way, the low-frequency roll-off can be curbed by maintaining a high primary inductance (often achieved by barring direct currents from the winding) and by keeping the winding resistances small, though there is a conflict of requirements here. The choice of core material and thin laminations or ferrite is also important.

Next month's final instalment of this short series will deal with the capacitor.

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**SCIENCE & TECHNOLOGY**

**MEDICAL LASER TECHNOLOGY**

by Douglas Clarkson

The application of lasers in medicine is all about the interaction of photons of radiation with tissue. It is the ability to precisely deliver such energy at sufficiently high continuous power levels or in the form of discrete pulses of energy that has led to the significant use of such systems in medicine. This use has largely come about as a spin-off of technology originating in industrial and military applications.

The human body can be considered to be an Aladdin’s cave of diverse types of tissue: muscle, fat, bone, cartilage, and so on. Conventional surgical procedures have evolved from using the scalpel, surgical diathermy, saws, drill and ultrasonic fragmentator systems to cut through the various types of tissue. Each of the various disciplines of surgery tends to develop standard techniques for its various procedures. Table 1 gives a brief ‘snapshot’ of the various surgical procedures associated with a range of surgical specialities.

The medical laser is finding particular application in areas where it allows specific procedures to be undertaken with reduced patient stay in hospital and incidence of complications.

Degree of ‘unique’ role of laser systems

It is important, also, to appreciate the degree of 'uniqueness' of laser technology in medicine. This factor can range from the one extreme of ‘entirely unique’, where the laser is the only way to undertake the procedure to ‘non unique’, where several alternatives are available. One such ‘entirely unique’
method relates to an application in ophthalmology, where there is the requirement to bombard the retina with pulses of focused radiation in order to preserve its function. This can be achieved by using an argon laser with an appropriate pulsed delivery system.

This could be contrasted with the use of a surgical laser to cut tissue during a general surgical procedure. There may be no significant advantage over a general-purpose diathermy system that 'cuts and coagulates' tissue by means of an arc of high-frequency current established along the line of an incision. Where, however, extreme care and precision was necessary in the cutting procedure, such as in the removal of a spinal tumour, the use of an appropriate laser system would be relevant as an 'entirely unique' solution.

Medical laser markets

In terms of size, the medical laser market is very much the poor relation of industrial and military laser systems. The technology developed within these larger sectors has, however, been readily transferred to the medical sector where products have been customized by generally scaling down the power and developing delivery systems appropriate for clinical needs. Thus, most laser systems in use in medicine have their 'big brother' counterpart in industrial applications. A good example of this is the carbon-dioxide laser, which at kilowatt levels can be used in industry to cut through thick steel plate and at levels of tens of watts cut through tissue in medical applications.

Tissue interaction mechanisms

Figure 1 shows a simplified outline of the four main mechanisms by which lasers can interact with tissue. Several of these mechanisms are considered in detail.

Coagulation/thermal

At reasonably long interaction times, the dominant mechanism is thermal. The precise effects of such thermal processes depend on the wavelength of the radiation and the level of power intensity. For carbon-dioxide—CO₂—lasers with a wavelength of 10.6 µm, energy is absorbed readily by 'fleshy' tissue, so that the thermal effects tend to be relatively localized. With Nd:YAG (neodymium:yttrium aluminium garnet) lasers, however, with a wavelength of 1.06 µm, the emitted radiation penetrates further, so that a deeper coagulating effect is produced than with the carbon-dioxide system.

Thermal mechanisms are also employed in treatments of the retina by argon lasers, where pulses of laser energy are focused to precise locations to preserve its viability. In this case, pulses typically of 200 ms duration at power levels of 0.5 W are used.

Vaporization

Where local power densities are higher and are achieved over shorter time intervals, the higher temperatures reached will tend to cause tissue to vaporize. This is because conduction processes cannot operate sufficiently fast to conduct away excess heat. The actual transfer from coagulation effects to vaporization effects is gradual one. Thus, when high power densities of a carbon-dioxide laser are incident on tissue, the tissue surface will be raised to such a high value that vaporization takes place and a smoke plume is emitted.

In most laser systems, the transition between coagulation and vaporization is under the control of the clinical operator in as much as it is the power density at the tissue interface that is being controlled.

