ETI SPECIAL REPORT: CABLE TELEVISION GOES DOWN THE DRAIN?

It might not happen, and even if it does, it might not be what we want

PLUS

● STEREO POWER METER—true reading of audio or DC power

● Z80 DRAM CARD—add more memory to Z80-based systems

● COMPLEX NUMBERS—take circuit calculations in your stride
Low-price robots from POWERTRAN

- hydraulically powered
- microprocessor controlled

The UK-designed and manufactured range of Genesis general purpose robots provides a first-rate introduction to robotics for both education and industry. With prices from as low as £245, even the home enthusiast can aspire to his or her own robot.

Each robot in the Genesis range has a self-contained hydraulic power source operated from single phase 240 or 120v AC or from a 12v DC supply. Up to six independent axes are capable of simultaneous operation and all except the grip axis have sensing devices fitted to provide positional control by a closed loop system based on a dedicated microprocessor. Movement sequences can be programmed by means of a hand-held controller or the systems can be interfaced with an external computer via a standard RS232C link.

The top-of-the-range P102 has dual speed control, enhanced memory and double acting cylinders for increased torque on the wrist and arm joints. There is position interrogation via the RS232C interface, increasing the versatility of computer control and inputs are provided for machine tool interfacing.

All Genesis robots are available either ready-built or in kit form. The latter provides not only extra economy but also valuable additional training as an assembly project.

HEBOT II Turtle-type robot

For under £100, Hebot II takes programming off the VDU and into the real world. Each wheel is independently controlled by a computer, enabling the robot to perform an almost infinite number of moves. It has blinking eyes, a two-tone bleep and a solenoid-operated pen to chart its moves. Touch sensors coupled to its shell return data about its environment to the computer enabling evasive or exploratory action to be calculated.

The robot connects directly to an I/O port or, via the interface board, to the expansion bus of a ZX81 or other microcomputer.

HEBOT II
Weight 1.8kg complete kit with assembly instructions £85
Interface board kit £10

MICROGRASP

A real, programmable robot for under £200! Micrograsp has an articulated arm jointed at shoulder, elbow and wrist positions. The entire arm rotates about its base and there is a motor driven gripper. All five axes are motor driven and four of these are servo controlled giving positive positioning. The robot can be controlled by any microcomputer with an expansion bus – the Sinclair ZX81 being particularly suitable.

MICROGRASP

Weight 8.7kg, max. lifting capacity 100g
Robot kit with power supply £145.00
Universal computer interface board kit £48.50
23 way edge connector £2.50
AX81 peripheral/RAM pack £3.00

GENESIS S101

Weight 2.9kg, max. lifting capacity 1.5kg
5-axis model (kit form) £475
4-axis model (kit form) £425
5-axis complete system (kit form) £737

GENESIS P101

Weight 34kg, max. lifting capacity 1.8kg
6-axis model (kit form) £675
6-axis complete system (kit form) £945

GENESIS P102

Weight 36kg, max. lifting capacity 2kg
6-axis system (kit form) £1175.00
Powertran Cortex microcomputer self-assembly kit £295.00

PORTWAY INDUSTRIAL ESTATE, ANDOVER, HANTS SP10 3PE. TEL (0264) 64455

ALL PRICES ARE EXCLUSIVE OF VAT. ALL GIFTS RANK FOR REG. VAT.
DIGEST

A new micro from Uncle Clive is amongst this month's news.

CABLE TV DOWN THE DRAIN?

Our special report on the state of cable television takes a look at the wide range of factors that are shaping the future of this medium.

MACHINE CODE

Bob Bennet gets a bit exclusive with his OR binary register operations, before telling us a very (program) moving story.

TECH TIPS

Amongst the circuit offerings this month is a rather ingenious data link circuit and a super-cheap envelope generator.

READ/WRITE

Modifications to our most recent active loudspeaker design and (almost) a competition are just two of the letters we've decided should grace our pages.

AUDIO DESIGN

John Linsley Hood sets out to prove that although circuit calculations employing complex numbers may lead to the odd bit of hairy algebra, there is nothing beyond the ken of the average ETI reader (intelligent lot that you are).

PROJECTS

TYPEWRITER INTERFACE

A few additional pieces of information and a correction that some of you have spotted already, all to make it easier to use this project.

STEREO POWER METER

Find out just what it is the neighbours keep complaining about with Walker's Watt-Watcher!

Z80 DRAM CARD

The other way of adding lots of extra memory to a Z80 system, other than upgrading existing memories, is to build a whole new 64K block — Bob Campbell shows how it's done.

THE OBEDIENT DIE

Ever wished you could throw a six when you wanted — well now you can with this design from Ian Hickman — but don’t blame us if your fellow Monopoly players send you to jail for using it!

FOIL PATTERNS

INFORMATION

NEXT MONTH'S ETI

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ADVERTISERS' INDEX

Subscription Rates, UK £14.35 including postage. For further details and Airmail rates etc, see the Readers' Services page.
## POLYESTER RADIAL LEAD CAPACITORS:

- **Capacitance:** 0.1 nF, 0.2 nF, 0.47 nF, 1 nF, 2.2 nF, 4.7 nF, 10 nF, 15 nF, 33 nF, 50 nF
- **Voltage:** 5 V, 10 V, 15 V, 22 V, 47 V
- **Other:**
  - **Lead Type:** Single Gang
  - **Availability:**
    - **Price:**
      - 0.1 nF: £5.50
      - 0.2 nF: £4.50
      - 0.47 nF: £3.50
      - 1 nF: £2.50
      - 2.2 nF: £1.50
      - 4.7 nF: £1.00
      - 10 nF: £0.70
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- **Shipping:**
  - Domestic: £0.30 (DPD / Royal Mail)
  - International: £0.75 (including VAT)

### Other Components

#### TRANSISTORS

- **BC182L**
- **MJE2955**
- **BF880/81**

#### DIODES

- **1N4148**
- **1N4149**
- **1N4158**

#### CRYSTALS

- **60 MHz**
- **100 MHz**

#### FILM RESISTORS

- **0.1Ω**
- **0.2Ω**
- **0.3Ω**

### Additional Information

- **Accessories:**
  - **P&P:** £0.75 to all cash orders. Overseas orders postage at cost. Prices government approved. All prices exclusive of VAT. VAT number: 222 476 476. Price and availability subject to change without notice.

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**Contact Information:**

- **Tel:** Watford (0923) 40588
- **Telex:** 895695
- **Address:** 33-35 Cardiff Road, Watford, Herts, England
- **Opening Hours:** Monday to Saturday: 9.00 am to 5.00 pm
- **Payment Options:** Access / Master Charge and Visa accepted.
BBC Micro Computer System

OFFICIAL DEALER

Please phone for availability

Software from ACORN/SOFT/PROGRAM POWER/GEMINI in stock

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SANYO DR101 Data Recorder £34 + £2.50 carriage
BBC Type Recorder £29.50 + £2.50 carriage
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HOBIT Floppy Tape £13.50 + £3.50 carriage
HOBIT Zero Memory Option £25 + £1 carriage
Computer Guide £12 cassette 50p each.
£4.50 for all leads + £1 carriage

MONITORS

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MICROVIEW 1411 14" RGB/PAL Hi Res £469
MICROVIEW 2022 20" RGB/PAL Std Res £287
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KAGA VISION 13" RGB/PAL Hi Res £459
KAGA 12" 'GREEN HI Res £389
SANYO DM112CX 12" Green Hi Res £99
All leads included. Carriage £29

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EPSON FX80 £700
EPSON FX10 £900
NECPC80 £310
SEIKOH 1001A £170
SEIKOH 2500X £190
SEIKOH GP-1000 Color £375
JUP 5100 Daily Wheel £355
MS 45 Col Printer/Plotter £120
Coscox Graphics Printer £3 £120
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Carriage £7

BBC EPROM PROGRAMMER

A fully self-contained EPROM Programmer with its own power supply, able to program 25/16, 2716/2725/2728 single chip EPROMs.
- It is simple to use.
- Personality selection is simplified by a single rotary switch.
- It can be used with the BBC keyboard and a printer
- It has a built-in timer and provides reliable easy erasing.
- The programmer can be used to test and program and verify at any address on the EPROM.
- It is supplied with a NAL guide to programming.
- It is supplied with a cassette transferable to disk.
- It is supplied with a manual.
£79.50 — £2.50 carriage.

PRODUCT PROGRAM: P8000

P8000 provides reliable, easy erasing of up to 8 EPROMs simultaneously with device sizes up to 16 x 8 bytes. Devices supported range from 2704 to 27128 in single and three rail formats. Simple menu driven operation ensures easy erasing and reliable programming in minimum programming times £695 + £6 carriage.

ACORN IEEE INTERFACE

This IEEE 488 standard interface is a general purpose system for exchanging digital data between a number of devices in a local area. The interface complies with the IEEE 488 standard and can be connected to up to 14 other devices.
- The interface is supplied complete with software in ROM, interconnecting cables IEEE cable for connection to computers and devices and a comprehensive manual.
- £282.50 + £25.50 carriage.

SMARTMOUTH

The "infinitely variable self-contained speech synthesizer. Uses only 5-10 bytes per word. No ROMs required, simply plugs into the user port. (Has Aux. Audio output 541.) Supplied with Demo/Development programs and simple software instructions. £37 + £2.50 carriage.

NEW COMPREHENSIVE CATALOGUE AVAILABLE — PLEASE SEND FOR PRICE LIST

FLOPPY DISC INTERFACE

£84 + £15 installation

BBC COMPATIBLE DISC DRIVES

All drives are supplied with manual, form disc and cables.
- Single Drive: 100k £150; 200k £215;
- 400k £325
- Single Drive with PSU: 200k £260;
- 400k £275
- Double Drive with PSU: 2 x 100k £330;
- 2 x 200k £450; 2 x 400k £495
- These drives are switchable between 40/80 tracks.
- 40/80 Switch Module 1 x 400k and 2 x 400k Drive £32

DIESKETTE: Packet of 10
- 40 track SSD £15; 40 track DSDD £22;
- 80 track SSD £24; 80 track DSDD £26
Carr: £2/Box

FLOPPICLENE Drive Head Cleaning Kit £14.50
Phone or send for our BBC leaflet

TORCH Z80 DISC PACK

Your BBC computer can be converted into a business machine with the addition of a TORCH Z80 disc pack. This gives your disc drive and the Z80 processor card greatly enhanced the computer's storage and processing capability. Z80 card comes complete with 64K RAM and a CMOS compatible full-size system. The complete disc pack is sold with 16K memory and software package supplied with PERFECT software package of DIRECTIONS, WORD PROCESSOR & SPREADSHEET and COMPANIX integrates an active business management game Complete Package £378 + £18 carriage.

TIME WARP

REAL TIME CLOCKS CALENDAR

A low cost unit opens up the full range of real time applications. With its fully battery backed possibilities include a digital clock, automatic date setting, precise timing & control in scientific applications, etc. Typical uses includes various end uses and are simply limited by one's imagination. Simply plug it in to the disc port - no specialist installation required - no ROMs. Supplied with extensive applications software £29.00

EPROM ERASERS

UV IT Eraser with a built-in timer and mains indicator. Built-in safety interlock to avoid accidental exposure to the harmful UV rays. It can handle up to 5 eproms at a time with an average erasing time of about 20 mins. £59 + £2.50 carriage.
UV IT above but without the timer £47
UV IT above but with timer £79

Many more books in stock.

ACORN INTERFACE

This IEEE 488 standard interface is a general purpose system for exchanging data between two or more devices in a local area. The interface is supplied complete with software in ROM, interconnecting cables IEEE cable for connection to computers and devices and a comprehensive manual.
- £282.50 + £25.50 carriage.
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**Please add 40p per pack**
TAKE OFF WITH ETI!
Next month will be the time to leave your cosy workshop behind and take to the air with a project from ETI. Unfortunately (or perhaps fortunately, because we'd like to keep our readers in one piece!), we shall not be giving you instructions on how to build a hang-glider. However, we shall have a design for a (g) natty little device called a vario, which indicates changes in height. This sort of instrument is particularly useful for pilots, to tell them when they've caught a 'thermal' (a column of hot air rising up from, say, a factory or hot ground). Anyway, it makes rather an interesting change from our normal run of projects.

BASS FOR BEGINNERS
As far as home-made audio goes, it isn't really possible to construct a home-grown amplifier that's cheaper than a cheap-but-OK manufactured amplifier (as opposed to constructing a very high quality amplifier that is much cheaper than commercially made units — more of this in a month or two!). However, it is possible to save a lot of money by building your own loudspeakers, be they passive or active, cheap or expensive. And what's more, it isn't that difficult to design your own either — and that's exactly what we'll be telling you how to do next month!

MAINS-BORNE REMOTE CONTROL
Remember the original mains-borne remote control system we published some time back? Good though this design was, there were a few problems with it which we now think we have overcome. This design provides for the on-off control of up to 16 groups of devices from a standard microcomputer parallel port. The system will be open to enhancement, with a mains borne burglar alarm being one possibility for a further extension.

ALL THIS AND MORE IN YOUR APRIL ISSUE OF ETI — PLACE YOUR ORDER NOW OR RISK MISSING OUT! ON SALE MARCH 2nd.
Fast Talker

Hanimek claim their new Soundpacer cassette recorder is an exciting development in speech reproduction technology which will prove invaluable to everyone who listens to speech recordings. The Soundpacer allows recorded speech to be reproduced at up to twice its original speed without any apparent increase in pitch. Hanimek give very little information on the system, which they call Variable Speech Control, but it presumably involves frequency shifting since both the speed of the tape and the pitch of the reproduced sound are variable over a wide range. Hanimek say that this facility allows spoken information to be accepted at up to twice the normal rate without loss of understanding and indeed, with some improvement in retention.

No general specifications are given for the Soundpacer, Hanimek being content to describe it as 'full featured'. Going by the photograph alone, it appears to include a condenser microphone, switchable sensitivity for external microphones, and a one-touch recording system.

Second UOSAT Launch

NASA has formally confirmed that it will launch UOSAT-8, the University of Surrey's second experimental scientific and educational spacecraft, and the University's UOSAT Project Team is racing against time to get the spacecraft built and tested in time for launch on 1 March 1984. This will mean that the spacecraft has been designed, built, and prepared for launching in under five months, a task probably without precedent in space engineering.

UOSAT-8, to be known after launch as UOSAT-2, will go into space as a secondary payload with LANDSAT-3 on a Delta 3920 rocket from the Western Test Range, Vandenberg, California. The launch is at present scheduled for 1 March 1984 at 1759-1809 hrs GMT, lifting UOSAT-2 into a sun-synchronous polar orbit at a planned height of 700 km (435 miles). The spacecraft will carry scientific and engineering experiments for use by professional scientists and radio amateurs, together with educational experiments primarily for schools and colleges. Working with Surrey University in building the experimental hardware are the Rutherford-Appleton Laboratory (SERC), the Universities of Sussex and Kent, and the UK, USA and Canada branches of the international Amateur Satellite Corporation (AMSAT).

Members of the UOSAT Project Team are working round the clock to assemble the spacecraft ready for environmental testing in January and transporting to the USA in February for integration with the launch rocket in time for the launch on 1 March. Any major hitch could still prevent the completion of part of the experimental hardware or even of the spacecraft itself, but so far all is going well. In addition to providing the free launch opportunity, NASA is doing all it can to assist the UOSAT Project Team to meet the launch deadline for what is scheduled to be the last Delta mission planned for a polar orbit. The Information Centre, Second Floor, Senate House, University of Surrey, Guildford, Surrey GU2 5XH.

New Sinclair Micro

Sinclair claim their new QL microcomputer, launched on January 12th, is a 'Quantum Leap' forward in computing performance. Features include a full-size 65 key QWERTY keyboard, 128K RAM expandable via a 0.5 MB RAM pack to 640K, two built-in 100K microdrives, and high resolution colour graphics. The QL has two microprocessors, a 32-bit 68008 to do all the clever stuff and an Intel 8049 to look after the keyboard, sound, and RS-232-C option. The complete package includes four microdrive programs covering wordprocessing, planning, information handling and graphics, and costs £399 including VAT.

The QL is now being produced by Thorn EMI who hope to be producing 20,000 units a month by the summer. The first samples of the new machine should be available towards the end of February, and will be supplied to mail order only. We haven't had a chance to play with one ourselves yet, but we hope to bring you more information when we have. Meanwhile, people out there with itchy fingers and £399 to spend should contact Sinclair Research Ltd, Stanhope Road, Camberley, Surrey GU15 3PS, tel 0276-685311.

