Win a DAB digital radio card – page 18

ELECTRONICS WORLD

FEBRUARY 2003 £3.25

Digital audio broadcasting

Impedance measurement part 3

Improved hybrid power amplifier

Robot guards homes

Frequency transform beats FFT

Novel serials shrink RF designs

Win a DAB digital radio card

CONTENTS

FEBRUARY 2003 VOLUME 109 NUMBER 1802

2

EDITOR
Phil Reed
p.reed@highburybiz.com

CONSULTANT
Ian Hickman

CONTRIBUTING EDITOR
Martin Eccles

EDITORIAL ADMINISTRATION
Jackie Lowe
020 8722 6054

EDITORIAL E-MAILS
j.lowe@highburybiz.com

GROUP SALES
Reuben Gurunlian
020 8722 6028

ADVERTISEMENT
E-MAILS
r.gurunlian@highburybiz.com

EDITORIAL FAX
020 8722 6098

CLASSIFIED FAX
020 8722 6096

PUBLISHING DIRECTOR
Tony Greville

MANAGING DIRECTOR
Roy Greenslade

ISSN 0959-8332
SUBSCRIPTION QUERIES
Tel (0) 1353 654431
Fax (0) 1353 654400

A change of focus

Some heartening news, amidst all the pessimism from the information technology sector, is that innovation continues to thrive. A glance at the who, what and where of patent applications suggests that the locus of innovation has begun to move from telecoms, computing and e-commerce towards fresher pastures - namely in genomics and nanotechnology. Nanotechnology seems to be one of the great new hopes for the generation after next of computing and signal processing chips.

Meanwhile, and contrary to reports of its death, the IT sector has proved itself still capable of innovating vigorously - though, understandably, the level of activity is nowhere near as high as during the feeding frenzy prompted by telecoms deregulation, panic over the (sometimes quite ridiculous) millennium bug, and the dotcom mania of only a few years ago. The (as has now been proved) unwarranted enthusiasm during the run-up to the millennium has saddled the IT industry worldwide with huge debts and overcapacity.

Fundamental lessons in the way the telecoms industry was deregulated need to be learnt before IT can enjoy any serious resurgence. By allowing (non-telco) suppliers to provide high-speed connections over the 'last mile' between the local telephone company's exchange and the subscriber, deregulation was supposed to speed up the availability of all manner of fat pipe data services for the home. We were promised hundreds of new channels 'on demand', online shopping and surfing the web at amazing speeds.

Nearly six years on and the real picture is very different. In terms of availability of cheap broadband, many consumers are worse off today with cheap broadband only available in large urbanisations and very expensive ISDN the only alternative in huge areas of the country. Where does the buck stop? Certainly, the deregulators failed to ensure a level playing-field and the telephone companies dragged their feet every bit as much as might have been expected.

But I sometimes wonder whether the wrong technology was being rolled out in the first place. Few of the newcomers and their financiers did their homework properly. The DSL (digital subscriber line) technology that most of them used was singularly inappropriate for the task. Apart from causing interference problems, the "2B1Q" algorithm used to send fast digital signals down a pair of copper wires cannot punch its way through the "bridge taps" where local lines are spliced. Even worse, few of the newboys appreciated that shipping data is a loss-leader. The only things that make money in the telecoms business are voice-based services. The handful of service providers that understood all this have prospered. The rest have gone bust, leaving piles of debt and over capacity that will take years to soak up. There are far better ways than 2B1Q for delivering broadband over the last mile. A technology known as TC-PAM has none of the other's problems and can move data at around three times faster. So why will governments not wake up and listen to the technologists? Beats me.

I know that a lot of you have noticed the 'thinning' of *EW*. Thankfully, the last two months of reduced pages are now behind us and we are trying our utmost to reduce costs, without reducing quality. Some of this is being achieved by increasing our advertising activity and sorting out our distribution problems. So, I'd like to ask again that you bear with us during these uncertain times and hope (like I do) that the 'glory days' will eventually return.

Phil Reed

Erratum

It would appear that yet another error occurred in Colin Attenborough's Wide USB' article in the November issue.

On figure 1, the legend "pin 12, U5 & U6" should read "pin 11, U5 and U6".

Figure 2 correctly implies this.

Electronics World is published monthly. Orders, payments and general correspondence to **Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey, SM3 8BZ**.