Thus, where, for example, the clinical operator is directing a CO₂ beam on to tissue, the effect on the tissue for a given output power is both a function of the areas over which the energy is directed and the time during which the energy is incident. Thus, the treatment may be 'underdone' or 'overdone' depending on the skill of the operator.

Photo-ablation

Where pulses of energy are delivered in shorter and shorter time intervals, so-called non-linear processes become important in determining tissue interaction. Generally, energy is absorbed by a thin superficial tissue layer with the possible occurrence of non-thermal bond breaking. Fast thermal expansion can lead to mechanical destruction of the target. Pulses that perform in this way are typically between 5 ns and 1 µs duration. This is, for example, the mechanism that is used in the ophthalmic pulsed Nd:YAG system where energy is dissipated in a very small volume in a very short time interval.

Photo-disruption

Photo-disruption is in some ways a more extreme case of photo-ablation in which the very high field strengths developed in the delivered beam result in ionization and plasma formation. Shockwave generation can result from such interactions. The optical systems required to deliver such short pulses are of necessity more complex and expensive.

Range of medical laser systems

These then are the main mechanisms by which lasers can interact with tissue. In general surgery applications, the emphasis is on controlled cutting/coagulation of tissue. For this, vaporization/coagulation mechanisms are sufficient. Various processes, such as the removal of plaque in coronary arteries, employing angioplasty techniques, use pulse energy to photo-ablate deposits. Photo-ablation/photo-disruption techniques are used in ophthalmology to create highly localized shock waves to puncture, for example, holes in the iris as an out-patient treatment for glaucoma.

For each medical procedure dealing with a specific set of tissue types, there will be an appropriate means of laser interaction with tissue to achieve the desired effect. The laser of choice for that procedure will be one that performs efficiently and also cost effectively. The laser used in practice for an application will not necessarily be one that provides the 'ideal' clinical result where the ideal laser is considerably more expensive than the one which is actually adopted. This is, for example, true for the emerging set of dental lasers where there is indication that wavelengths around 3.50 nm are more effective in removing caries infection than those at the Nd:YAG wavelength of 1.064 µm which are actually used in practice.

Table 2 outlines typical types of laser used currently with indication of tissue interactions.
teraction mode, wavelength, power/energy levels and, where appropriate, pulse duration values. The broad range of wavelengths, tissue interaction modes, power level and pulse energy levels provides a broad range of options to the clinician.

**Principles of laser systems**

Figure 2 shows the basic diagram of a laser system. The key element of such a system is that atoms or molecules are raised in energy to an ‘excited’ state. This can be achieved by collision of ions and electrons in an ionized gas, or by thermal excitation of molecules of a gas. Also, atoms in solid-state materials can be excited by, for instance, the output from a xenon flashlamp.

The atoms or molecules that are excited can return to their base energy by two main mechanisms: spontaneous emission and stimulated emission. The optical design of the laser encourages the atoms or molecules to release their stored energy by stimulated emission. This kind of emission takes place, for example, when a photon interacts with an excited atom or molecule, causing a photon to be released with identical wavelength and phase.

The optics of the laser encourage light to build up between two resonating mirrors. While these can be completely flat, in practice, at least one is slightly convex. One mirror is usually completely reflective, while the other is partly transmitting, allowing laser energy to ‘escape’ from the resonator system.

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Principles of laser systems

A typical laser system consists of a resonator system, a laser power generation unit, and a laser cooling system. The resonator system consists of a laser cavity and a laser medium. The laser power generation unit is responsible for providing the energy required to excite the laser medium. The laser cooling system is responsible for removing the heat generated during the laser operation.

### Specific laser systems

There is a broad range of efficiencies of the laser generation process. The argon laser has a low efficiency in the region of around 0.05%, whereas the carbon-dioxide laser has a high efficiency: of the order of 20%.

The low efficiency of the argon laser is a result of the inefficiency in ‘pumping up’ a population of excited ions to release their energy by stimulated emission. A large part of the released energy is in ultraviolet radiation that is not allowed to be transmitted from the laser generation system owing to the optical properties of the laser tube material.

In the laser power generation unit, use is made of laser resonator tube to improve the efficiency of the tube’s laser action. The angle at which the windows are slanted allows the transmission of a significant fraction of the incident radiation polarized in the vertical plane of the tube (E vector). Without this feature, the tube would have to be operated at higher power levels in order for a set level of output to be delivered by the tube system. Figure 3 shows the details of a typical laser resonator and mirror resonator assembly.