Stereo TV Sound

The BBC has been investigating for some time the possibility of adding stereo sound to TV broadcasts. Now, following a series of over-air tests from the Wenvoe transmitter in South Wales, they believe they have found a digital system which will make this possible.

The BBC have tried a number of different systems, including proposals from Japan and Germany, and had previously conducted a series of over-air tests from the Crystal Palace transmitter. They concluded that the second frequency modulated carrier would prove satisfactory, a digitally modulated second sound carrier would be a more attractive proposition. A series of digital tests were then carried out, the Wenvoe transmitter being chosen because nearby mountains can produce severe multipath propagation or 'ghosting' and it was important to establish that a digital sound signal could receive satisfactorily in such conditions. The effect of multipath was found to be very small, the digital signal provided excellent stereo quality, and the signal was found to travel successfully through the five-station relay chain that is used to feed one of the more remote valleys.

The conclusion is that this digital system is perfectly viable, provides good quality, and remains compatible with existing mono receivers. The system has a bit rate of 700 kbit/s which is sufficient for two high quality sound signals, and uses a phase modulated carrier set at about -20 dB and separated by about 6.55 MHz from the vision carrier. It now remains to make quite sure that the digital system really is compatible with the wide range of monophonic receivers in use, and a further series of tests from Crystal Palace on BBC2 is planned early this year. The BBC say they are also starting discussions with Industry, the IBA, and the Home Office in order to arrive at an agreed UK standard.

The Engineering Information Department, BBC, Broadcasting House, London W1A 1AA, tel 01-927 5432.
Bench Power Supplies

A family of four bench power supplies, the GPL series, has been introduced by Gresham Powerdyne Ltd. The series offers a choice of single, dual and triple output models featuring excellent voltage and current regulation, low ripple and noise and compact mechanical construction.

The smallest model, the GPL 20, offers variable 0-20 volts, 1 amp max output plus a fixed 5V, 1 amp max output. Ripple and noise is less than 0.5mV rms on both rails, while the variation in output voltage for a 10% mains variation is also less than 0.5mV. Output resistance is less than 5 millionths and output impedance less than 100 ohms at 100 kHz. The GPL 20 has variable current limiting, a moving coil meter, measures 91 x 300 x 200 mm, and weighs 4 kg.

The GPL 23a unit features two independent 0-30V, 2 amp max outputs with a choice of constant current or constant voltage modes, and a fixed 5V, 3 amp output. Load regulation for the variable rails is better than 3mV (zero to full load), with ripple and noise better than 1mV in constant voltage mode and line regulation better than 0.5mV for a ±10% mains change. For the fixed 5V rail, load regulation is better than 50mV (zero to full load), and ripple and noise less than 5mV rms. The unit measures 190 x 355 x 230mm, weighs 7.6kg, and has a high resolution 10-turn potentiometer which provides setting resolutions better than 5mV.

The two large moving coil instruments are read in conjunction with a range change switch and are accurate to approximately 1% of full scale deflection.

Model GPL 25 has a single 0-40V, 1 amp output and features variable current limiting and two meters for simultaneous indication of voltage and current. It measures 91 x 300 x 200 mm, offers a 0.5mV max output regulation for a ±10% mains change, ripple and noise of less than 0.5mV rms and has an output resistance of less than 5 milliohms. Weight is less than 4kg.

The largest unit in the series is the GPL 28, which offers a single 0-60V, 2 Amp output with dual tracking (0-30V, 2A) facilities as standard. Weighing 7kg and measuring 122 x 300 x 243 mm, the GPL 28 offers the same standard of regulation found on the other units in the series.

U.K.'s First Electronics Supermarket

Marco Trading have just opened a new self-service supermarket-style electronics components shop with approximately 1000 square feet of floor space. This is believed to be the first shop of its type in the UK.

The shop is next door to the warehouse, so there are lots of items on sale that don't often find their way onto advertising lists, and of course, there should be minimal delay in obtaining fresh stock items.

The shop is at The Maltings, High Street, Wem, Shropshire, which is just outside Shrewsbury. Marco Trading say there is ample parking, useful if you intend buying some heavy transformers!

Back-to-Back Adaptor

Eurotech Electronics have introduced a male to male adaptor, which allows two female terminated ribbon cables to be connected to one another. The two sets of pins in the adaptor are connected in a 'mirror image' fashion so that two cables normally travelling in the same direction will not have their pin sense reversed by being connected back-to-back. The adaptor is available with from 10 to 60 contacts arranged on a 0.1" pitch and in a variety of latching lengths. It can also be supplied as a solder header for reversing the ribbon cable exit on a printed circuit board. Eurotech offer a wide range of other products, and details of both these and the adaptor can be obtained from the Passive Components Division, Eurotech Electronics Ltd, Durns House, St. Pauls Road, Salisbury SP2 7BE, tel 0722 744222.

International Optical Fibre Cable

British Telecom have announced plans for an underground optical fibre system which will carry telephone calls and computer data between the UK and Belgium. The 122 kilometre cable will be made in Britain and should be ready for use in about two years time.

There are already four cable systems linking the UK and Belgium but this will be the first international undersea link anywhere in the world to use optical fibres. The £7.25 million contract has been awarded to the submarine systems division of Standard Telephones and Cables and the investment will be shared between four countries, British Telecom holding half and the remainder being divided between Deutsche Bundespost, the Belgian RTP and the Netherlands PTT.

The cable will contain three pairs of fibres each working at 280 mbit/s and carrying 3,840 64kbit/s circuits, giving the complete cable the capacity to carry 11,520 simultaneous telephone calls. The system will use long-wavelength singlemode transmission and there will be three submerged repeaters in the cable, each of which will contain three bidirectional optical regenerators. Single mode transmission of laser light along optical fibre cables requires higher than one sixth of the number of repeaters which would be required by an equivalent co-axial cable.

British Telecom say the cable will be laid by their cableship Alert in the spring of 1985, and will be buried to protect it from trawlers and other shipping. Digital communications via the cable should become available in the second half of 1985.
New Micro From Oric

A new Oric 1 computer has been launched at the Licor Products International at the National Exhibition Centre in January. The new micro supercedes the original Oric 1 and contains a number of new features and refinements compared with the earlier machine, most notably a professional full-pitch typewriter keyboard and a case which has been restyled in black and red.

The Oric 1 has a new ROM operating system from which, Oric claim, all the quirks of the original Oric 1 system have been removed. Several new commands have been incorporated including print and user controlled repeats, and there are a number of new cassette facilities designed to improve tape loading. There is also a new command which allows the program to use memory normally reserved for graphics. Oric claim that there is at least 44K of memory available even when a colour printer and disc drives are attached to text mode. In spite of these changes, the operating system remains fully compatible with Oric 1 software written in BASIC.

Low Cost Dual Trace 'Scope

Bridge Scientific Instruments, who recently took over the producing Scopes, have introduced a new general purpose oscilloscope which is available in single and dual trace versions, is British built, and costs less than £200.

The single trace SB 121 and the dual trace DB 242 are described as small and highly portable. Bridge do not give the bandwidth figure in their press release but they do say that the 'scopes are suitable for television servicing work. Sweep speeds can be varied from 1 us/cm to 0.2 s/cm and the maximum sensitivity is 50 mV/cm. A medium persistence phosphor is used and the CRT display area is 60 x 50 mm. Features include a trace locate button which returns over-scaned traces to the screen regardless of other control settings.

The DB 242 is expected to sell at a little under £200 excluding VAT, but no price is given for the SB 121. Bridge Scientific Instruments Ltd, 63-65 High Street, Skipton, North Yorkshire BD23 1EF, tel 0756-69511.

Small Rack Enclosure

New from STC Electronic Services is a unique modular enclosure, the BICC Vero KMT, suitable for housing small electronic products and circuits. The KMT comprises two blue plastic side panels and 2mm-thick anodised aluminium front covers which are available in 42, 35, 21, 18, 12, 7 and 6 HP widths. Accommodating plug-in cards and units up to 42 HP (1HP=5.08mm or 1/5), the front section features moulded fixing flanges for 21-way plug connectors specified to DIN41617. The rear section is a purpose-designed aluminium extrusion for mounting the power supply, providing both electrical and thermal screening, and is designed to clip easily onto the enclosure to ensure optimum cooling. Optional accessories include front panel sets, plug-in card sets, circuit board kits, connectors and card guides (packs of 10). Prices are £6.93 for the KMT Module Set and between £0.90 and £4.98 for the accessories. For further information, contact STC Electronic Services, Edinburgh Way, Harlow, Essex, tel 0279-26777.

Radio Teleswitching

Radio Teleswitching is the name given to a new system recently agreed between the BBC and the Electricity Council. The system involves the use of BBC transmitters to provide remote control of suitably adapted tariff controlled appliances in consumers premises, allowing the Electricity Supply Industry to smooth peak demand and hence avoid the need for excess generating capacity.

Using the BBC Radio 4 (UK) low frequency (200 kHz) transmitters at Droitwich, Burghhead and Westerglen, which have nearly nationwide coverage, the system superimposes an audiable data signal by phase-modulating the main carrier of the transmitters. The data signals come from a message assembler in Broadcasting House, London. Information from the Central Electricity Generating Board is used to key information onto the message assembler and the resultant waveform is sent to the transmitters. The data waveform is a 50 baud bi-phase signal giving an effective 18 bit/second useful data rate that modulates the carrier by ± 22%. Because of the narrow band nature of the data signals, the signal can be received in areas such as basements or steel framed buildings where the field strength from the transmitters is too low for normal reception.

The signals are received and decoded by Radio Teleswitching receivers installed in consumers' premises, where they are used to control appliances operated on 'off-peak' or other tariff systems such as water or storage heaters. It is understood that consumers will have complete freedom of choice as to whether their appliances operate on the new system or on time switches as at present. Provided storage heaters and the like receive their full 'on' period, the actual times at which they are switched on and off are not critical, and with the ability to directly control a large number of appliances throughout the country, the CEBG will be able to even out demand and thus reduce the overall generating capacity needed.

The Engineering Information Department, BBC, Broadcasting House, London W1A 1AA, tel 01-580 4468.
High-Speed, Low-Power Op- Amp

Burr-Brown has announced a high-speed low-power operational amplifier that draws only 230µA maximum quiescent current at ±15V supply voltage. Known as the OPA21, it is a monolithic device employing advanced laser trimming techniques and intended for use in low-power instrumentation amplifiers, isolation amplifiers, portable equipment and battery operated equipment.

At ±15V supply voltage, the OPA21’s power consumption is only 6.9mW while at ±2.5V, power consumption is as little as 1.1mW. Other advantages include an input bias current of 50nA maximum and an offset current of 4nA. This is particularly important in low-power applications where the high resistor values used can create large voltage errors due to bias currents. Other specifications include a slew rate of 0.2V/μs (typical) allowing it to be employed in high-speed applications, and a low offset voltage of 10μV drift with temperature at 1μV/°C maximum. In addition, the OPA21 offers 100dB common mode rejection ratio and an open loop gain of 120dB minimum. Burr-Brown International Limited, Cassiobury House, 11-19 Station Road, Watford, Herts WD1 1EA, tel 0923-33837.

Infra-Red Pre-Amplifier

Plessey Semiconductors have added an infra-red pre-amplifier to their family of remote control circuits. The SL486 is a high gain pre-amplifier with AGC which is designed to form an interface between infra-red transmitting diodes and the digital inputs of a remote control receiver circuit.

The device has a signal handling range of 120 dB which gives a range of 6-9 metres (20-30’) in very bright sunlight and between 18-24 metres (60-80’) in dull sunless conditions. An on chip gyrator circuit allows operation in environments with high background light levels and fast acting AGC improves operation in noisy environments. Other features include differential inputs to reduce noise and improve stability aided by an on-chip stabiliser which allows operation with a wide range of supply voltages, a pulse stretching circuit for low frequency operation, and a minimal component count to achieve low system costs. The SL486 is available in a 16-pin plastic DIL and is specified over the temperature range 0°C to +70°C. Full details are available from Plessey Semiconductors Limited, Cheney Manor, Swindon, Wiltshire SN2 2QW, tel 0793-36251.

DRAM Controllers

The SN74S408 and SN74S409 are single chip multimode dynamic RAM controller/drivers fabricated in bipolar technology, driving up to eighty-eight 64K or 256K multiplexed-address dynamic RAMs. Each of the 0.2V/µSec gain of 180dB and a slew rate of 4V/µs, and can be used for automatic refreshing of DRAMs. The SN74S408 has eight address outputs and can drive 16K and 64K DRAMs. The SN74S409 has nine address outputs and drives 16K, 64K, and 256K DRAMs. Both feature address lines rated at 500 pF and are available in a small pin dual-in-line package. The SN74S408 and the SN74S409 are pin compatible with each other for convenient system uprating and to allow four-fold increases in memory size.

Further details are available from Microlog Limited, 1st Floor, Elizabeth House, Duke Street, Woking, Surrey GU21 5BA, tel 04862-66771.

Stackable Optocouplers

A new series of end-stackable LED/Phototransient optocouplers has been launched by Norbain Electro-Optics Limited of Reading. The new components have been specifically designed for use in circuits where space is limited.

The S7FH610 and S7FH611 series are contained in 4-pin dual-in-line plastic packages measuring 5.8mm by 6.4mm wide with a pin spacing of 2.34mm by 7.62mm. Except in the polarity of the LED and phototransistor pin-out, the two devices are identical in specifications providing an isolation voltage of 2800V. The optical power output of the LED is 15μW and the LED is designed to accept inputs up to 5.2V. The optocouplers are banded in four groups with minimum and maximum current transfer ratios of 10% to 40%, 63% to 125%, 100% to 200% and 160% to 320% respectively.

These devices provide circuit designers with the choice of using exactly the number of optically coupled channels needed whilst keeping the space occupied to a minimum. Applications include the direct replacement of quad packaged couplers such as the ILQ74 and dual couplers such as the ICT26 with the added advantage of needing to replace only one channel in the event of circuit failure. Norbain Electro-Optics Ltd, Norbain House, Bolton Road, Reading, Berks RG2 0LT, tel 0734-864411.

Dual Op-Amp

The Siemens TCA 2365 offers two power op-amps on a single chip. Each amplifier has an output of 2.5A, and the use of an additional inhibit circuit enables three output states to be selected. Siemens claim that combining two amplifiers in a single package costs significantly less than two equivalent single devices and that, at the same time, assembly costs are cut.

The double op-amp comes in a 9-pin single-in-line package. Integrated protection circuits make the outputs DC short-circuit-proof with respect to negative and positive supply voltages and also prevent thermal overload of the internal amplification circuits. The output voltage rise time is 4V/µs, and Siemens believe the new device will find application in fields such as climate control, instrumentation and control, machine controls, and monitoring and alarm systems. Siemens Limited, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS, tel 09327-85691.

ETI MARCH 1984
SX 1000 Electronic Ignition
- Inductive Discharge
- Extended dwell circuit stores greater energy in coil
- Three-position changeover switch
- Contact breaker triggered by delay to lock or remote initiating
- Rugged die-cast case
- Contactless adaptors included for majority of 4 & 6 cylinder vehicles
- Easy to fit

TX 1002 Electronic Ignition
- Inductive discharge
- Extended dwell circuit stores greater energy in coil
- Three-position changeover switch
- Contact breaker triggered by delay to lock or remote initiating
- Rugged die-cast case
- Contactless adaptors included for majority of 4 & 6 cylinder vehicles
- Easy to fit

AT-40 Electronic Car Alarm
- Guards doors. boot. bonnet from unauthorised entry
- Arm/disarm by using concealed switch
- 30 second delay to arm. 7 second entry delay
- Can be armed in conjunction with flashing headlights & sounds horn intermittently for 60 seconds when activated
- Roller door or remote initiating
- Rugged die-cast case
- Contactless adaptors included for majority of 4 & 6 cylinder vehicles
- Easy to fit

TX-2002 Electronic Ignition
- Two separate systems in one unit
- Inductive or Inductive Discharge
- Three-position changeover switch
- Gives highest possible spark energy
- Contacts or contact breaker triggered
- Contactless adaptors included for majority of 4 & 6 cylinder vehicles
- Easy to fit

AT-80 Electronic Car Security System
- Guards doors. boot. bonnet from unauthorised entry
- Arm/disarm from outside vehicle by magnetic fob passed across sensor pad adhered to inside of windscreen
- Individually programmable case
- 30 second delay to arm
- Flashes headlights and sounds horn intermittently for 60 seconds when activated
- Security loop protects accessories
- Function lights to assist setting up
- Low consumption C-MOS circuitry

RULTRASONIC Intruder Detector
- Supplementary to AT-40 & AT-80
- Will work in conjunction with any door switch input or voltage sensing alarm
- Detectors attempt to break-in and movement within passenger compartment & triggers alarm
- Can be mounted in or out of line of sight
- Crystal controlled for low drift & high senstivity
- External sign theft function
- Low current consumption

VOYAGER Car Drive Computer
- 12 functions
- Functions
- Fuel
- Speed
- Distance
- Time
- Single chip microprocessor
- Large high brightness fluorescent display with auto dimming feature
- High accuracy distance & fuel transformers included
- Displays MPG, 110km and miles at the flick of a switch
- Voice & audible warnings of excess speed
- lights on
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- Low consumption crystal controlled circuitry

MAGIDICE Electronic Dice
- Triggers by waving hand over dice
- Completely random selection
- Steady & flashing display 4 pin rumble
- Throw displayed for 10 seconds then flashes to conserve battery
- Low consumption C-MOS circuitry

**NEW**

**SPECIAL OFFER**
**FREE** MAGIDICE KIT WITH ORDERS OVER £40.00

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<thead>
<tr>
<th>KIT</th>
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<th>NEW PRICE</th>
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**PRICES REDUCED ON SUPER SAVE D.I.Y. KITS**
Hand-held Insulation Tester

Osborne Electronics have introduced a new type of 500 volt insulation tester which they believe offers radical improvements over existing test units. Designated the model 4100, it is a completely self-contained hand held unit which offers the same order of accuracy as units currently selling for three times its price.

The complete unit, comprising the electronics, battery, display and probe, is contained in a slim-line case measuring 32 x 22 x 100 mm overall. Weighing just 75 grams, the unit nestsles comfortably between thumb and forefinger and can be operated with one hand. The bright red bargraph display has a total of ten steps ranging from 1 to 100 Mohm, and is almost impossible to misread. In order to ensure total operator safety the model 4100 has been fitted with a current limiting circuit as standard. The unit's power consumption is 110mA at 9 volts... for continuous use applications, it can be fitted with a rechargeable battery or powered by Osborne's optional mains adaptor.

Further information is available from Osborne Electronics, Binstead Road, Rayde, Isle of Wight, tel 0983-63622.

SHORTS

Following their decision to establish a new research and development centre in Bristol (reported in January News Digest), Hewlett Packard have doubled equipment worth around £40,000 to the Engineering Department of Bristol Polytechnic. The equipment is intended for use in advanced silicon chip design and development, and marks the start of a number of joint ventures between the Polytechnic and Hewlett Packard.

Lucas Electrical have issued a brochure giving extensive details of methods for suppressing transients in telecommunications and data transmission systems. The brochure illustrates the use of Lucas' latest surge suppressors using silicon pn diffused junction construction, and is available from the Sales Engineering Department, Lucas Electrical Electronics & Systems Ltd, Mere Green Road, Four Oaks, Sutton Coldfield, West Midlands B75 5NH.

Esselte Dymo, manufacturers of anti-static cleaning agents, have published a booklet entitled "Caring for your Computer or Word Processor". The booklet describes the problems caused by static in data handling systems and how to overcome them, and is available free from Esselte Dymo Ltd, Esselte Dymo Ltd, Spur Road, Feltham, Middlesex TW14 0SL.

The twenty-second International Electronics Exhibition, Electrex '84, will be held at the National Exhibition Centre, Birmingham from February 27th to March 2nd. More than 1200 companies will be represented and the number of visitors could well exceed last year's 43,000. Details from Electron Ltd, Wix House, West Horsley, Surrey KT24 6DZ, tel 0483 222988.

Russell Electronics offer a repair and calibration service for multimeters and other test equipment. They use the Royal Mail parcel service, will quote on repairs before carrying them out, and can be contacted on 0737 71958. R. S. Electronics, 511 Fulbridge Road, Werrington, Peterborough PE4 6SB.

The latest products for ITT Cannon products take the form of a glossy calendar. Presumably nothing like Pirelli's success with pictures of unat-tyred women, Cannon's calendar will show..."...stunningly beautiful models, wearing only a smile and a precise array of the latest Cannon connectors, but for this 'corporate and subtle product promotion' will be limited to 2500 copies and Cannon envisage it becoming a collectors' item. But what has it all got to do with plugs and sockets, dare we ask?

ETI March 1984
MULLARD SPEAKER KITS

Type E: £119.00 each. Type L: £34.00 each. Type S: £27.60 each. Type T: £24.00 each. Type U: £16.40 each. Type V: £14.90 each. Type W: £11.20 each. Type X: £8.50 each. Type Y: £7.99 each. Type Z: £7.39 each. Type A: £7.29 each. Type B: £6.75 each. Type C: £6.29 each. Type D: £5.99 each. Type E: £5.59 each. Type F: £5.29 each. Type G: £5.00 each. Type H: £4.75 each. Type I: £4.50 each. Type J: £4.25 each. Type K: £4.00 each. Type L: £3.75 each. Type M: £3.50 each. Type N: £3.25 each. Type O: £3.00 each. Type P: £2.75 each. Type Q: £2.50 each. Type R: £2.25 each. Type S: £2.00 each. Type T: £1.75 each. Type U: £1.50 each. Type V: £1.25 each. Type W: £1.00 each. Type X: £0.75 each. Type Y: £0.50 each. Type Z: £0.25 each.

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Compact 8-track stereo deck in a convenient size. Includes chromed face plate, chrome fitting, and black metal finish. With a built-in tape counter and a well-planned circuit. Includes a freebie LED display indicator. Available in black or silver. Price: £27.80.

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CABLE TELEVISION DOWN THE DRAIN?

If you live in Aberdeen or Ealing, Glasgow or Belfast, or one of the other 11 initial areas for cable television, you could well be offered cable television in the next year or so. But what of the rest of us, and what might it be like if we do get it?

A month or so ago, the government announced the granting of 11 initial franchises to companies to allow them to set up cable TV services in selected areas, none of them encompassing more than 100,000 homes. There were a total of 37 applications for the franchises, and the government had initially intended to licence 12 franchises.

These initial franchises are not trial franchises: they are seen as the first of many; however, all concerned, including the Government, are feeling their way carefully, and it is expected to be a year or two at least before any further franchises are approved. Table 1 shows the first batch, with a rough outline of their plans.

There are two major paradoxes at the heart of the debate over cable television — the first is well known though rarely admitted to: there are lots of people who want it but nobody is prepared to pay for it. The second is that the cable is intended to be ‘entertainment led’ investment in information technology; that is, what is being bought is the facility to have extra television channels; however, what comes with it, riding piggy-back almost as an after-thought, is the wiring of UK homes ready to take the full force of the information revolution.

When commercial television first came to the UK it was described as a ‘licence to print money’. There certainly haven’t been any bankruptcies amongst TV companies, and there is certainly a fair amount of competition for broadcast TV franchises when they come up for renewal, so this must still be the prevailing attitude. There must be plenty of investors around who’d like to get an ‘in’ on television — or are there?

There are, however, very significant differences between the cable and the broadcast TV. In broadcast TV, you build (or lease space on) a handful of transmitters and aerials; in cable TV, you have to provide a network of cables to physically connect each home that you intend to serve (and you have to provide this network not knowing how many of the homes you are passing with the cable will take the service); in broadcast TV, you provide one channel; in cable TV, you have to provide several channels (a dozen or more) or you won’t attract people to take the service. You also have to provide facilities to receive all the broadcast channels as well.

These factors combine to make the amount of money required to set up a cable service to a medium-sized conurbation — such as the 100,000-home in the initial block of franchises — around £25 million.

Some cable TV companies are taking a slightly different option, in that they are finding someone else, often British Telecom, to lay the cable which will then be leased; however, the cable-providing companies will not be charitable bodies, and will want to charge a fair rent for their investment, which has led most cable companies to decide to install their own cable. In any case, someone somewhere has to shell out for the laying of the cable.

In fact, it has been predicted that the quantity of money required will severely limit the growth of cable TV. A back-of-the-envelope calculation suggests that cable TV will require an investment of around £10 billion to reach half the population. As a result, there will be a lot of cable TV companies chasing a very limited amount of money, should the government ever give the go-ahead to all-out cabling.

Who Will Buy?

To reach profitability, a cable network will need to attract a fairly high proportion of the potential customers to actually take up the service that passes their front door. Estimates of how many people actually will take up the service vary a great deal, as do estimates of the exact percentage needed to make the service financially viable. For the former, estimates span 12 to 36% by the mid 1990s; however, for the latter, one estimate is that even a 50% take-up would be marginal as far as investors in cable are concerned. (Contrast both these sets of figures with the findings of a recent survey in Which? magazine that indicated that only 15%, of households might be prepared to pay to receive extra TV channels.)

Another factor is that at the moment we have a government that is relatively welcoming to the prospect of cable TV — what would happen if another government came along that was horrified at the prospect of £10 billion being dragged out of the economy?
to pay for cable TV? I must interject, ironically, that it was the economist Keynes who said that the economy would be stimulated simply by employing people to dig holes in the road and fill them in again. This sounds remarkably like the laying of cables to me. Unfortunately, Keynes' ideas have been supplanted by the monetarist policies of Mrs Thatcher's government.

Even though the present government is, as already mentioned, fairly 'pro' cable, there are a couple of fairly tough conditions applied to the franchised companies. Firstly, the franchise is for a fixed term: in the case of the initial franchises the term is either 12 or 20 years, depending on the type of system installed (12 for tree and branch systems, 20 for switched star — see later for explanation of terms).

The second condition is that the company must complete the wiring of the network once it has begun, no matter how poor the up-take to the system is. This may seem a rather odd requirement — what is the point of laying cable if you cannot then afford to run the service? — but it is as a consequence of the government's view that one of the objectives is the wiring of Britain for other purposes, not just TV, all using the same service. Also related to this is that the actual cable network itself has zero value — what bank, for instance, would wish to risk having to foreclose a company whose major asset was several hundred miles of copper buried in the ground?

What's On Offer?

What the cable TV companies are offering in the trial areas are all fairly similar. For a basic monthly fee of around £5 to £9 per month, you will get the basic service, consisting of a number of channels: up to 16 may be provided in some areas; although exactly what the companies will be offering is still being decided, channels proposed include local news, children's programmes, sports, music, teletext, national news, general entertainment, classified ads, general interest, business news, educational (possibly including Open University programmes), and community access.

Some of the companies plan to offer a second tier of channels for which an additional fee will be payable (usually of around £5 per month); this will 'cream off' the most popular items from the above list. However, all the companies will have 'premium' channels, which will cost an additional £6 to £8 each per month and will mainly be feature-film channels, carrying newer films than the broadcast channels can afford to buy.

The film channels are, to the customer, one of the most attractive features of the cable TV service; unfortunately, there are a number of problems with this very aspect of the service. They are:

- expense: by the time customers have paid the basic fee plus one or two premium fees, they will be shelling out around £11 to £17 per month; many prospective customers will already have videos, and at a cost of as little as £1 per night, the hiring of films looks very competitive;
- convenience: unlike a video, you will still have to watch the film when it is broadcast, not when convenient; however, it isn't necessary to visit a shop to get the film;
- supply: on average, approximately three full-length English-language feature films are completed each week; obviously, some of these will be dire or unsuitable for use on cable for other reasons, so at the somewhat restricted rate of showing one film per night (actually, we would seem a more realistic figure) demand will still outstrip supply, and prices of films to the cable companies will rise;
- resources: although the investment sums involved in cable TV are relatively high, it is unlikely that it will have the resources to be able to generate much in the

<table>
<thead>
<tr>
<th>Town</th>
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<tr>
<td>Aberdeen</td>
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<td>Basic 11-16 channels for £8; classic first-run film channels £7 each</td>
</tr>
<tr>
<td>Coventry</td>
<td>Coventry Cable</td>
<td>Basic up to 10 channels for £6; premium movie channel £7 per month</td>
</tr>
<tr>
<td>Belfast</td>
<td>Ulster Cablevision</td>
<td>Basic 12 channels for £7; premium film channels (3) £8 each; sport channel</td>
</tr>
<tr>
<td>Croydon</td>
<td>Croydon Cable</td>
<td>Basic: £5 per month; extended: £4; premium channels £2 to £8 per channel</td>
</tr>
<tr>
<td>Ealing</td>
<td>CableTel Communications</td>
<td>Basic: 8 or 9 for £10 or less; two premium movies £8 each</td>
</tr>
<tr>
<td>Glasgow</td>
<td>Clyde Cable Vision</td>
<td>Basic: £8 per month; premium film channels £6 each</td>
</tr>
<tr>
<td>Guildford</td>
<td>Rediffusion Consumer Electronics</td>
<td>Basic: £6 per month; premium movie £8; also many interactive channels planned</td>
</tr>
<tr>
<td>Liverpool</td>
<td>Merseyside Cablevision</td>
<td>Basic: £8 to £9; second tier £4 to £5; two movie channels £6 to £8 each; interactive services</td>
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<tr>
<td>Swindon</td>
<td>Swindon Cable Services</td>
<td>Basic: 8 for £5; two premium movies £7 each</td>
</tr>
<tr>
<td>Westminster</td>
<td>Westminster Cable</td>
<td>Basic: 14 channels for £6 to £7; super-basic: 5 for £2 to £3; premium: 3 for £7 each</td>
</tr>
<tr>
<td>Windsor</td>
<td>Windsor Television</td>
<td>Basic: 11 channels for £6.90; premium channels £8 each (several planned)</td>
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</table>

Table 1 The initial batch of franchises; note the details and prices are very preliminary, and that some companies may also decide to charge connection fees as well.
way of its own premium material, in the way that Channel 4 has been able to finance the making of films. For example, £1m for a 1½ hour feature film now seems to be regarded as "low-budget"; even television documentaries cost around £30,000 for every hour that the viewer sees, and this is probably well outside the reach of the cable companies.

What Will Pay Its Way

Actually, the cable TV companies will probably not be that closely involved in the purchase of material for transmission over their particular networks; they will probably 'buy in' pre-programmed material from programme providers. As it happens, London Weekend Television seriously considered entering this business, and did some research into what people would be prepared to pay for; having decided that they were not, at least at this stage interested, they made their findings public at a recent Seminar.

LWT found that there would definitely be a market for three types of channel:

- the movie channel, provided the difficulties mentioned above do not confound it, would definitely be very popular;
- an "adult" or "club 18" channel, with sexually not-too-explicit material and slightly nasty films would also be successful (note that the Government has made it plain that it will not permit the 'excesses' that cable TV in the USA has sunk to);
- finally, what they dub "wall-to-wall, heart-to-heart" would also be popular (this would consist of continuous soap opera — imagine it — 12 hours a day of Dallas). This last possibility is the most horrifying, but also the most interesting. For a start, there is no problem in obtaining enough material for this sort of channel. LWT found that they could easily buy in enough material to fill three 12-hours-a-day channels! Also the audience for this sort of "undemanding" TV is quite high ("Why do you think people watch soaps?"). However, people would not be prepared to pay any extra for "wall-to-wall, heart-to-heart", and to make the channel viable it would have to carry advertising. For advertising to be viable, this channel would have to reach 50% of households in the catchment area.

There is another sort of channel that LWT discovered might make a living, and that is a pop music channel, provided that the material was given free to the cable companies.

Note that these possibilities do not include a sports channel. The Government has ruled out the possibility of the cable companies being allowed to buy sole rights to national events, such as the FA cup final for instance, and has also ruled out pay-per-view. There is a debate going on as to who has who over a barrel over the future of the regulation of the channel. Cable companies think that they're the ones who hold the upper hand, because without them being able to make a healthy profit, the government will not get the cableing of Britain that it wants, so they think they will be able to force concessions in the future. On the other hand, the government obviously wants any new service to force concessions in the future. On the other hand, the government obviously wants the upper hand once the companies have installed their networks.