The resonator of a CO₂ system is of a simpler design than that of an argon ion laser. In conventional systems, one side of the laser resonator tube is evacuated to a low pressure and a supply of gas introduced from the opposite end. The gas is made to conduct and ionize by the passage of a high-frequency voltage between a pair of electrodes. A water jacket removes excess heat generated. The design of such a tube system is shown in Fig. 4. Because the CO₂ laser is so efficient, there is no point for a mirror to be used to improve the efficiency of the laser power generation system.

The Nd:YAG laser uses essentially the principle of flashlamp excitation of a solid material of Nd:YAG. Usually, this crystal is positioned at the focus of a parabolic reflector that focuses the output from the flashlamp on the crystal element. Figure 5 shows details of a specific Nd:YAG resonator. Light from a xenon flashlamp is used to pump a Nd:YAG laser system.

### Table 2. Types of laser and typical clinical uses.

<table>
<thead>
<tr>
<th>Mode</th>
<th>λ (μm)</th>
<th>Power (W)</th>
<th>Pulse duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>10.6</td>
<td>100</td>
<td>20 ns</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1.06</td>
<td>100</td>
<td>20 ns</td>
</tr>
<tr>
<td>Argon</td>
<td>0.54</td>
<td>5 (max)</td>
<td>200 ms</td>
</tr>
<tr>
<td>Krypton</td>
<td>0.63</td>
<td>20 (max)</td>
<td>200 ms</td>
</tr>
<tr>
<td>Holmium</td>
<td>1.06</td>
<td>20</td>
<td>10 ns</td>
</tr>
<tr>
<td>YAG Excimer</td>
<td>2.06</td>
<td>500</td>
<td>100 ns</td>
</tr>
<tr>
<td>XeCl</td>
<td>0.308</td>
<td>500 mJ</td>
<td>20 ns</td>
</tr>
</tbody>
</table>

Fig. 3. Details of a typical Brewster window and mirror resonator assembly. The Brewster windows are indicated c and d. The laser resonator is formed by the totally reflecting mirror e and the partially reflecting mirror b.

Fig. 4. Design of a typical CO₂ system. Gas is passed along the resonator space between electrodes (not shown) and excess heat is removed by a water jacket.

Fig. 5. Example of an Nd:YAG resonator unit. Light from a xenon flashlamp is used to pump a Nd:YAG crystal.
crystal. The 'enclosure' in which the pumping system is housed is coated with a highly reflective spluttered gold surface. The resonator section with the partially reflecting mirror on the left and the totally reflecting mirror on the right, is more compact than either a CO$_2$ system or an argon system.

### Delivery systems

The preferred primary element of a delivery system is certainly an optical fibre. In Nd:YAG surgical systems, for instance, the power is conveniently transmitted along fibres of between 200 and 500 µm diameter. Typical Nd:YAG systems merely use a polished fibre end as the 'contact' with the treatment site. Some systems use sapphire tips attached to the end of an optical fibre as the point of contact with the tissue. The sapphire tip absorbs energy from the Nd:YAG beam and provides the surgeon with a 'hot tip' with which to cut the tissue. The correct use of such tips comes with clinical experience. The surgeon runs the risk of vaporizing the sapphire tip if power is applied to it and it is not in contact with tissue and of tissue adhering to the tip if it is not at a sufficiently high temperature.

Specialist optical fibre elements of argon laser systems couple the output power from the laser generation system to the slit lamp which in turn is used to treat the patient. Argon lasers are usually configured to more demanding technical limits with, typically, 50 µm diameter optical fibres and require invariably more service attention. Figure 6 indicates the typical delivery interfaces of such an installation and Figure 7 shows a typical clinical system.

The 10.6 µm radiation of the carbon-dioxide laser, however, is heavily attenuated by conventional optical fibres. While some promising results have been reported with the use of hollow metal wave guides, most systems use conventional articulated arm units that comprise six or seven mirror elements. This difficulty restricts the range of surgical procedures in which the CO$_2$ radiation can be used successfully.

Figure 8 shows a surgical laser that incorporates both a CO$_2$ resonator (upper horizontal section) with articulated arm delivery system and a Nd:YAG resonator with an optical fibre delivery system. This 'combination' laser allows dual CO$_2$/Nd:YAG output via the articulated arm section where the specified benefits of each wavelength can be used simultaneously.

One of the most demanding delivery system is that used with laser angioplasty where a precisely directed beam of pulses laser radiation is directed to obstructing plaque within the coronary arteries. The operator usually views the area to be treated through an optical fibre. Laser energy is normally directed down an array of fibres to the treatment site.

### Conclusion

Lasers have made unique contributions to modern medicine and will certainly be at the forefront of future medical technology.
Cellphones Explained
by Bill Higgins

Cellular telephones, once the symbol of people who cannot be without a telephone, are now becoming commonplace useful tools. How does the cellular telephone work? What are its advantages and disadvantages over other types of communications?

A cellular telephone system is basically a radio-telephone system that works duplex and allows connection to the Public Switched Telephone Network—PSTN. A geographical area is subdivided into smaller cells and transceivers sited at the centre of each cell. Users of cellphones carry around a hand-portable, or have mounted in their vehicle the necessary equipment to make cellphone calls. In the UK, there are two systems set up for cellphone use:

(a) Vodafone,
(b) Cellnet.

At the time of writing (February 1992), Vodafone has the most subscribers, 700 000, against Cellnet’s 535 000.

As the name implies, the feature of the system is the way a cell pattern is used to cover a geographic area. Often, one site has three directional antennas to create three cells.

The siting of base stations is all important in the overall cell structure of the appropriate network. Base stations are selected along with appropriate antennas to create the desired r.f. wave pattern.

Two main types of antennas are used in creating the wave pattern: omni-directional and uni-directional. The latter employ reflectors to obtain the directional capability.

Into Europe and beyond

As users of cellphones hop around with their equipment, a need to have standardization with cellular system within Europe and further abroad has grown. Combined with the 1992 withdrawal of trade barriers, this galvanized the regulatory authorities to come up with Groupe Special Mobile—GSM—standard. The frequency bands in GSM are:

<table>
<thead>
<tr>
<th>Mobile transmit</th>
<th>890-915 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base transmit</td>
<td>935-960 MHz</td>
</tr>
</tbody>
</table>

with a channel spacing of 200 kHz. The standard uses Time Division Multiple Access—TDMA—with eight time slots.

Mobile transmitters are allocated into one of five classes, depending upon the peak power radiated:

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vehicle or portable</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Vehicle or portable</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Hand-held</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Hand-held</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Hand-held</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Gaussian Minimum Shift Keying—GMSK—modulation with a BT value of 0.3 at a gross data rate of 270 kb/s is used. Phase and frequency synchronization must allow for Doppler shift on vehicles travelling at up to 250 km/h (156 mph). Compensation must be allowed for propagation delays for round trips between transmitter and receiver in cells up to 35 km (22 miles) radius.

Digits
As the processing of voice transmissions is into digital form, the easiest way to think of the operation of the system is in digital terms.

- The overall data rate for each radio channel is 270 kb/s.
- Data is sent in bursts of 577 μs, each having 116 encrypted bits.
- There are eight time slots per TDMA frame—see Fig. 5.
- Transmission and reception are staggered so that the mobile is not able to try to do

### Table 1. Typical antennas used for cellular radio systems.

<table>
<thead>
<tr>
<th>Antennas</th>
<th>Type 7558</th>
<th>Type 7562</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (MHz)</td>
<td>870–960</td>
<td>870–960</td>
</tr>
<tr>
<td>Impedance (Ω)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>VSWR (no beam tilt)</td>
<td>&lt;1.5:1</td>
<td>&lt;1.5:1</td>
</tr>
<tr>
<td>(with beam tilt)</td>
<td>&lt;1.3:1</td>
<td>&lt;1.4:1</td>
</tr>
<tr>
<td>Gain (dBi)</td>
<td>10.5</td>
<td>18</td>
</tr>
<tr>
<td>Horizontal pattern</td>
<td>Omni ±0.2 dB</td>
<td>Directional (60° H; 16° V)</td>
</tr>
<tr>
<td>Max. power (W)</td>
<td>500</td>
<td>300</td>
</tr>
<tr>
<td>Length (m)</td>
<td>28</td>
<td>47</td>
</tr>
<tr>
<td>Material, antenna reflector</td>
<td>Glass fibre</td>
<td>Brass-copper aluminium</td>
</tr>
</tbody>
</table>

For Doppler shift on vehicles travelling at up to 250 km/h (156 mph). Compensation must be allowed for propagation delays for round trips between transmitter and receiver in cells up to 35 km (22 miles) radius.