And, almost as a postscript to this section, another factor over the actual programme content that hardly needs pointing out is that if cable TV were to become successful, the broadcast channels, and in particular the commercial channels, would be obliged to try and compete with the cable channels, and on their own terms; there are a number of commentators who believe that this would lead to the destruction of the diversity that goes to make British television the best in the world. Programs that are not specifically aimed at the lowest common denominator would disappear from our screens to be replaced with continuous second-rate soap opera.

Advertising

At the heart of much of the uncertainty of the future of cable TV is how well the advertising will sell. Really, it is a chicken-and-egg situation — if advertising sells well, then prices to the viewer are likely to be lower, so more people will take the cable, so more advertisers will want to use it, etc. However, advertisers are very reluctant to use cable TV due to its very low uptake: even a relatively optimistic estimate of a 35% up-take amongst households offered the cable is likely to be much too low to interest any of the 'Mainstream' advertisers.

All the same, when most of the 11 franchisees were asked about advertising, they made quite optimistic noises, largely on the basis that they felt that they could get many smaller, local advertisers to use them. As far as television advertising goes, these are uncharted waters.

It is perhaps instructive to look at the situation in the USA to see how well cable TV advertising sells over there. In 1982, approximately $180 to 200 million was spent on cable TV advertising, compared with the figure of around $12.7 billion on just three major broadcast companies (NBC, CBS and ABC) over a similar period. So while the money spent on advertising is not be ignored, compared to the other sums of money involved (and compared to the investment required to lay the cable), it isn't a great deal.

The Technology

Existing cable systems are in many cases pretty antiquated; for example, the Rediffusion network uses a twisted pair to distribute a HF signal (not even VHF, never mind UHF), so major changes in technology will have to take place.

There are two areas that can be examined here; firstly, there is the overall shape of the system. It could either be tree and branch (as in Fig. 1) where all the

![Fig. 1 The tree and branch distribution system.](image-url)
subscribers have all the channels supplied to their house by a single cable. A conventional coaxial cable will have ample bandwidth for up to thirty or more channels of television; however, the channels that require an extra subscription would have to be scrambled in some way, so that they can be received only by the use of a special unscrambler which you would get upon payment of the extra fee.

The other system, shown in Fig. 2, is the switched star arrangement. Here all the available channels are supplied to a local 'switch'. Individual subscribers are then supplied with the channel they select by the 'switch'. Obviously, the method here involves an interaction between the users and the switch, and this is the reason why the government is encouraging this system. The switched star system is seen as the system of the future, as the interactive nature of the service can be extended easily to include interactive banking, shopping, and many more options as viable ideas come forward.

Thorn EMI disagree over the dismissal of the tree and branch system as the less adaptable of the two. They have their own system — teletext addressability and control for cable systems (TACCS) that they think could offer all the advantages of switched star at a much lower cost. According to them, by extending the teletext system, they can offer 30 TV channels plus 35 radio programmes, a down (to the subscriber) data capacity per channel in excess of 200Kbs on locally generated TV channels and 12 Kbs on broadcast channels, with a potential up capacity of 750Kbs (presumably not from each individual subscriber but from the system as a whole), and using various interrogation techniques and data storage at the users' receivers, they say that they would be able to supply virtually all the interactive facilities that a switched star system could support.

However, Thorn EMI seem to be fighting a losing battle and most of the initial franchisees have opted for switched star.

The Cable
The other aspect of the technology that is cause for concern is the actual carrying medium being used. All the companies will, for the foreseeable future, be using coaxial cable for the transmission of the signals to our homes. Now it is obvious that optical fibres are the medium of the future — they are cheap to produce in themselves, have much higher bandwidths with coaxial cable, and would therefore have ample room for future developments. They should also be less susceptible to the ingress of moisture — a continual problem with underground coaxial cables which causes a major maintenance burden.

However, the technology of optical fibres is very young, and although the fibres themselves are cheap, the rest of the system is pretty expensive when compared to that associated with coaxial cable: prices of approximately ten to twenty times more for a fibre system overall have been mentioned. It is predicted that optical fibres will not be price competitive until the mid-nineties at the earliest, but after that the price will continue to become more favourable in comparison to coaxial cable (and what happens if world copper prices rise?).

The mid-nineties, is rather an interesting time for cable TV: not only is it the time that some of the tree and branch system trial franchises will run out, it is also the time that cable systems should be coming on stream in a big way. So, it is most worrying that the technology used should become obsolete just as the whole system is getting on its feet.

Beyond Television
As yet, exactly what will go into the interactive services is still at a relatively early stage of planning, with no one able or willing to commit themselves to exactly what will be available or when. Rediffusion who have the Guildford franchise say that they will be using this to develop their expertise in interactive services. They claim that their plans are probably the most advanced, but even so they are unable to give any definite details.

The services proposed include public data lines, and private. Public services will, they hope, include home banking (the banks, facing increasing competition from the building societies, are said to be receptive to the idea), teleshopping (at least one major mail-order firm is interested), telebetting, meter reading, home security (ie monitoring of a burglar alarm while you are out and possibly a 'panic button' facility for the elderly), video games and formal learning. The private data lines would be leased to large organisations such as hospitals or the police to enable them to pass around information such as records or electronic mail.

Conclusion
In this brief article, it hasn’t been possible to delve very far into all the details of what looks like becoming a multi-million pound industry. However, it is hoped that a flavour of the situation has been conveyed, along with the controversies involved. As a personal note, I find myself agreeing with one commentator at the seminar mentioned earlier: that cable TV is the right thing to do, but now is the wrong time for it.

* The seminar mentioned was Whose Cable?, organised by the Consumers’ Association. I should like to thank Dianna Collins of Rediffusion for answering my stupid questions, and Mark Phillimore of Cabletime (Systems) Ltd for providing the front cover shot of TV cable being laid in a sewer.
THE 1984 GREENWELD CATALOGUE

Now in the course of production, the 1984 GREENWELD catalogue will be published in January (sorry about delay), its Bigger, Better, more informative than ever before. With each copy there's a discount voucher, Bargain List Wholesale Discount List, Bulk Buyers List, Order Form and Reply Paid Envelope. All for just £1.00! Order now for early delivery!

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In the cut-throat world of consumer electronics, one of the questions designers apparently ponder over is: "Will anyone notice if we save money by chopping this out?" In the domestic TV set, one of the first things that you want to get right is the sound quality. Small speakers and passive tone controls are common and all this is really quite sad, as the TV companies do their best to transmit the highest quality sound. Given this background a compact and independent 'TV tuner' that connects directly to your Hi-Fi is a must for quality reproduction. The unit is mains-operated.

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As expected, this has proved to be a very popular project; there were, however, one or two problems that we hope this will resolve.

There were a few errors in the typewriter interface project, one of which was major, while the majority were fairly minor and would probably have been found during construction.

The major error is that the software listings (both the EPROM listing and the data for the alternative BASIC program) were for a different generation of prototype from that for which the circuit diagram was given. There are two ways of amending this; you can EITHER:
- modify the circuit, by exchanging the connections to IC1 pins 9, 10, 11 with pins 13, 14, 15 in that order
- change the data in your computer program or EPROM (depending on which method of driving the board you have chosen); revised data is given in Tables 1 and 2.

The minor errors are as follows:
1. The ribbon cable connector is, in fact, the wrong way round on the PCB (although this only becomes apparent if a right-angled connector is used). Pin 1 is at the end marked with an arrow on the connector and should be connected to the coloured wire of the ribbon cable. The connections inside the typewriter are as shown in Fig. 1. As long as the correct connections are made, it does not matter that the PCB layout is incorrect — it is simply a matter of convention.
2. The interface is powered entirely from the typewriter. The note 'Microcomputer VCC' should not have appeared on the circuit diagram. Pin 1 of SK2 is connected to VCC — there was some problem in reproducing the drawing here. The ground of both the microcomputer and the typewriter should be connected to the interface.
3. It was not mentioned that timing can be done by printing, for example, 50 characters continuously from the microcomputer and using the second hand of a watch.
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Other Points
Readers have raised a number of other points, and we can answer some of them here:
1. The interface could have been placed in the typewriter casing, but this was not done to avoid possibly invalidating any guarantee.
2. The interface should work with an EX42 model, but it must be connected in the way described for the EX42, not via the edge connector.
3. The best price we know of for the EX42 at the moment (though if anyone can tell us of a better one, we'll pass it on) is £199 + VAT, from Discount Typewriters of Meadow House, Fair Oak, Lane, Oxshott, Surrey, who advertise in Exchange and Mart (but not ETI yet!). Alternatively, it is widely available from many high-street office suppliers (eg Ryman's) for around £245 including VAT. These prices are correct at the time of going to press (early January 1984) but please check them yourselves.
4. The interface should, in principle, work on any microcomputer. Obviously, though, the BASIC program will be different in each case, and we are unable to account for every computer out there! The program given was written in Micrologic BASIC and some of the statements used may be unfamiliar to some readers. These are:

Line 70: open file number 1, the file name being the string variable B5; if the end of the file is reached, then go to line 340;

Line 80: read one line from the input file number 1;

Line 210: output to the port number 7E (hexadecimal radix) the contents of variable X;

Line 220: output to port 7F all zeros; this port is used as the strobe signal to initiate printing;

Line 230: output to port 7F a 1 on bit 0. The strobe is connected to bit 0 of the port;

Line 240: input from port 7F; bit zero is the busy signal and is true when high.

5. The interface can probably be used with other electronic typewriters provided they have their keys arranged on an 8 x 8 matrix. Unfortunately, rather a lot of work would be involved in generating this data, so we cannot give advice in this respect; however, if someone out there has already done it with a popular model of typewriter, and wants to earn a penny or two by writing an article, we shall give it full consideration for publication.
6. There is already an RS232 interface available from Silver Reed, although we are prepared to consider publishing a design if someone offers us one.
7. We hope to organise an EPROM programming service, but details are not yet available.

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Last month I told you that there are usually three logical instructions that can be used and looked at the first of these, the AND instruction. We begin this month by looking at the two remaining instructions.

The second binary operation that we can use is OR, which will have the same register format as for AND. Loading Register A with COh, and register B with AA; Fig. 20 shows the result of the instruction OR,B. Note that, as with AND, only the A register is altered. Let's have a look at a practical use for the OR operation.

```
11000000 = Register A before the instruction
10101010 = Register B before, and after, the instruction
11101010 = Register A before the instruction
```

**Fig. 20 The operation of the instruction OR,B.**

Because machine code is so very fast it is prudent to have delay loops at certain points in the program. A delay loop just wastes time for a while in a manner similar to, but smoother than, the PAUSE instruction in BASIC. The simplest way of obtaining a loop would be to load a register with a count and then decrement the count to zero, using the zero flag to indicate that condition. However, counting down even FFh is incredibly fast, so it seems that a register pair is required to hold a larger number. Alas, although a register pair can be decremented, there is no flag indication to let us know when zero has been reached. Study carefully the delay loop in Fig. 21 which has instructions from the Z80 set. The instruction 20h – JR NZ,e means jump back (on this occasion) by e, until register A reaches zero. This loop can be finely 'tuned' by adjusting the low (in C), or high (in B), count.

![Fig. 21 A delay loop.](image)

Even longer delays, and more precise 'tuning' can be achieved by the use of a single register to hold a count which represents the number of times we go through the loop. For example, suppose we wish to run through the loop 4 times, just before the loop in figure 21, load a register with 4d then push that register. After going through the loop, pop the register, decrement it, and if not zero jump back to push again. Any register pair could be used for the loop, except of course AF, provided you use the instructions pertaining to the register pair. You could use register A to hold the count outside the loop if you wanted, because even though register A is used inside the loop, the count would be preserved by the push instruction.

Using Fig. 20 to sum up, the use of OR will ensure that the corresponding bit in the A register is set if that bit in either A or B is set. To remind you, set is 1, and reset is 0.

The exclusive set . . .

The last binary logic operation we can use is exclusive or, which is shown as XOR. Put into words, and using registers A and B as examples, it goes like this; the corresponding bit in register A will be set if either, but not both, bits in each register are set. Loading register B with COh, and register A with DAh,
Fig. 22 shows the result of the instruction XOR,B. XOR,A will clear register A, and reset the carry flag for you. By studying the binary pattern of the data that you are manipulating, and the binary pattern of the expected answer, a knowledge of the logical operations may help you decide what to do. If they don’t help, what about the next lot?

\[
\begin{align*}
1000000 & = \text{Register A before the instruction} \\
11011101 & = \text{Register B before, and after, the instruction} \\
00011010 & = \text{Register A after the instruction}
\end{align*}
\]

Fig. 22 The operation of the instruction XOR, B.

Movement of data within a register is quite feasible, and the Z80 set has a number of instructions that will do just that. These are the rotate, and shift instructions, which will allow movement of data, either to the right or to the left. Because there are so many instructions, doing similar things, I have ‘lumped’ all the drawings together, but explanations are in order. Those instructions which involve register A, such as RLA — Rotate Left A, will only affect the carry flag, with two exceptions which I’ll explain below. Rotate or Shift instructions involving registers other than A will affect all of the flags. To find out what happens after a Rotate or Shift instruction, write down the binary code before, and after, the operation, and convert both to decimal, but watch out for the carry flag if it is involved.

![Fig. 23 The operation of the Rotate and Shift instructions.](image)

Fig. 23 The operation of the Rotate and Shift instructions.

![Fig. 24 The half-byte (or nibble) movement.](image)

Fig. 24 The half-byte (or nibble) movement.

Figure 24 shows the two exceptions that I mentioned above from the Z80 set; these are half a byte (or nibble) manipulations. RLD or Rotate Left Decimal (don’t confuse this with RL D, which is Rotate Left, D register), is the first of the nibble manipulations. In this operation bits 0 to 3 of (HL) are moved over to occupy the most significant nibble position, that is they become bits 4 to 7 of (HL). The first four bits, 0 to 3, of register A are now moved to occupy bits 0 to 3 of (HL). The previous bits, 7 to 4, of (HL) now occupy bits 0 to 3 of register A. How it is done, and in what order, doesn’t matter, but the result will be as described. RRD or Rotate Right Decimal, as you can see from Fig. 24, does a slightly different ‘shuffle’. RRD and RLD operations affect all flags except carry. Notice also the use of brackets, (HL); this means that it is the data in the address pointed to by HL that is manipulated.

Because of the lack of registers in the 6502 CPU, most data manipulation is done with the accumulator (register A), via the index registers and/or memory locations. However, sometimes the index registers themselves can be used, as in this example. The instruction EOH — CPX will compare the byte in index register X with a memory location, in fact the address after the byte EO. The result would effect the sign, carry, and zero flags. I shouldn’t have to tell you that the example was in the immediate addressing mode.

A Bit At A Time . . .

Bit instructions fall into two categories; one will actually alter the bit, either set it or reset it, while the other will just test whether the particular bit is set or not. The result of testing will be either zero or not zero, which can be the indicator for the next instruction. If you can’t think of a use for testing a bit, how about this example: suppose that you wanted to print, to the screen, a certain number of squares, alternating between, for example, black and white. Load a register with the total number of squares that you...
FEATURE: Machine Code

As you can see, the codes for the coloured squares only need occupy two locations. To test how it works, assume that the count was 16d, write down the binary 16, then underneath the binary for 15, then 14, and so on until zero, then examine the pattern of bit zero, the rightmost bit. If you then write down, for example, black, opposite the 0s, together with the address of black, then do the same for white opposite the 1s, you need only do this for 3 or 4 squares before the pattern of the program becomes apparent.

A Moving Story...

Often, when developing a machine code program, I can never be sure how many bytes the program will ultimately occupy. One method I use is to put the control program approximately where it should go and write the bulk of the program well out of the way. If I leave room either side of this bulk of program then I can extend in either direction. When I am satisfied that the program works I move the bulk down towards the control program. This usually means altering a few addresses, but that's far better than having to re-write the program because I didn't leave enough room in the first place. So how is a program moved about in memory? Study carefully the program in Fig. 25, which uses instructions from the Z80 set. The HL pair is pointing to the address from which we wish to start moving the program. The DE pair point to the address to which we are going to move the program, and the number in the BC pair represents the number of bytes we wish to move. Register A is now loaded with the byte held in the address pointed to by HL, in other words, let A equal PEEK (HL). This byte is then loaded into the address pointed to by DE, in other words POKE (DE) with the contents of register A. Both HL and DE are then incremented, and BC decremented, and this goes on until BC reaches zero.