Antennas Type 7558 and 7562.
Monitoring is performed by receivers to determine signal strength of adjacent cells to allow for a possible handover.

In Europe, there are a number of operators involved in the GSM system. Table 2 shows who is involved where.

<table>
<thead>
<tr>
<th>Country</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>PTV</td>
</tr>
<tr>
<td>Belgium</td>
<td>RTT</td>
</tr>
<tr>
<td>Denmark</td>
<td>Dansk Mobil Teleføl</td>
</tr>
<tr>
<td>Finland</td>
<td>Radiolinja</td>
</tr>
<tr>
<td>France</td>
<td>France Telecom</td>
</tr>
<tr>
<td>Germany</td>
<td>DBP Telekom</td>
</tr>
<tr>
<td>Ireland</td>
<td>Telecom Eireann</td>
</tr>
<tr>
<td>Italy</td>
<td>SIP</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>PTT</td>
</tr>
<tr>
<td>Netherlands</td>
<td>PTT Telecom</td>
</tr>
<tr>
<td>Norway</td>
<td>Norwegian Telecom</td>
</tr>
<tr>
<td>Portugal</td>
<td>CTP</td>
</tr>
<tr>
<td>Spain</td>
<td>Telefonica</td>
</tr>
<tr>
<td>Sweden</td>
<td>Convik GSM</td>
</tr>
<tr>
<td>Switzerland</td>
<td>SwissITT</td>
</tr>
<tr>
<td>Turkey</td>
<td>PTT</td>
</tr>
<tr>
<td>UK</td>
<td>Cellnet</td>
</tr>
<tr>
<td></td>
<td>Vodafone</td>
</tr>
</tbody>
</table>

**Fig. 1. Cell pattern obtained with the use of three base stations operating on pairs of frequencies: f₁, f₂ and f₃. The same pattern can be obtained by using directional antennas sited at the node of the three cells.**

**Fig. 2. Ideal situation: seven base stations working on different pairs of frequencies, f₄ to f₇. In the real world, four different pairs of frequencies are used.**

**Fig. 3. Sitting of four base stations relative to one another, which build up into the pattern shown in Fig. 4 below.**

**Table 2. European countries and their cellphone operators.**

**Peak performance**

Good communication between subscribers and base stations is dependent on a useable radio link between the two. Antennas for base stations have already been discussed. Mobiles need to have an antenna that receives the correct signal with as little loss as possible. They should be mounted vertically on vehicles at the centre of the roof.

System operators go to considerable lengths in enlightening their subscribers on the merits of having a good radio link. Leaflets are distributed that feature cartoons, diagrams and plenty of text to persuade users to have their antennas mounted at the centre of the roof. It may not look so stylish, but it gives a much better signal.

With all the complexities of systems, it is not surprising that accurate test equipment has been designed to verify the various parameters of cellphone systems. One such equipment is called Comtest 800/150 by RTT (Radio Telephone Test) Systems. Marketed as an 'Integrated Test System', it can check modulation, frequency, power and more. It works up to 1000 MHz and is housed in one case. Indeed, a very useful device to keep systems and mobiles at peak performance.

**Advantages of cellphones**

- The ability to have your own handset that works wherever you are.
- By linking in with PSTN, the number of destinations for calls is the total of PSTN subscribers.
- Ease of operation: most cellphones are designed to be used in a manner similar to that of a standard telephone.

**Disadvantages of cellphones**

- The short delay after speaking to allow for reception along with any signal failure can be annoying.
- Different, competing systems can make the choice of what to use difficult, especially when the added complexity of 'does it work with GSM?' is taken into account.
- High costs. The equipment itself has to be bought outright or leased on top of which there are the installation charges. Then there are subscription charges to the appropriate system and, last but not least, there is the cost per individual call.

Personally, I do not use a cellphone as it is far too expensive. Instead, I use a BT Charge-card*, which enables me to use any public telephone and charges calls to my regular telephone bill.

**Conclusion**

Cellphones are increasingly being used by people in all walks of life as they can be useful tools to people on the move.

Transceivers are used to provide duplex communication between subscribers and the appropriate network.

Cell structure is achieved by the use of four pairs of frequencies that build up over a geographical area.

Two types of antenna are used, omni-directional and uni-directional.

As trade barriers in Europe are brought down, increased provisions are made for subscribers on the move, that is, GSM standardization.

Advantages of cellular radiophones are flexibility and ease of operation. The main disadvantage is the very high cost of using cellphones compared with that of using regular payphones.

**Acknowledgments**

Cellnet Ltd
Jaybeam Ltd
RTT Ltd
Vodafone Ltd

*Moreover, this card can be used anywhere in the world. (Bd)*
READERS’ CORNER

LETTERS

WOT IS A WOK?
Dear Editor—Your contributor Mr. Kirwan (Design Ideas. March 1992) tells of WOK cooking and as he is evidently bent upon stuffing himself with victuals, the pan only mean Kitchen. But What Of the other two letters? I looked up the matter in my Concise Oxford Dictionary (vintage 1979) but it ignored the subject. I then queried my computer (Dictionary and Thesaurus 1989) and they both told me that the word was not found.

Yours is an international periodical and I think it important that you define uncommon acronyms for the likes of those no longer with it, be they pale-faced natives, ex-patriates, Welshmen or otherwise.

K. Jones, Varino, Italy.

SAVE DECODER
Dear Editor—Is there any more information on the SAVE decoder you published two years ago?

H. Hjemmen, Norway (and many others).

We are under legal restraint not to publish, or make available by other means, any information on the 'SAVE decoder', whose copyright is vested in the British Broadcasting Corporation. Sorry!

Editor

COMPUTERSCOPE
Dear Editor—Although I do not build the projects you publish I have learnt a lot from them: you are streets ahead of the competition.

My scope has recently died and as I have a 286, 20 MHz PC, I thought a computer scope would be good, but the one you published in 1986 has no software for a PC though it has a small bandwidth. Would it be possible for you to update that design to include more advanced technology with a bandwidth of, perhaps, 5–10 MHz and include PC software. Or maybe produce a new design from scratch.

Also, would it be possible to run a course on programming in assembly language for say, Z80-based hardware and software, as 8051s don’t grow on trees, you know.

A. Sutton, Leicester.

We have asked our design department, as well as some of our regular free-lance contributors to report on the possibility of updating the ‘Computerscope’ published in our September and October 1986 issues. Their findings will be published in this column in a few months’ time.

Your comments on the 8032 in comparison with the Z80 have been noted. Bear in mind, though, that our research, and that of our associate companies world-wide, indicates waning interest in Z80-based equipment. Moreover, we do not get many offers, if any, from free-lance contributors on this type of equipment. Nevertheless, there is a two-part article on a ‘Multi-purpose Z80 card’ in this and our May issues.

As to your remarks regarding the price of the 8032, why not use a 8032? The course is geared to both devices without any reservations, but the 8032 is considerably cheaper than the 8051.

Editor

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Like its predecessors in the 300 Series, 303 Circuits offers a comprehensive collection of practical ideas, concepts, and developments in the gamut of electronics. Unlike its predecessors, the book is arranged in 11 subject sections to make it easier for the reader to find that long-sought circuit.
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ISBN 0 905705 33 5
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BUILD A COMPACT DISK PLAYER
Dear Editor—In his article 'Build a compact disk player', Mr Giffard mentions a Philips CDM-4 deck, which is included in a kit that has recently become available in the UK retail trade. I immediately contacted my local branch of the Philips organization to ascertain how a kit could be purchased. They could not furnish me with any information and requested that I contact you to find out the relevant information as to which branch of the Philips organization was making this kit available.

Your local Philips representative or dealer should contact Philips Consumer Electronics, Industrial Supplies, Business Group KMG, A.R. Baldock, B.Sc., APTC, Kalamunda, kit available.

A.R. Baldock, B.Sc., APTC, Kalamunda, Australia.

Dear Editor

Your local Philips representative or dealer should contact Philips Consumer Electronics, Industrial Supplies, Business Group KMG, A.R. Baldock, B.Sc., APTC, Kalamunda, kit available.

A.R. Baldock, B.Sc., APTC, Kalamunda, Australia.

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A.R. Baldock, B.Sc., APTC, Kalamunda, Australia.

SPEED CONTROL OF LARGE DC MOTORS
Dear Editor—I have a DC motor (from the ill-fated Sinclair electric car), 12 V, 29 A, 3000 r.p.m., which I would like to use to motorize my auto winch on the telescopic mast that supports my amateur radio antennas. However, there is a problem with the motor's speed.