Although that little program works quite well, take a look at the program in Fig. 25, which illustrates the use of an automatic instruction to load (DE), (HL), increment those two registers, decrement BC and repeat until BC reaches zero, which is exactly what happened in my program. As you would expect, because the automatic program is slightly shorter it will work a little faster. I have provided two examples for two reasons: First, if your CPU does not have any automatic instructions the first example should give you an idea how to make up a program of your own. Second, to introduce the automatic and semi-automatic instructions from the Z80 set. There are two very important things to note regarding the automatic instruction in Fig. 26. The first is that the transfer of bytes is from (HL) to (DE) only, so make sure which way round you are working. The second point is that when BC has reached zero the zero flag will not be affected, so the only flag you can use is the Parity/Overflow flag which will be reset on BC reaching zero.

Another automatic instruction is ED88h — LDDR which still loads from (HL) to (DE) but this time HL and DE are both decremented along with BC, and again, only the P/O flag is affected. A very useful instruction in this group is ED81h — CPIR which can be used to search a block of memory for a particular byte. It works like this; load HL with the starting address of the memory to be searched, load BC with the number of bytes you wish to search through, and load register A with the byte that you are looking for. If you remember, a compare instruction will only compare something with what is held in the A register. This time the comparison will be made with the byte in the address that is pointed to by HL, in other words, compare A with (HL). The program will stop either if a match has been found, in which case the zero flag will be set, or when BC has reached zero, in which case the P/O flag will be reset. Until either condition has been met HL will be incremented, and BC decremented. The other automatic instruction for comparing is ED89h — CPDR which works in the same way but BC is decremented instead of incremented.

The four instructions that I have just described each have a non-automatic instruction format. The two byte moving instructions are EDA1h — LDI and EDABh — LDD which only perform the operation once. You will have guessed by now that the I in the instruction stands for Increment, the D stands for Decrement, and the R for Repeat. The non-automatic comparison instructions are EDA1h — CPI and EDA9h — CPD. One very useful instruction in the Z80 set which is automatic in operation is 10h — DJNZ,e, this stands for Decrement, jump if Non Zero, by the amount of the offset byte e. This instruction only works on the B register but as I said, it is very useful indeed.

Fig. 25 Moving a block of memory.

Fig. 26 Moving a block of memory using an automatic instruction.
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The Circuit

The circuit consists of two identical power measuring channels and a fairly standard power supply. The power supply provides +15 V and -15 V regulated supply rails offering up to 100 mA each. The regulators are necessary as the rest of the circuit uses them as a reference.

Each of the power measurement channels consists of a current measurement circuit, a voltage measurement circuit, an overload indicator, an analogue multiplier and a meter circuit. The voltage measurement circuit is very simple and consists of a switched attenuator feeding a buffer. The current measurement circuit detects the voltage developed across a low value resistor in series with the load, amplifies it and passes it on to a buffer. The voltage across the current sense resistor is also passed via a switched attenuator similar to that in the voltage circuit.

The buffers in both current and voltage circuits have switchable gains of 2, 2.8 and 4, this provides compensation for the variation in voltage and current levels with different load impedances at the same power level. Note that when the gain of one buffer is at 2 the gain of the other is at 4 and vice-versa. This maintains the meter response at the current level.

The next part of the circuit is the overload detector. This uses an op-amp with some resistors and diodes to detect when either the voltage or the current detectors are giving too much output and are therefore likely to overload the analogue multiplier. This condition will light up an LED on the front panel which tells the operator to change the power range switch or the impedance selector or both.

The analogue multiplier used in this project consists of one half of a transconductance amplifier. This has the property of producing an output current which is the product of two of its input currents divided by a third one. The rather complex circuitry around this section is merely to balance out all the offsets and other unwanted effects.

Following the multiplier circuit is a high impedance buffer whose gain can be varied over a wide range. This drives a moving coil meter which averages the output to give a reading. The series resistor and diodes are present to protect the meter from damage.

Construction

This should pose no great problem provided all the normal precautions with regard to PCB assembly are taken. Start with the wire links then move on to the other components, making sure that the ICs are inserted correctly and that things like capacitors, diodes and transistors are the right way round. The PCB is actually designed in two distinct parts and could be separated into power supply and meter circuit quite easily if desired (note that the overlays for these two sections are shown separately anyway). The PCB mounted fuse can be either an open type like the one we used or a PCB mounting enclosed type for extra safety.

The main problem will probably arise when you come to wire the switches on the front panel, and great care must be taken here to get things in the right order. Two four pole, three way switches were used in the prototype and...
Fig. 1 Component overlay of the main PCB (larger than actual size).

PTAS LIST

RESISTORS (% watt 5% carbon film unless otherwise stated)
- R1,101 0R1 SW W.W. (or more)
- R2,3,102,103 220k
- R4,5,104,105 100k
- R6,7,106,107 100k
- R8,106 220k
- R9,109 10M
- R10,11,5,110, 1k
- R12,13,112,113 56k
- R14,19,20,21,23, 24,30,114,119, 120,121,123,124, 130 10k
- R15,18,115,118 5k
- R16,17,116,117 3k
- R22,25,122,125 470k
- R27,28,127,128 390k
- R29,31,32,129, 33k
- R33,34,133,134 15k
- R35,36,135,136 47k
- RV1,101 220R min. horizontal preset
- RV2,102 10k min. horizontal preset
- RV3,103 100k min. horizontal preset

CAPACITORS
- C1,2 47uF 25V axial electrolytic
- C3,4 22uF 25V tantalum bead sockets
- C5,6 1000uF 40V axial electrolytic
- C7,8 10uF 25V axial electrolytic

SEMI:CTORS
- IC1,2 TL084
- IC3 1N11400
- IC4 TL082
- IC5 7815
- IC6 7915
- IC7 78143
- Q1,101 BC214L
- BR1 200V 1 amp potted bridge rect.

MISCELLANEOUS
- M1,101 500uA moving coil meter
- T1 0-15,0-15 V 3 VA PCB transformer
- FS1 1 A 20mm filler PCB mg holder
- SW1,2 4 pole 3 way rotary switch
- SW3 mains switch
- SK1,2,101,102 PCB (see bylines); Verobase 104; 2 off 3 way PCB screw connectors; wire, nuts, bolts, knobs, etc.

The appropriate resistors for range switching and impedance matching are mounted on the back. This is a little fiddly but gives a neat result and reduces the amount of inter-wiring required. The input and output sockets are wired directly to each other with the earth line passing via the 0.1 ohm current sense resistor in each case. These are wired directly to the range switch.

The front panel LEDs all have their anodes wired to the 0 volt line, the meters are wired straight to the PCB. The mains switch for this project was mounted on the back panel next to the grommet for the power cable as it was thought better not to bring mains to the front panel as it could be avoided.
Setting up

The aim here is to use the three presets in each channel to adjust for DC balance, multiplier function balance and scaling of the meter. First, after checking carefully to make sure that there are no mistakes and that nothing gets too hot, with no input adjust RV1 (101) to get a zero reading on the meter. Next, apply a signal to the input with no load on the output and adjust RV2 (102) for zero reading on the meter. Readjust RV1 if necessary after removing the input signal. Lastly, connect the signal source and a suitable load resistor, adjust RV3 to get the correct scale factor, then check that the meter gives similar readings with SW2 in all positions so long as the LEDs do not indicate an overload. If any of these steps is not possible check the circuit again looking especially at the wiring around the range and impedance switches. If the meters read in reverse you may rewire them but check first that your signal connections are correct.

In Use

The meter should be very easy to use as it is just connected in the signal path. Bear in mind that there will be a small power loss due to the current measuring resistor and that the load side earth line is not connected directly to that on the input side. Also note that the input side earth lines are commoned internally. The reading on the meter should be independent of the load impedance, but beware of overload at less than full power caused by extremes of voltage or current when the wrong impedance range is selected. The LEDs on the front panel should warn of this condition.
Power is provided by a very simple dual rail supply derived from a centre tapped transformer and bridge rectifier. The output from this is smoothed by C5,6 and regulated to + and -15V by IC5,6. C7,8 remove any residual noise and improve transient performance.

The main part of the circuit is in two identical parts so we shall only consider one of them. The signal whose power is to be measured enters SK1 and leaves SK2. En route it passes through R1 which develops a voltage across it proportional to the instantaneous current flowing. At the same time the voltage across the input is also sampled. Two sections of SW1 tap off portions of the voltage and current signals and pass them to IC2a and IC1a respectively. The resistors R2 to 8 are chosen to give the ranges indicated on the panel. IC1a amplifies the current signal by a factor of just under 60 while R11 and R12 enable a small amount of common-mode signal on the earth lines to be eliminated if desired. From IC1a the current signal passes to IC1b which is a buffer whose gain can be set to approximately 2, 2.8, or 4. IC2a performs a similar job on the voltage signal except that when the gain of IC1b is 2 that of IC2a is 4 and vice versa. The diode network (D1 to 4 and ZD1,2) together with IC2b detect overload conditions. If the peak signal exceeds the zener voltage then either the + input of IC2b will be pulled low or the - input pulled high. Either of these conditions will cause the output of IC2b to switch from the positive supply rail to the negative supply rail and illuminated LED1, R26 and DS limit the current and prevent reverse voltage on the LED.

The next section is the multiplier and this is constructed around one half of an LM14600 transconductance amplifier. The part we use for this project has the property that its output current is proportional to the product of the input current and the bias current and inversely proportional to the current through the linearising diodes on the device. R34, D6 and Q11 form a simple virtual earth summing point for producing the bias current which is a constant (via R33) plus a signal component (via R31). The other input to the device is via R29 which converts the voltage signal into a suitable current. The output from IC3a is developed as a voltage across R32 but this has one of the input voltages applied to its other end and a subtraction occurs which is essential to the correct operation of the circuit. The resulting output voltage is buffered and amplified by IC4a before driving the meter circuit.
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ETI MARCH 1984
Cheap Data Link
Jake Thomas, Sheffield.

This circuit was designed to provide a data link between a pedalboard consisting of eight switches, and an effects box situated some distance away. This would normally require expensive 9-way cable, terminated by expensive multiway connectors. This circuit allows these to be replaced by el cheapo 5-pin DIN plugs (!) and standard 4-way audio cable.

IC1a,b,c comprises the system clock. IC2 scans the switches in sequence. This gives a series of logic highs and lows on the DATA line, depending upon the state of the switches. IC3,4,5 pass these signals to the appropriate sample and hold circuit (IC6,7 and associated components) in the decoder.

Q1 is used to reset IC3. The voltage on the DATA line is normally maintained at around 2V by R2 and R3 (which may need adjustment if a much lower supply voltage is used).

This keeps Q1 hard on. When IC2 '0' output and the clock both go to high, IC1d output goes low, taking the DATA line to 0V. This turns Q1 off, resetting IC3 to '0'. Thus the two 4017s are kept in synchronism. R4, 5 protect the decoder inputs from static when the encoder is unplugged.

With the exception of the sample & hold time constants, which are uncritical, the system is totally independent of clock frequency — unlike conventional 2-wire data links which also have more complicated circuitry. This makes the system more reliable. It can also be easily extended, either by using the spare conductor as a second data line (if you used 4-core and screen cable) or by chaining the 4017s.

You may wish to have an LED indicator for each switch. If using a 15V supply, it is rather wasteful to connect each diode to the supply by its own series resistor. At 20mA each, 8 LEDs would use 160mA when on simultaneously. Fig. 2 shows a way round this, by driving the LEDs in series, with a constant current. This consumes around 20mA however many LEDs are on (those not required are shorted out, using the other half of the appropriate switch). The circuit should just about light 8 red LEDs simultaneously, with a 15V supply. With more LEDs or a lower supply voltage, the required voltage drop across the diodes becomes too great.
CB Frequency Meter
R. Stevenson, Leyton E10.

This circuit is unusual in that there is no electrical connection to the CB rig — it picks up the signal to be measured from a wire adjacent to the aerial coax. It consists of just four chips, including a regulator.

IC1 receives the signal, amplifies it, and divides it by 100. IC2 converts the output of IC1 to TTL standard for IC3. IC3 is the frequency counter — it contains a high frequency oscillator, timebase counter, data counter and latches, a seven segment decoder, digit multiplexers and display drivers. IC4 provides a 5 volt supply rail which is derived from the power source that supplies the rig.

The displays are driven directly from IC3 and are the common-cathode multiplexed type. The single core unscreened pick-up wire is run alongside the aerial coax for a few yards. If the signal is found to be insufficient, lengthen the wire or move the meter closer to the aerial. Greater resolution and accuracy can be achieved with extra digits connected to the unused digit drivers, but remember that the decimal point and range connections will have to be changed. Extra digits, however, result in longer display settling times.

PS: The SP8629 prescaler chip can be obtained from Watford electronics.

Cheap Envelope Generator
Jeff Macanley, Crawley.

Although the ADSR envelope generator has become standard there are occasions when a simpler and cheaper alternative is desirable.

The accompanying circuit shows such a device. The basis is the humble flip flop, IC2, half a 4013B. When a positive going pulse is applied to the set input the Q output goes high allowing C1 to charge via the attack pot, RV1, and D1. Notice, though, that the reset pin is connected back across C1: in consequence, as soon as the voltage across this component exceeds about 50% of the supply voltage, the flop flop resets, reverse-biasing D1, C1 now discharges through the decay pot and D2. With the values shown both attack and decay are variable from a few milliseconds to several seconds. The two current limiting resistors should not be left out because the maximum current that can be drawn from the output is only about 10mA peak.

If negative triggering is required the inverter circuit shown can be employed. This has the advantage of allowing the device to be triggered from open collector devices. IC1 can be any inverting CMOS gate, NAND or NOR, with unused inputs wired to +ve (NAND) or 0V (NOR): it can even be an inverter gate! Note that supply connections to IC1 and 2 will need to be added.
Simple Cassette Motor Control

David Allen
Bolton.

In this circuit, motor control is achieved using a single STOP pulse. The position of the stop button is sensed using a dual opto-isolator. The cassette motor is normally allowed to be on. At the end of the READ or WRITE cycle a +ve going pulse must be applied to the input to stop the motor. The motor therefore stops with the play button pressed. The opto-diodes are connected back-to-back so the polarity of the motor voltage is irrelevant.

The stable condition of the circuit is with the motor relay energised and sensing circuit inactive (opto-isolator). The cassette player is started manually by pressing the play button. At the end of reading or writing a +ve pulse is applied to the input. Flip-flop IC1 changes state, the motor relay turns off and the motor stops. The REMote input to the cassette then has the motor voltage across its contacts and the opto-isolator circuit senses this voltage. One of the opto-transistors will turn on and after a delay of 80 msecs a low is applied to one input of IC2.

The reset input to IC1 is maintained high and so the motor relay remains off. Meanwhile, the Q output of IC1 is high, and after a delay of 300 msecs the other input of IC3 goes high. The circuit will remain in this condition until the stop button is pressed. When this happens the motor voltage disappears and the opto-transistor turns off. After 120 msecs the output of IC3 goes low and resets IC1. This closes the relay contacts and the circuit returns to the initial condition.
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ETI MARCH 1984
Z80 DRAM BOARD

Here it is, the project you've all been asking for. Bob Campbell describes a 64K DRAM board for use with Z80 based systems.

Last month we examined two possible methods of increasing the available dynamic memory in Z80 based systems, either by modifying the original 6502 based 64K DRAM board (published in ETI September '83) or by extending an existing 4116 based system using 64K chips. This article describes the third option, a 64K DRAM board designed specifically for use with Z80 based systems.

Although the 74LS608 memory cycle controller used in the original 64K DRAM design proved most successful, it did require a considerable effort to develop the actual hardware from the theoretical design layout. In addition, the chip performs only one of the three functions that the more modern dynamic RAM controllers can achieve. There are two other chips within the series that can cope with the multiplexing and refresh control but because this three chip system never became very popular the price has remained relatively high.

The newer RAM controllers are single chip systems, adaptable to almost any configuration and capable of several functions in addition to the main requirements, address multiplexing, RAS CAS MUX generation, refresh row address and RAS control.