After reading 'Speed control of large d.c. motors' (May 1991) by K.A. Nigim, I wonder if Mr Nigim's circuit could be adapted to control the speed of my motor? I have a 30 A transformer to drop the voltage from 240 V to 18 V and I could use that for the power circuit.

J. Lekevys, Huddersfield.

We have passed your letter to Dr Nigim. As soon as we have his reply, we will be in touch.

Richard.

SWITCHBOARD

Switchboard allows all PRIVATE READERS of Elektor Electronics one FREE advertisement of up to 108 characters, including spaces, commas, numerals, etc., per month. Write the advertisement, which MUST relate to electronics, in the coupon on this page; it MUST INCLUDE a private telephone number or name and address; post office boxes are NOT acceptable. Elektor Electronics (Publishing) can not accept responsibility for any correspondence or transaction as a result of a free advertisement or for any inaccuracy in the text of such an advertisement. Advertisements will be placed in the order in which they are received.

FOR SALE—All kinds of components. Send SAE for list to Alan Auden, 206 Ellerdine Road, Hounslow TV/3 2PX.

FOR SALE—PC-based 8051/80C552 development kit; 8051 assembler/democompiler, software simulator. £180. Phone (0275) 878 238.

FOR SALE—FM TUNER

Dear Editor—Could you please supply details of where to obtain the TQF-2599 crystal filters used in the 'FM tuner' (March–July, 1992).

P. Holton, Durban, South Africa

The TQF-2599 crystal filter for the FM Tuner should by now have become available from several electronics retailers. Unfortunately, there is a delay in delivery from the manufacturers (some suppliers, even Japanese manufacturers have their problems) and, consequently, the filters are not expected to be with the retailers until July. We are fortunate in being able to buy small quantities directly from the manufacturers, so that we have been able to complete our prototypes.

ELEKTOR ELECTRONICS JUNE 1992
PRODUCT OVERVIEW
JUNE 1992

A number of projects carried out in Elektor Electronics are supported by ready-made printed-circuit boards (PCBs), self-adhesive front panel foil, ROMs, EPROMs, PALs, microcontrollers and diskettes, which may be ordered through our Readers Service using the order form printed every month opposite the Readers Service page.

The list printed here is complementary to the shorter one opposite the Readers Service page elsewhere in this issue. This two-page overview of all currently available products is regularly updated and will appear in the March, June, September and December issues of Elektor Electronicas.

Items marked with a dot (•) following the product number are in limited supply only, and their availability cannot be guaranteed by the time your order is received.

Items not listed here or on this month's Readers Service page are not available.

The artwork for making PCBs which are not available ready-made through the Readers Service may be found in the relevant article (from March 1990 onwards).

Prices and item descriptions subject to change, please confirm at the time of ordering.

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MARCH 1991

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VCO preamp (1) 86113-A 5.65 0.68

APRIL 1991

VCO preamp (2) 87005-1 19.32 2.19

Automotive inverter 87103-1 8.93 1.25

JULY 1991

(argumenter amplifier 87342 9.65 1.16

AUGUST 1991

Electronic read-out 87017-1 157.50 1.95

BBD sound effect 87048-1 20.00 1.16

MIDI decoder 87049-1 39.50 1.16

November 1991

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September 1991

MIDI interface 87051-1 35.00 1.16

MIDI controller board 87052-1 35.00 1.16

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JANUARY 1992

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Compact cassette player 87055-1 35.00 1.16

JUNE 1992

VCO preamp (3) 87101-1 6.60 1.16

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JULY 1992

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  - Set your unique security code.
  - TX size 45mm x 45mm.
  - RX size 35mm x 90mm.
  - A small VHF transmitter with digital encoder and receive unit with decoder.
  - Operation good for 1000m range.
  - Kit price £13.45

- **TXL Ultra-miniature room transmitter.**
  - Smallest room transmitter in the world!
  - Incredible 10mm x 20mm.
  - Mic 3.12V operation.
  - 1000m range.
  - Kit price £16.45

- **MTX Micro-miniature room transmitter.**
  - Best selling micro-miniature transmitter.
  - Just 17mm x 17mm including mic.
  - Mic 3.12V operation.
  - 1000m range.
  - Kit price £13.45

- **STX High-performance room transmitter.**
  - High performance transmitter with a buffered output stage for greater stability and range.
  - Measures 22mm x 22mm.
  - Operates on 9V.
  - Kit price £16.45