The most readily available and cost effective controller on the market at the moment is the Texas 4500 (although the Author admits that this is a somewhat subjective statement, and there are probably many people ready to disagree). In addition it is well suited for use with the type of processor which we have in mind, the Z80. Figures 1 and 3 show details of the controller, and further information can be found in either the Cortex project article in the November 1982 issue of ETI or in TI's 'TMS 4500A Dynamic RAM Controller Users' Manual', available from wherever you usually get your data or from TI in Bradford.

Fig. 1 shows the main functional blocks within the controller. These are:-
1) row address latches
2) column address latches
3) address multiplexer
4) refresh row address counter
5) chip select latch
6) timing and control block
7) refresh/memrory access cycle arbiter
8) programmable refresh rate generator
The features of this chip include:-
- asynchronous or synchronous control with the MPU clock
- internal or external refresh initiation
- programmable refresh rate
- no crystals, delay lines, or RC networks required.
- burst, transparent, or cycle steal refresh modes
- programmable WAIT state generation for slow memories
- drives up to 256k bytes without external drivers.

I don't intend to present all the details of the design here as a great deal of information is given in the manual, and the design philosophy of the PROM decoder was adequately covered in the DRAM project article in September '83.

There is, however, one criterion which must be met. The system requires an 8 MHz clock, or at least a clock that runs at exactly twice the frequency of the CPU clock. If the intended system runs...
Fig. 2 Circuit diagram of the Z80 DRAM.
The 4 and 8 MHz clock generators are formed by ICs 1, 2, and 3 together with the associated resistors and the crystal. The raw 8 MHz signal is first cleaned up by the Schmitt gate and then divided by 2 by the D type flip flop, IC3, to give the new CPU clock of 4 MHz. The primary signal, 2φ, is fed directly to the TMS 4500 and the divided signal, 1φ, is fed out to the rest of the system. All sixteen address lines are connected to the 4500; these are then multiplexed out to the RAMs during each cycle on the MA0-MA7 outputs. The upper eight address lines are used to decode the memory array, via the PROM, into 256 x 0.25K blocks. Unlike the DRAM project where the smallest decoded block was 1K, this should allow scope for even the smallest bootstraps PROMs to be accommodated. The output for the PROM decoder is gated with MREQ and RFSH to select a memory cycle for the 4500. The latter signal RFSH is included to prevent MREQ causing an access during refresh. The 4500 itself handles all the refresh and memory cycle control, and all of the cycles are performed synchronously with the CPU clock (during T3 and T4). This excludes the need for any refresh arbitration via the RDIY signal, and the need for any wait states during access. It also has the capacity to introduce additional refresh cycles during extended periods of WAIT or DMA cycles when only the system clock is present.

The data bus is buffered using the ubiquitous LS245 octal trunceiver which is also controlled by the same CS signal as the 4500 and has its direction determined by the WR line. Note the difference between this synchronous approach and the asynchronous approach used in the CORTEX, where there was a 10% refresh overhead. Here the refresh is totally transparent, i.e. 0% overhead.

Table 1 Details of pin functions.

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>RA0-RA7</td>
<td>Input</td>
<td>Row Address — These address inputs are used to generate the row address for the multiplexer.</td>
</tr>
<tr>
<td>CA0-CA7</td>
<td>Input</td>
<td>Column Address — These address inputs are used to generate the column address for the multiplexer.</td>
</tr>
<tr>
<td>MA0-MA7</td>
<td>Output</td>
<td>Memory Address — These three-state outputs are designed to drive the addresses of the dynamic RAM array.</td>
</tr>
<tr>
<td>ALE</td>
<td>Input</td>
<td>Address Latch Enable — This input is used to latch the 16 address inputs, CS and REN1. This also initiates an access cycle if chip select is valid. The rising edge of low level signal of ALE returns RAS to the high level.</td>
</tr>
<tr>
<td>CS</td>
<td>Input</td>
<td>Chip Select — A low on this input enables an access cycle. The trailing edge of ALE latches the chip select pin.</td>
</tr>
<tr>
<td>REN1</td>
<td>Input</td>
<td>RAS Enable 1 — This input is used to select one or two banks of RAM via the RAS 0 and RAS 1 outputs when chip select is present.</td>
</tr>
<tr>
<td>ACR, ACW</td>
<td>Input</td>
<td>Access Control, Read; Access Control, Write — A low on either of these inputs causes the column address to appear on MA0-MA7 and the column address strobe. When ACR and ACW are both low, MA0-MA7, RAS0, RAS1, and CAS go into a high-impedance (floating) state.</td>
</tr>
<tr>
<td>CLK</td>
<td>Input</td>
<td>System Clock — This input provides the master timing to generate refresh cycle timings and refresh rate. Refresh rate is determined by the TWST, F51, FS0 inputs.</td>
</tr>
<tr>
<td>REFREQ</td>
<td>Input/Output</td>
<td>Refresh Request — (This input should be driven by an open-collector output.) On a low-going edge initiates a refresh cycle and will cause the internal refresh timer to reset on the next falling edge of the CLK. As an output, a low-going edge signals an internal refresh request and that the refresh timer will be reset on the next low-going edge of CLK. REFREQ will remain low until the refresh cycle is in progress and the current refresh address is present on MA0-MA7.</td>
</tr>
<tr>
<td>RAS0, RAS1</td>
<td>Output</td>
<td>Row Address Strobe — These three-state outputs are used to latch the row address into the bank of DRAMs selected by REN1. On refresh both signals are driven.</td>
</tr>
<tr>
<td>CAS</td>
<td>Output</td>
<td>Column Address Strobe — This three-state output is used to latch the column address into the DRAM array.</td>
</tr>
<tr>
<td>RDY</td>
<td>Output</td>
<td>Ready — This totem-pole output synchronizes memories that are too slow to guarantee microprocessor access time requirements. This output is also used to inhibit access cycles during refresh when in cycle-steal mode.</td>
</tr>
<tr>
<td>TWST</td>
<td>Input</td>
<td>Timing/Wait Strap — A high on this input indicates a wait state should be added to each memory cycle. In addition it is used in conjunction with FS0 and FS1 to determine refresh rate and timing.</td>
</tr>
<tr>
<td>FS0, FS1</td>
<td>Inputs</td>
<td>Frequency Select 0; Frequency Select 1 — These are strap inputs to select Mode and Frequency of operation as shown in Table 1.</td>
</tr>
</tbody>
</table>

Fig. 3 Pin connections of the TMS 4500A.
at 4 MHz with only a 4 MHz clock source, a new 8 MHz clock generator will have to be provided and its output divided by two to give the 4 MHz CPU clock rate.

**Construction**

The Z80 DRAM is constructed on a 100 x 160 mm (3U eurocard size) double sided PCB. Printed circuit boards supplied by our PCB service will be double sided but the holes will not be plated through. This means that you will have to solder a link through each of the holes, but it does make the PCB a lot cheaper than it would otherwise be. Note also that some of the links are underneath ICs 4, 5 to 12, and 13, and crop the ends of these links off very close to the surface of the board. Note also that component leads have been used as links in some cases, and take care to solder such leads on both sides of the board. All links have been shown on the overlay diagram (Figure 4) regardless of whether they are individual wire links or component leads. Alternatively, you could produce your own single sided PCB using just the underside pattern and then use wire links on the component side, in which case you should solder the links in place first and use IC sockets which clear the board sufficiently to allow the wires out at the ends.

When the board is ready, and the links are in place, assemble the other components making sure that the diode, the electrolytic capacitors, and the ICs are the right way round, and taking care not to overheat the crystal. We recommend that you use IC sockets and insert the ICs themselves last of all. We have labelled all the connections on the board itself but obviously, what happens at the other end depends upon which micro you are using, so you will have to sort that out for yourself. Don't forget to remove or disable the original CPU clock if you are now using the DRAM board clock.

Finally, you will have to programme the PROM. The programming procedure for the TBP 24510 is given in the book “Bipolar Microcomputer Components and Memories” which is published by Texas Instruments and should be readily available. A detailed description of the required memory contents lies outside the scope of this article, but some general guidelines were given in the original 64K DRAM project in the September 1983 ETI, and readers are referred to that article. Once programmed, the board should be ready for use because the TMS 4500A does not require any alignment.

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**PARTS LIST**

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<th>RESISTORS (all %W, 5%)</th>
<th>R1, 2, 3, 5</th>
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<td>R4</td>
<td>330 R</td>
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**CAPACITORS**

| C1                      | 10n ceramic |
| C2, 3, 4, 5, 6, 7, 8    | 100n ceramic |
| C9, 10, 11, 12, 13, 14, 15, 16 | 1u tantalum |

**SEMICONDUCTORS**

| IC1, 2                   | 74LS00     |
| IC2                     | 74LS14     |
| IC3                     | 74LS74     |
| IC4                     | TMS4500A   |
| IC13, 7, 8, 9, 10, 11, 12 | TMS4164-15 |
| IC10                    | TPS24510   |
| IC14                    | 74LS02     |
| IC15                    | 74LS00     |
| IC16                    | 74LS245    |
| DT                      | 1N4148     |

**MISCELLANEOUS**

PCB; 32 x 2 way DIN 41612 A + C connector (plug and socket); 8 MHz crystal; connector, cable, etc to link with microcomputer.

---

**BUYLINES**

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<th>Dyn-loads</th>
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<td>FPA100</td>
<td>21.95</td>
<td>50-150W</td>
<td>4.8</td>
<td>Physically small (x27 ½ x 5)</td>
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<tr>
<td>FPA250S</td>
<td>28.52</td>
<td>100-300W</td>
<td>4.8, 16</td>
<td>High watt/kg ratio</td>
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<td>PFA/HV</td>
<td>36.04</td>
<td>200-300W</td>
<td>4.8, 10</td>
<td>50dB dynamic headroom</td>
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<td>*FPA800</td>
<td>45.25</td>
<td>250-600W</td>
<td>4, 8</td>
<td>30A cont. output current</td>
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*The power output of these amplifiers can be increased by approx 15% with no diminution in quality by adding PSU102 (£7.41) to your existing power supply (PFA250S is an improved version of PFA200).

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Dear Sir

As one who has been involved in the design of active speakers for many years, may I make a suggestion or two that will improve the performance of the design in your November issue?

Accepting the typographical error that reversed the values of R8 and R9, the filter stages are, as stated, standard 12dB per octave Butterworth networks, which are not really suitable for use in an active cross-over. The filters described in your article have a -3dB frequency at 2.885 kHz (the cross-over frequency), and the outputs are summed, will give a 3dB peak in the overall frequency response. The ideal filters should be 12dB per octave (or 24dB per octave, but not 6 or 18 dB per octave for reasons that are too complex to go into here) but should each be 6dB down at the cross-over frequency, so that the summed response is flat. Suitable filters may easily be configured as shown in Fig. 1.

The modified filters do not add to the cost or complexity of the project, but by increasing the parts count by a small amount, further very worthwhile improvements may be included.

Although the KEF B200 is a good choice of bass unit, its response is not flat enough to avoid using a limited amount of equalisation, a suggested circuit being given in Fig. 2.

The response of this stage gives unity gain at very low frequencies, then introduces a falling response that is -1dB at 300 Hz, -3dB at 650 Hz and -6dB at 3 kHz, thereby removing a hump in the B200 response that can introduce considerable colouration if left untreated. As this stage is inverting, the connections to one of the drive units should be reversed so that both units are connected in the same phase.

Additional colouration may be caused by the downward-titting radiation pattern at the cross-over frequency. This is caused by the non-alignment of the acoustic planes of the drivers, and may be corrected by the application of a suitable delay in the high-frequency signal. As the B200 radiates at a point about 38mm behind the plane of the HD100/25, the required delay is 38 x 10^-3 / 343 = 110.8 µs. A suitable all-pass filter, giving 28.2 µs delay per stage may be formed from four op-amps as shown in Fig. 3.

\[
\text{Delay} = \frac{2RC}{1 + (2\pi RC)^2} = 28.2 \mu s \text{ at } 2.68 \text{ kHz per stage} = 112.8 \mu s \text{ total (equiv. to } 38.7 \mu m)\]

Various other 'improvements' could be incorporated, but would increase the cost out of proportion to the gain in performance; however, the suggested modifications will bring a number of benefits over the very basic published circuitry without increasing the cost by more than about £10.00.

Yours faithfully
Barry E Porter
Kings Lynn

We thank Barry Porter for his suggested enhancements to the simple active loudspeaker design, and we suggest that interested readers should 'suck them and see'.

Fuses

Dear Sirs,

I recently built your Dec '82 Spectracolumn, and was very pleased with it, until, that is, one of the bulbs blew. This in itself was of course not a major calamity. It did, however, take its controlling triac with it. Please tell me whether I can expect a triac casualty every time a bulb blows (it was a 'normal' domestic 100 W type). If not please offer an explanation and remedy to prevent further sympathetic suicides.

Yours faithfully
Paul Gallagher
Edinburgh

PS can 100 W spots be used with the Spectracolumn?

The reason for the 'sympathetic suicide' is that sometimes when a bulb blows, a piece of filament will short across the conductor supports, so momentarily reducing the bulb's resistance to a very low value and causing a high current to flow. This transient is usually much too small to damage conventional electrical switchgear, or even blow the house fuse (and most domestic bulbs have an integral fuse, or
For this reason, many manufacturers of domestic light dimmers have started to fit special, very fast blowing fuses in their units. However, these fuses are not that easy to obtain (if you go into most suppliers and ask for them you'll probably be given a blank look or a standard 20mm fuse), and a project such as the Spectracolumn would necessitate several, along with associated fuse holders. In any case, they're quite expensive — more expensive, often, than a cheap, plastic-packaged triac. So, for gear you build yourself, you might as well reconcile yourself to having to replace the odd triac now and then.

An alternative solution is to use considerably over-rated triacs, in T03 packages. The editor has fitted one of these (of somewhat dubious origin — it just turned up somehow in the junk box) to a domestic dimmer with success. It has proved capable of surviving quite extended shorts — on one occasion, a bulb in a multi-bulb fitting blew and shorted the supply long enough to dip all the other lights in the fitting for a fraction of a second (admittedly the wiring wasn't too great in that particular flat) but the triac survived! However it would be necessary to check that there is sufficient driving current for the devices used.

In any case, frequency of shorts will probably be a function of bulb design — so change make if the bulbs take the triac with them more than, say, 50% of the time (no, we don't know which brands are best, sorry).

Finally, given our last comment above, there is no reason why you shouldn't use spot bulbs with the spectracolumn — but they may, because of their design, be more likely to short out on blowing.

Holophony

Dear Sir,

I have read with some interest what you have had to say about the so-called "holphonic" sound. I think I am in a position to throw some light on the subject, so here goes.

Last Easter I was visiting a colleague, a Dr Peter Damaske, in Goslar (Windsor's twin town in Germany) who did his doctorate at Gottingen University on just this subject, and who is still active in the field, although he now teaches physics at the "Gymnasium" in Goslar. What follows is what he told me, as near as I can remember; your German edition could always get in touch with him direct.

When a recording is made by putting microphones into the ears of an artificial head, the exact effect can be re-created by playing the recording through stereo headphones. This isn't surprising, of course, but doesn't answer the question of how the brain locates sound. In fact, the direction is perceived by the brain measuring the time difference between the sound reaching the two ears. Although this seems incredible — the times are of the order of tens of microseconds — it is quite a well established fact, and it explains why you can tell where the keys are even with one ear partly blocked. Someone deaf in one ear, though, cannot tell which phone in an office is ringing — I know someone in Windsor who suffers from this problem.

The plot thickens when we consider how to tell the difference between sounds coming from the front and from the back. A sound at 45° left front will have exactly the same time lag as one from 45° left back, and in practice it is not easy to tell one from another. If you move your head slightly, of course, it is easy, since the two sounds behave differently. Moving the head to the left more or rightwards and the back source leftwards. However, you can't do this with a recording, yet the distinction is still there. It appears that the sound from the rear has a different quality, since its spectral composition is modified by the hair and ear lobes. We learn quite early in life to recognise these differences, and this is how the trick is worked. It is possible to think sounds coming from in front come from behind — especially footsteps — and this may be due to the surface walked on modifying the sound in a similar way to the ears. Footsteps on soft ground in front may sound like footsteps on hard ground behind, for instance.

When loudspeakers are used and not headphones, the left ear hears some of the sound intended for the right ear, and vice-versa. It is possible to compensate for this by adding some left ear signals in antiphase to the right channel to cancel this out, with the appropriate time delay, but the sound must be filtered first to imitate the
effect of the nose, face and earlobes. In an anechoic chamber this apparently works very well, and two speakers physically in front of the listener can make sounds seem to come from all round. However, the echoes in a real room mess all this up, and the effect is lost. The next thing to try is highly directional speakers to beam the sound to the ears and not the walls — Dr Damase uses arrays of small speakers. The effect of these in a well draped room is pretty good, but the front-back effect is not easy to achieve at the same time as high quality sound. Work continues. I have heard recordings on this system, and the front-back distinction was not very good — Dr Damase tells me it was better when his speakers were not so good!

I have not mentioned up-down cues. Humans are not good at localising the elevation of a sound, as one might expect. Mostly we know where to expect sounds to come from, but everyone knows how easy it is to be fooled by a voice from up a tree. Owls need to be good at measuring elevation if they are to find their prey, and they do so by having the right and left ears at different angles to the horizontal. The time delay then gives the direction, and the relative volume in the two ears the elevation. It follows that an owl with earache in one ear will have problems!

Yours sincerely,
Gerald Bettidge
Physics Dept, Etón College.

Nearly A Competition
Dear Sir,
I hope you do not mind me writing to you but I have a problem you and subscribers to your magazine may be able to help me with.

I was a professional bass guitarist for ten years until three years ago when I suffered a stroke in my right side (I was 29). Although I got back some movement and feeling, my right side remains largely useless, so since then I have been trying to come up with a practical idea to enable me to play again. The City University in London modified a bass guitar utilising the limited movement in my right arm to trigger off solenoids to sticke whichever string was selected by my left hand but for various reasons (mainly the expense of replacing the solenoids should they very likely go wrong, about £70 each) the idea was impractical.

So could I appeal to you and your readers to come up with a practical, reliable idea for modifying a bass guitar so it can be played using 1½ hands. We could perhaps appeal using a competition formula with me donating a prize of some sort (but not too expensive)!

Yours sincerely
Alan Todd
Birmingham

Certainly! If anyone out there has an idea, please contact the Editor before the end of February 1984. We will channel suggestions to Alan, and help to get the one or two most practical built and tried out. The solution that Alan prefers will, eventually, appear in the pages of the magazine, and we'll pay the designer(s) our standard page rate — which isn't a fortune, we'll admit, but they'll also have Alan's gratitude as well.
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THE OBEDIENT DIE

Here is a project for the man or woman who has everything except a conviction for fraud — a cheating die. Fun for party games, but definitely not for serious use. Design and development by Ian Hickman.

Dice have been used for centuries, both for gambling and as the element of chance in the more innocent games such as Ludo or Snakes and Ladders. Unscrupulous persons have from the earliest times employed “loaded” dice. A loaded die has a piece of lead embedded within it, slightly off-centre, so that a certain number, for example a six, occurs more often than it should. (Normally, of course, the chance of a die throwing a six is just one in six and a pair of dice throwing a double six is 1 in 36.) The degree of loading is naturally kept small, as otherwise suspicions would soon be aroused. A loaded die is more likely (by a small margin) to throw the “loaded” number than the other numbers, regardless of who throws it. Thus the unscrupulous gamester would arrange either that the “banker” (himself!) always threw the dice, or that the rules of the game were so framed that sixes favoured the bank, whoever threw them. The idea of a die that could be commanded to throw a six whenever desired would have seemed like magic!

This article describes an electronically loaded die, which can provide a lot of innocent amusement at parties, but which should obviously not be used for gaming. Its ability to throw a six whenever commanded can also liven up an otherwise tedious board game such as Ludo.

Construction And Testing

The prototype die was constructed in a hollow perspex cube bought in the fancy goods department of a well known chain store. The bottomless plastic cube came with a block of soft plastic foam inside, which was meant to retain five photographs, one behind each of the five visible faces of the cube. The printed circuit board

Fig. 1. Circuit diagram of the die.
The full circuit is shown in Fig. 1, where the components forming the remote control circuit are grouped at the bottom while the basic electronic die components are at the top. IC2a & b form a free-running clock oscillator, which can be inhibited by a +9V at the anode of either D1 or D2. The clock is fed to a three-stage binary ripple counter IC2a, IC3a and IC3b. This is constrained by gated feedback to count from 1 to 6 rather than from 0 to 7 as it would normally do. Whenever three Ts are simultaneously presented at the Q outputs of the three stage counter (i.e. a count of 4+2+1 or 111 in binary), the output of the AND gate IC4b goes true or high, i.e. +9V. This instantly resets IC3a and b to 0 and sets IC2a to 1, thus states 7 and zero are skipped over.

The output of the one counter drives LED1 via the buffer IC1c. The output of the 2s counter IC3a drives the diagonally-placed LEDs, LED2 and 3, which are also lit via D4, along with LED4 and 5, by the output of the 4s counter IC3b. IC4c detects the presence of a 6 by ANDing the 4s and 2s outputs, and lights LEDs 6 and 7. The result of this simple bit of decoding is a traditional dice display with 2 and 3 displayed along a diagonal. (By lighting the four corners LEDs from the 4s counter and LED6 and 7 from the 2s counter, one can save a few components, but it hardly seems worthwhile putting up with a non-standard display for such a marginal economy.)

The LEDs will only light if micro-switch S1 is in the operated position, C (common) to Q (normally open), which occurs when the die is set down on a flat surface. The LEDs then light and as there is +9V at the anode of D2, the clock oscillator is inhibited. The LEDs therefore display whatever number the counter had reached when the die was set down. On picking up the die, the LEDs extinguish and the counter counts at around 1kHz until it is set down again. Thus the number 'thrown' (please don't actually throw the die!) is effectively random. This was proved by a series of nearly 400 consecutive throws, in which 1 occurred 67 times, 2 - 64 times, 3 - 61 times, 4 - 67 times, 5 - 70 times and 6 - 62 times.

Each time the die is picked up, S1 returns to the normally closed condition and a short +9V pulse is applied to the reset input of IC2b via C8. Thus both the Q output of IC2b and the output of AND gate IC4a normally remain indefinitely at 0V, but now we come to the devious bit. Connected to the input of the amplifier IC5a is an ultrasonic receiver Rx. This is sensitive to a narrow band of frequencies in the region of 40kHz, and its output is amplified by IC5a and IC5b. When a 40kHz sound wave impinges on Rx, the output of IC5b via C5 is DC restored negative-going with respect to +9V by D5 and applied to Q1. This conducts on the negative going half cycles, charging C6 to +9V, and if the supersonic 40kHz signal persists for more than 20ms or so, the voltage across C7 will rise to a level where IC2b will be set. If this occurs while the die is lifted, i.e. while the clock oscillator is running, the clock will be stopped at a count of six. The 1 at the Q output of IC2b enables IC4a, and the next 'six' output from IC4c will result in a 1 at IC4a's output, disabling the clock oscillator via D1. If a 40kHz signal is received after the die is set down, it will set IC2b, but this will have no effect as the clock has already been inhibited via D2; IC2b will be reset as normal when the die is next picked up.

With so much gain in a confined space, following a high impedance transducer, the dual op-amp circuit has been designed carefully. Supply line decoupling R11, C3 prevents supply line ripple due to clock edges getting into the amplifier, whilst hum pick-up problems (always a headache with high impedance transducers) are avoided by rolling off the LF gain of the op-amps, e.g. with R10 and C2 at IC5a. However if the same circuit were used around IC5b, instability could result due to the coincident breakpoints. This is avoided by using a different time constant and limiting the LF roll-off of IC5b with R12.

The receiver Rx will not respond to shouting, singing, whistling or other audible sounds, but impulsive sounds (such as clapping, or tapping the die) contain supersonic components up to 40kHz and beyond. To prevent these from operating the 'force a six' function, the detector circuit includes filtering. The time constant R14/C6 is just sufficient to prevent the collector voltage of Q1 falling appreciably below 9V between one half-cycle of the 40kHz signal and the next, but it falls rapidly as soon as the sound disappears. On the other hand, the filter R15/C7 requires that the 40kHz tone remain present for at least 20ms before IC2b will be set, forcing a six. Thus brief impulsive noises such as clapping are discriminated against. If you hiss loudly at the die it will throw a six, so it is not recommended for use in a boiler room where steam is escaping!

Reverse polarity protection diode D6 protects the circuit — but not the battery — in the event of the latter being connected the wrong way round. Fig. 2 shows the circuit of the 40kHz ultrasonic transmitter.
shown is a snug fit inside the cube and is mounted on a carrier-cum-battery-box fabricated out of an old tin can. This is retained by a couple of countersink screws picking up on opposite faces of the cube. For the control transmitter any small plastic box, with room for a PP3 battery and the few components mounted on a piece of Veroboard, can be used. The transmit transducer should be mounted behind a hole in the front panel and the on-off switch should be a push-to-make pushbutton.

It is easier to fault-find on a small amount of circuitry, especially if you do not have an oscilloscope, so it is a good idea to construct the die in parts. Start off by mounting IC1, 2 and 3 and their associated components but NOT D1, D2 or IC4. On S1, temporarily link C to NO and tie the output of IC4b to OV. Fit a 10µF non electrolytic capacitor (or two 22µF capacitors back-to-back — Ed) at C1 instead of the final value and connect the battery. You should see the LEDs cycle through the usual dice display of 1 to 6, followed by 7 and 0. If not, the fault should be fairly easy to locate, with so few components fitted to the board. Now switch off and fit IC4, remembering to remove the temporary short at its output. Now, the display should cycle through the states 1 to 6 only. Change C1 to 10nF, fit D2 and S1 (remove the link) and check that the basic die now operates correctly, i.e. LEDs out until S1 is pressed, then display a

### Parts List

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<td>PCB, perspex case for transmitter, veroboard for transmitter, on/off switch for die, microswitch for throw, (see drawing), push button switch for transmitter, batteries.</td>
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Fig. 3 Overlay diagram for the main PCB.
number at random.

Now fit the remaining components of the die and make up the control transmitter of Fig. 2. Monitor the voltage at the collector of Q1 with respect to 0V using a 20,000Ω voltmeter. With both die and transmitter powered up, point the transmitter at the receiver transducer at a distance of a few feet. Adjust the transmitter frequency, by means of RV1, for maximum response at the receiver. Use an insulated trimmer tool to avoid stray capacitance, otherwise the transmitter frequency may change when the screwdriver is removed. When carefully set for best response, the transmitter should cause Q1 collector to go to +9V from anywhere in the room. Check that raising and setting down the die causes a random number to be displayed unless the transmitter is on, in which case a 6 should appear. The systems is now operational.

With the component values shown in Fig. 1 the circuit consumes 4 mA from the PP3 battery when picked up and only 8 mA when set down and displaying a 6. However for a brighter display, especially if you are not using high-efficiency LEDs, R4 can be reduced to 2k2 and R5 – 7 to 1k8 each.

Using The Obedient Die

When correctly set up, the control transmitter will operate the die even when it is concealed. It may be hidden in a trouser or jacket pocket, provided the intervening distance is not more than a few feet, the material of the garment is not excessively heavy and the transducer is pointing in the general direction of the die. The die is used to best effect when the operator is not involved. For instance, at an office party invite the boss's secretary to take a go, when she throws more sixes than you do persuade her to take on the boss. Now melt into the bystanders and take it from there. For example, when the secretary seems to have all the luck, get an accomplice to suggest to the boss that there is a gravity switch inside the die and perhaps he ought to tilt it sideways before putting it down. When he tries this, lo and behold (you switch sides) it works, and suddenly he is winning.

Many other scenarios are possible, with or without an accomplice, and will doubtless occur to you. For example, Ludo gets distinctly boring when one player is miles ahead of the others. But a non-playing controller of the die can turn a game into a neck and neck contest by judicious use of occasional extra sixes. Remember not to force too many sixes or suspicion will soon be aroused. After all, you can only add extra sixes, not inhibit them.

Absolutely nothing here to cause any problems. The 40kHz transducers are available from Maplin and Watford amongst others, the perspex case is discussed in the text, and everything else is perfectly standard. The PCB is available from our PCB service, for which see page 65.
A lot of unnecessary mystique surrounds the subject of imaginary numbers, so in this coda to his series, John Linsley Hood sets out to clear a path through the muddle and to demonstrate the value of the technique in audio design work.

One of the features of audio circuitry, with the partial exception of audio power amplifiers which are largely flat frequency response devices, is that some modification of the gain/ frequency characteristic is needed to correct for uneven recording or replay frequency responses, or to emphasise or exclude desirable or unwanted parts of the frequency spectrum. This is done by inserting a combination of resistors and capacitors (or inductors) in the signal path, or, possibly, in the feedback path around an amplifier. This is a very powerful technique, and with sufficient ingenuity in the circuit design, all sorts of shapes of frequency response can be achieved. However, it requires the ability to do reasonably accurate calculations of systems using capacitors or inductors in combination with resistors, and this immediately runs into the problem of the phase shifts which occur within such networks. I will explain.

If one passes an alternating current through a series combination of a resistor and a capacitor or a resistor and an inductor, the voltages developed across the two components will be 90° out of phase with each other. I have shown this graphically in Fig. 1a and 1b. Also, while the voltage developed across a capacitor will ‘lag’ in phase in relation to the current flowing through it, (because the voltage across a capacitor depends on the charge within it and it takes time for the capacitor to charge up or discharge), the opposite is true of an inductor, in which the voltage will ‘lead’ in phase with reference to the current (due to the instantaneous generation of a ‘back EMF’ in an inductor which seeks to oppose any change in current).

We have seen earlier in this series that the impedance of a capacitor (Zc) is related to its capacitance and the operating frequency by the equation \( Z = \frac{1}{2\pi fC} \). Similarly, the impedance of an inductor \( Z_i = 2\pi fL \), where \( f \) is the frequency and \( C \) and \( L \) are in Farads and Henries respectively. Because of the effects of phase shifts, any calculation we made, say, of the attenuation of an RC or LC network based on these formulae for impedance would probably give incorrect answers. We therefore need a better method.

**The j Symbol**

There is, conveniently, a mathematical trick which enables us to do calculations which take into account the phase shifts produced by inductors and capacitors, and this is the operator \( i \) or \( j \), which is numerically \( \sqrt{-1} \). Pure mathematicians call this \( i \) to denote the fact that it is an imaginary number, since all real numbers give positive values when they are squared. However, since electrical engineers have already adopted the symbol \( i \) to denote electrical current, we refer to \( \sqrt{-1} \) as \( j \). Instead of this, operator is not as barmy as it might seem, as a way of describing a 90° phase shift, for the following reason.

In DC systems, the opposite of a positive voltage +V is a negative voltage -V. In an AC system, the opposite of an instantaneous positive potential (and it is convenient to refer to such AC potentials as E to distinguish them from DC potentials ±V) is the same potential half a cycle (180°) later when it has swung from positive to negative. A 180° phase shift in an AC signal therefore has the effect of multiplying the potential by -1, provided always that the signal we are talking about is sinusoidal.

Now, if we have two RC (or LC) networks in series, both of which produce a 90° phase shift (and two such networks in series will have a multiplying effect on the signal, just as \( \frac{1}{2} \times \frac{1}{2} = \frac{1}{4} \)), the final effect is a 180° phase shift (= -1). If we want to represent these phase shifts mathematically, we must find something which, when multiplied by itself gives the result -1. \( \sqrt{-1} \) is just such a thing. It can therefore be used in our sums as a way of denoting 90° phase shift.

Another bit of shorthand which circuit engineers normally use in these calculations is the symbol \( \omega \) (Omega in Greek) to denote 2\( \pi \), since these terms nearly always occur together. The true impedance of a capacitor or inductor is, therefore, not \( Z = \frac{1}{2\pi fC} \) or \( Z = 2\pi fL \), but \( Z = \frac{1}{\omega C} \) and \( Z = \omega L \). In shorthand form this becomes \( Z = \frac{1}{j\omega C} \) and \( Z = j\omega L \).