- **VTX Voice activated room transmitter.**
  - Triggers only when sounds are detected.
  - Very low standby current.
  - Operates on 9V.
  - Kit price £22.95

- **VTX180 Crystal controlled room transmitter.**
  - Narrow band FM transmitter.
  - Operates on 9V.
  - Kit price £32.95

- **SCRX Subcarrier scrambled room transmitter.**
  - Scrambled output from transmitter cannot be monitored without the SCDM decoder connected.
  - Operates on 9V.
  - 1000m range.
  - Kit price £40.95

- **SCDM Subcarrier decoder for SCX.**
  - Connects to receive subcarrier and provides decoded audio output to headphones.
  - 9V operation.
  - Kit price £11.95

- **HVX400 Main powered room transmitter.**
  - Connects directly to 240V a.c.
  - Supply for long-term monitoring.
  - 35mm x 35mm.
  - 500m range.
  - Kit price £19.45

- **A3R Micro-size telephone recording interface.**
  - Connects between telephone line (anywhere) and cassette recorder.
  - Switches tape automatically as phone is used.
  - All conversations recorded.
  - Size 16mm x 32mm.
  - Powered from line.
  - Kit price £13.45

- **UTX Ultra-miniature telephone transmitter.**
  - Smallest telephone transmitter kit available.
  - Incredible size of 10mm x 20mm.
  - Connects to line anywhere.
  - 6-12V operation.
  - 1500m range.
  - Kit price £19.45

**SPECIFICATIONS**

- **Stationary**
  - Channel 5
  - 5mW output
  - 1000m range

- **Mobile**
  - 5W output
  - 3000m range

**AVO MULTIMETERS**

- **UTLX Ultra-miniature telephone transmitter.**
  - Smallest telephone transmitter kit available.
  - Incredible size of 10mm x 20mm.
  - Connects to line (anywhere) and switches automatically with phone.
  - Size 22mm x 22mm.
  - 1130MHz operation.
  - 1000m range.
  - Kit price £15.45

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- **MAPLE BROADBAND FM TRANSMITTER 95MHz-108MHz**
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  - Smallest telephone transmitter kit available.
  - Incredible size of 10mm x 20mm.
  - Connects to line (anywhere) and switches automatically with phone.
  - Size 22mm x 22mm.
  - 1130MHz operation.
  - 1000m range.
  - Kit price £15.45

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</thead>
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</tr>
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<td></td>
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</tr>
<tr>
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INDEX OF ADVERTISERS

<table>
<thead>
<tr>
<th>Name</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertising Standards Authority</td>
<td>7, 8</td>
</tr>
<tr>
<td>B H Systems</td>
<td>7</td>
</tr>
<tr>
<td>B K Electronics</td>
<td>Inside back cover</td>
</tr>
<tr>
<td>Bull Electrical</td>
<td>6</td>
</tr>
<tr>
<td>Cricklewood Electronics</td>
<td>7</td>
</tr>
<tr>
<td>Display Electronics</td>
<td>72</td>
</tr>
<tr>
<td>Elektor Electronics</td>
<td>8, 9, 64, 73, 74</td>
</tr>
<tr>
<td>Henry’s Audio</td>
<td>7</td>
</tr>
<tr>
<td>J P Distribution</td>
<td>8</td>
</tr>
<tr>
<td>Lloyd Research</td>
<td>9</td>
</tr>
<tr>
<td>Maplin Electronic Supplies</td>
<td>Back cover</td>
</tr>
<tr>
<td>MicroAmps Ltd</td>
<td>Inside front cover</td>
</tr>
<tr>
<td>John Morrison</td>
<td>8</td>
</tr>
<tr>
<td>Number One Systems Ltd</td>
<td>10</td>
</tr>
<tr>
<td>Stewart of Reading</td>
<td>73</td>
</tr>
<tr>
<td>Suma Designs</td>
<td>75</td>
</tr>
<tr>
<td>Technology Partners Publishing</td>
<td>7</td>
</tr>
<tr>
<td>TF Electronics</td>
<td>7</td>
</tr>
<tr>
<td>Tsien (UK) Ltd</td>
<td>4</td>
</tr>
<tr>
<td>Viewcom Electronics</td>
<td>5</td>
</tr>
<tr>
<td>J. Vincent Books</td>
<td>8</td>
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