Since the phase shift produced by L or C elements in RC or LC networks is 90°, we can represent the behaviour of this circuitry in a graphical form, as shown in Fig. 1, as a right angled triangle, where the ‘j’

---

**Fig. 1 Phase angle relationships in RC and RL networks.**
term denotes the right angled limb, and this allows us to derive some further bits of information. Taking the case of a simple RC series network, as in Fig. 1a, the circuit impedances can be represented as in Fig. 2a, in which the vertical and horizontal limbs represent the resistive and capacitive impedances $R$ and $1/j\omega C$ respectively. It is unnecessary to write the $j$ symbol in the capacitance impedance limb of the drawing; that is implicit in its position at right angles to the $R$ limb. From the theorem of Pythagoras, the length of the hypotenuse, $h$ in Fig 2b, is $\sqrt{a^2-b^2}$, and from fairly simple trigonometry, the angle $\theta$ is such that $\tan \theta = b/a$. More conveniently, $\theta = \tan^{-1} b/a$, a calculation which a lot of pocket calculators will do very quickly.

Returning to our impedance diagram of Fig 2a, the resultant impedance of our network is therefore

$$Z = \sqrt{R^2 + (\omega C)^2}$$

We can also determine the phase angle, $\theta$, between the voltage developed across this network and the current flowing through it which will lag by $\theta$, which is $\tan^{-1} 1/j\omega CR$. (If $C$ were very large indeed, or $R$ were very large, the phase shift would be nearly zero.)

To recapitulate, we can identify the phase shifting characteristics of Cs and Ls by coupling the symbol $j$ to their impedance equations, and we can derive the resultant impedance and phase angle of these ‘complex’ networks by sorting out the terms with and without the $j$ symbols, and using them in simple geometric or trigonometric calculations. This process holds good no matter how many Rs, Cs and Ls we have in our network, it just becomes more complicated if there are more phase shifting elements.

The thing, however, which we must watch, is that we keep the real and the imaginary ($j$ containing) parts separate in the final equation at which we arrive. Now let us look at some real life examples.

**Impedance Of RC Parallel Network**

If the components were $a$ and $b$ as in Fig 3a, their impedance, when in parallel, would be

$$\frac{ab}{a+b}$$

Therefore, if they are $R$ and $1/j\omega C$, as in Fig. 3b, their parallel impedance will be

$$Z = \frac{(1/j\omega C). R}{1/j\omega C + R}$$

If we multiply the top and bottom of this equation by $j\omega C$, we can get it into the much more manageable form

$$Z = \frac{R}{1 + j\omega CR}$$

The next mathematical dodge is to get rid of the $j$s in the bottom line of this equation, so that we can divide it up into two separate parts, one without $j$s and one with them, representing the in-phase and the 90° ‘quadrature’ components.

This can be done by using the relationship

$$(a + b)(a - b) = a^2 - b^2$$

If it was $(a + jb)(a - jb)$ the result would be $a^2 + b^2$. bearing in mind that $j^2 = +1$. The important thing is that $j$ terms have disappeared. We can, therefore, multiply the top and the bottom of an equation containing $j$ term in the bottom line by $a - jb$ and eliminate these terms from the denominator leaving two separate fractions, which meets our original requirement for a usable equation. Treating the

$$Z = \frac{R}{1 + j\omega CR}$$

and equating this, we end up with

$$Z = \frac{R}{1 + (\omega CR)^2}$$

which allows us to calculate both the impedance and the phase angle between current flow and voltage, in our CR parallel network.

**Attenuation Of An RC Network.**

The circuit shown in Fig. 4b is a very versatile one in that, as it stands, it is a useful ‘step’ attenuator network, while if $R2 = 0$ it is a simple HF attenuator circuit. Looking at the resistor network of Fig 4a, the attenuation of this would be

$$\text{Eout} = \frac{Rb + Rc}{Ra + Rb + Rc}$$

By analogy, therefore, the performance of Fig. 4b will be

$$\text{Eout} = \frac{R1 + 1/j\omega C + R2}{1 + 1/j\omega CR2}$$

and this can be simplified to

$$\text{Eout} = \frac{1 + j\omega CR2}{1 + 1/j\omega C (R1 + R2)}$$

by multiplying top and bottom of $j\omega C$. Doing the necessary mathematical manipulation extracts the in
\[ Z = \frac{1 + j\omega CR}{j\omega C} \]

\[ Z = \frac{R}{1 + j\omega CR} \]

\[ \frac{E_{out}}{E_{in}} = \frac{1}{1 + j\omega CR} \]

\[ \frac{E_{out}}{E_{in}} = \frac{j\omega CR}{1 + j\omega CR} \]

\[ \frac{E_{out}}{E_{in}} = \frac{1 + j\omega CR2}{1 + j\omega C (R1 + R2)} \]

\[ \frac{E_{out}}{E_{in}} = \frac{C1 + j\omega C1C2R2}{C1 + C2 + j\omega C2 (R1 + R2)} \]

\[ \frac{E_{out}}{E_{in}} = \frac{C1 + j\omega C1R1R2}{R1 + R2 + j\omega R1R2 (C1 + C2)} \]

\[ \text{Gain} = -M \quad \frac{1 + j\omega CR2}{1 + j\omega C (R2 + MR1)} \]

\[ \text{Gain} = -M \quad \frac{R2}{R2 + MR1 (1 + j\omega CR2)} \]

\[ \frac{E_{out}}{E_{in}} = \frac{1 - \omega R1R2C1C2 + j\omega (R1C1 + R2C1 + R2C2)}{1 + j\omega R2 (C1 + C2)} \]

Fig. 5 Characteristics of some common RC networks.
phase and quadrature components as
\[
E_{\text{out}} = \frac{1 + \omega^2 C^2 R^2}{1 + \omega^2 C^2 (R + R_2)^2} R + \frac{\omega C R_1}{\omega C R_1}
\]
and we make \(R_2 = 0\), the right hand side of this equation simplifies to
\[
\frac{1}{1 + \omega^2 C^2 R^2 - \omega C R_1}
\]
In this case also we have separated out the in-phase and quadrature components, so that the transmission factor is obtained by doing a square-root of the sum of the squares of these, and the phase angle of the output is given by
\[
\tan^{-1} \left( \frac{\text{quadrature}}{\text{in-phase}} \right)
\]
It is always useful, when one comes to the end of an algebraic manipulation like this, to check that one hasn’t done anything wildly silly by putting in some limit values. For example, in the equations above, consider the effect of \(C = 0\). This causes the equation to become
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = 1
\]
which is what we would expect, (assuming the load is infinitely high in resistance). On the other hand, if \(C\) is extremely large, the first example gives
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = \frac{R_2}{R + R_2}
\]
and the second gives
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = 0
\]

Modern programmable pocket calculators make the task of calculating the characteristics of such RC networks relatively easy, once the labour of working out the maths has been done, and although I haven’t shown any yet, the process of calculation in RL networks is very similar. One can then, for example, write a suitable programme with the component values held in the calculator memory, and let the calculator go through the process for any frequency value which one enters before pressing the run button.

To remove some of the labour in calculation I am showing in the composite Fig. 5 a selection of RC networks with their impedance and transmission equations.

**Resistor-Inductor Networks**

The method of calculating the performance of these is identical to that for RC networks, except that one uses \(j \omega L\) instead of \(1/j \omega C\) in the equations. For example, the circuits of Fig. 6a and 6b have transmission
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = \frac{j \omega L}{R + j \omega L} \quad \text{and} \quad \frac{R}{R + j \omega L}
\]
respectively, which can be broken down into the in-phase and quadrature components as
\[
\frac{\omega L}{R^2 + (\omega L)^2} \quad \frac{R + j \omega L}{R^2 + (\omega L)^2}
\]
and
\[
\frac{R^2}{R^2 + (\omega L)^2} \quad \frac{j \omega L}{R^2 + (\omega L)^2}
\]

In all of the equations shown, it is possible (as I am sure you will have spotted) to change one kind of network into a simpler one by putting values of \(R\) or \(C\) or \(L\) equal to 0. As an example, if we make network (7) of Fig 5 have values of 0 for \(C_1\) and \(C_2\),
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = \frac{R_2}{(R_1 + R_2)}
\]
which is what we would expect. Or, by just deleting \(C_1 (C_1 = 0)\) we will end up with the equation of a type 3 network, when there is a resistor across the output.

**Some Practical Examples**

A lot of the above may have been a bit dull reading for the non-mathematically inclined (which, I suspect, is 99% of us) and may tempt the reader to ask ‘Well, that’s all very nice, but what real use is it?’. So I propose to show a few examples where there are some slightly surprising outcomes from the sums.

(1) The LC series circuit.

Let us take first the LC series circuit of Fig. 7. Now, it’s impedance is just the sum of the two bits, \(Z = 1/j \omega C + j \omega L\). If we multiply through by 1 (=\(j \omega C/j \omega C\)), we get
\[
Z = \frac{1}{\omega^2 LC}
\]
This has an interesting characteristic, that if \(\omega^2 LC = 1\), \(Z = 0\). This condition is met if \(\omega = 2 \pi \sqrt{LC}\). So, at resonance, this series LC network looks like a short circuit. Away from resonance, there is a quadrature component due to the \(j \omega C\) term in the bottom line, which causes the phase of the transmitted signal to swing from \(+\) to \(-\) as the input passes through resonance.

Fig. 7 LC series resonant circuit.

(2) The Wien network.

This interesting and useful circuit, shown in Fig. 8, and the basis for a lot of oscillator designs is basically a network of the type shown in Fig. 5 (1) in series with one of the 5(2) type, with both Cs and both Rs being of the same value. Since we have already worked out the impedance characteristics of 5(1) and 5(2), we can write down the output, as a proportion of the input, using the familiar \(a/(a+b)\) form, where 5(2) is a,
\[
\frac{E_{\text{out}}}{E_{\text{in}}} = \frac{1}{2 \pi \sqrt{CR}}
\]
at \(f_0 = \frac{1}{2 \pi \sqrt{CR}}\)

Eout = \(\frac{1}{3}\) Ein
with no phase shift.

Fig. 8 The Wien network.
and $S(1)$ is b.

This gives the rather unwieldy looking equations

$$
E_{out} = \frac{R}{1 + j\omega CR} + \frac{1 + j\omega CR}{1 + j\omega C} + j\omega Cj\omega CR
$$

$$
E_{in} = \frac{R}{1 + j\omega CR} + \frac{1 + j\omega CR}{1 + j\omega C} + j\omega Cj\omega CR
$$

Fortunately, this simplifies to:

$$
\frac{E_{out}}{E_{in}} = \frac{j\omega CR}{1 - (\omega CR)^2 + j\omega CR}
$$

When $(\omega CR)^2 = 1$, or $\omega CR = 1$, since $(1/1=1)$, this becomes,

$$
\frac{E_{out}}{E_{in}} = \frac{j\omega CR}{3j\omega CR} = 1
$$

with no 'j' terms left. Now $\omega CR (=2\pi fCR) = 1$ when $f = 1/(2\pi CR)$, which gives the frequency at which the Wien network output is in phase with the input, and has a magnitude of $1/3$ that of $E_{in}$.

Fig. 9 Sallen and Key type active filters.

(3) The Sallen and Key active filter.

This is one of the archetypes of the class of circuit known as active filters, and is valuable because it can be built with a single op-amp in the form shown in Fig. 9a or 9b. These are high-pass and low-pass versions of the filter. The behaviour of this circuit is such that the gain is substantially level (and x1) at frequencies above, or below, some critical turnover frequency — depending upon whether we are using a high-pass or low-pass arrangement — but beyond this frequency the gain falls at $-12$ dB/octave, as shown in 9c and 9d. If we substitute impedance 'blocks' for the Rs and Cs, as shown in 9e, we can work out a model for the analysis of this circuit using the 'j' techniques described above. However, to simplify your calculations we will assume that our amplifier is an ideal one with unity gain, and has an infinitely high input impedance and a negligibly low output impedance.

We can derive the following relationships.

$$
E_{in} = E_{out} + (i_1 + 2)Z1 + i_2Z2
$$

(1)

and $E_{out} = i_2Z4$ therefore $i_2 = E_{out}/Z4$ ........... (2)

also $i_l = (Ex-E_{out})/Z3$ and $i_2Z2$.

Therefore $i_l = i_2Z2/Z3$ .................................. (3)

From (1) and (3)

$$
E_{in} = E_{out} + (i_1 + 2)Z1 + i_2Z2
$$

and $E_{out} = i_2Z4$ therefore $i_2 = E_{out}/Z4$ ........... (2)

also $i_l = (Ex-E_{out})/Z3$ and $i_2Z2$.

Therefore $i_l = i_2Z2/Z3$ .................................. (3)

From (1) and (3)
Therefore and

\[ \text{Ein} = \text{Eout} + i_2 Z_1 Z_2 \] \( \text{Z3} \) \( \text{Z4} \) \( \text{Ein} = \text{Eout} (1 + Z_1 Z_2 / Z_3 Z_4 + Z_1 / Z_4 + Z_2 / Z_4) \) \( \text{(5)} \) \( \text{Therefore} \)

\[ \frac{\text{Ein}}{\text{Eout}} = \frac{1}{1 + \frac{Z_1}{Z_4} + \frac{Z_2}{Z_4} + \frac{Z_1 Z_2}{Z_3 Z_4}} \]

\( \text{Z3} Z_4 + Z_1 Z_3 + Z_2 Z_3 + Z_1 Z_2 \)

We can now fit in the Rs and \( 1/j\omega C s \) in place of the Zs, and get the formulae for the real circuits. In the case of the low-pass filter, (9b and 9d), where \( Z_1 = R_1, Z_2 = R_2 \) and \( Z_3 = 1/j\omega C_1 \) and \( Z_4 = 1/j\omega C_2 \):

\[ \text{Ein} = \frac{1 + j\omega C_2 (R_1 + R_2) - \omega^2 (C_1 C_2 R_1 R_2)}{1} \]

\( \text{(7)} \)

Several things can be deduced from this: where \( f = 0 (\omega = 0) \) the output is 1/1 (unity gain at VLF), where \( \omega (C_1 C_2 R_1 R_2) = 1 \) the denominator is at its smallest, and the output is therefore at a maximum. This is the turn-over frequency where \( f = 2\pi / R_1 R_2 C_1 C_2 \), and at this point the output of the circuit is \( 1/j\omega C_2 (R_1 + R_2) \), which we can call the ’Q’ of the circuit.

There is one further small trick which can be done with this calculation. Suppose we say that \( x = R_1 / R_2 \) and \( y = C_1 / C_2 \), then \( R_1 \times R_2 \) and \( C_1 \times C_2 \), and suppose that we can call the frequency at which \( \omega (C_1 C_2 R_1 R_2) = 1 \), \( \omega_o \), then \( \omega_o = 1/xy(C_2 R_2)^2 \) and \( \omega_o = 1/C_2 R_2 \pi xy \). Also, our middle term \( j\omega C_2 (R_1 + R_2) \) becomes \( j\omega C_2 R_2(1+x) \).

Let us now express our equation for frequency as a fraction of \( \omega_o \), the turn-over frequency, we then find that \( \text{(7)} \) becomes,

\[ \frac{\text{Eout}}{\text{Ein}} = \frac{1}{1 + j(\omega (1+x) - \omega_o) / \omega_o} \]

\( \text{and the ‘Q’, or gain at f}_{o} \) (when \( \omega = \omega_o \)) is \( \frac{\sqrt{xy}}{1 + x} \). This gives us a means of calculating the performance of this filter circuit over a range of frequencies, of determining what its turn-over frequency will be, and of predicting the circuit Q at that frequency (for an optimally flat response from a 2 element filter of this type, Q should be \( 1/\sqrt{2} \) or 0.707).

I have only gone through the sums for a low-pass filter in this instance, but the high-pass version will follow if appropriate R2 and Cs are put in place of the Zs.

**Conclusions**

The use of the ‘j’ operator, to simulate mathematically the effect of the phase shift in an inductor or capacitor allows useful and instructive calculations to be made on networks which contain Ls and Cs as well as resistances. With a programmable calculator, to take the labour out of the repetitive sums, it becomes practical to calculate a frequency response — and phase shift — for any network which one has the patience to work out. This then, should allow us to explore the performance of our circuitry, while it is still at the ‘drawing on paper’ stage, and thus avoid surprises!

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<td>200V</td>
<td>5p</td>
<td>14p</td>
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<tr>
<td>400V</td>
<td>6p</td>
<td>19p</td>
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<tr>
<td>800V</td>
<td>8p</td>
<td>20p</td>
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<th>Branding</th>
<th>8 pin</th>
<th>10 pin</th>
<th>14 pin</th>
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<tr>
<td>Range</td>
<td>22 pin</td>
<td>25 pin</td>
<td>25 pin</td>
<td>27 pin</td>
<td>40 pin</td>
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