Newstrade: Distributed by COMAG, Tavistock Road, West Drayton, Middlesex, UB7 7QE Tel 01895 444055.
Subscriptions: Wyvern Subscription Services, Link House, 8 Bartholomew's Walk, Ely Cambridge, CB7 4ZD.
Telephone 01353 654431. Please notify change of address.
Subscription rates
1 year UK £38.95 O/S £64.50
US$100.62 Euro 102.55

Overseas advertising agents: France and Belgium: Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008. United States of America: Ray Barnes, Reed Business Publishing Ltd, 475 Park Avenue South, 2nd Fl New York, NY 10016 Tel; (212) 679 8888 Fax; (212) 679 9455
USA mailing agents: Mercury Airfreight International Ltd Inc, 10(b) Englehard Ave, Avenel NJ 07001. Periodicals Postage Paid at Rahway NJ Postmaster. Send address changes to above.
Printed by Polestar (Colchester) Ltd,
Filmsetting by G&E 2000
A1 Parkway, Southgate Way, Orton Southgate, Peterborough, PE2 6YN

HIGHBURY
Business Communications
A SUBSIDIARY OF HIGHBURY HOUSE COMMUNICATIONS PLC

Quasar Electronics Limited
PO Box 6935
Bishops' Stortford, CM23 4WP
Tel: 0871 717 7168
Fax: 0871 277 2728
E-mail: sales@quasarelectronics.com

Add £2.00 P&P to all UK orders. 1st class recorded - £4. Next day (Insured £250) - £7. Europe - £5. Rest of World - £10. We accept all major credit/debit cards. Make cheques/PO's payable to Quasar Electronics. Prices include 17.5% VAT. MAIL ORDER ONLY. Free catalogue with order or send 2 x 1st class stamps (refundable) for details of over 200 kits and publications.

QUASAR electronics

0871 CREDIT CARD SALES 717 7168

Controllers & Loggers

The I/O Module and the Call Logger include plastic cases and don 't need to be attached to a computer during operation. Complete documentation available from our web site.

Rolling Code 4-Channel UHF Remote

State-of-the-Art. High security. 4 channels. Momentary or latching relay output. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 4 indicator LED 's. Rx: PCB 77x85mm, 12VDC/6mA (standby)
Kit Order Code: 3180KT - **£41.95**
Assembled Order Code: AS3180 - **£49.95**

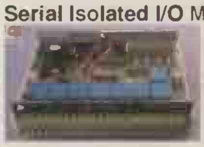
Computer Temperature Data Logger

4-channel temperature logger for PC serial port. Deg. C or F. Allows continuous logging of 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 38x38mm. Powered by PC. Includes one DS1820 sensor and four detachable header cables.
Kit Order Code: 3145KT - **£23.95**
Assembled Order Code: AS3164 - **£29.95**
Additional DS1820 Sensors - **£3.95 each**

Telephone Call Logger

Stores over 2,800 x 10 digit DTMF numbers. Records all buttons pressed during a call. The time and date also recorded. No need for any connection to a PC during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. 9-12VDC.
Kit Order Code: 3164KT - **£54.95**
Assembled Order Code: AS3164 - **£59.95**

Serial Isolated I/O Module



PC controlled 8-Relay Board. 115/250V relay outputs and 4 isolated digital inputs. Useful in a variety of control and sensing applications. Uses PC serial port for programming (using simple text batch files). Once programmed unit can operate without PC. Includes plastic case 130x100x30mm. Power: 12VDC/500mA.
Kit Order Code: 3108KT - **£54.95**
Assembled Order Code: AS3108 - **£64.95**

Infrared RC Relay Board

12-channel relay board. Each relay individually controlled with included Infrared remote control unit. Toggle or momentary. Over 15m range. PCB: 112 x 122mm. Power: 12VDC/500mA
Kit Order Code: 3142KT - **£44.95**
Assembled Order Code: AS3142 - **£64.95**

PIC & ATMEL Programmers

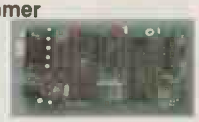
We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £15.00
Power supply (PSU201) £5.95
Parallel Cable (CSLEAD108) £4.95

Enhanced "PICALL" ISP PIC Programmer

Will program virtually ALL 8 to 40 pin PICs plus certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. Also supports In System Programming (ISP) for PIC and ATMEL AVRs. Free software. Blank chip auto detect for super fast bulk programming. Requires a 40-pin wide ZIF socket (not inc.)
Kit Order Code: 3144KT - **£59.95**
Assembled Order Code: AS3144 - **£64.95**

ATMEL 89xxxx Programmer



Uses PC serial port. No special programming software required. 4 LED's display the status. ZIF sockets not included. 16VDC.
Kit Order Code: 3123KT - **£29.95**
Assembled Order Code: AS3123 - **£39.95**

P16Pro PIC Programmer

Super low cost programmer for 8/18/28/40 pin DIP serial PICs including 16F84 & 12C508. Software needs to be registered @ £20.95. 17-30VDC or 13-20VAC
Kit Order Code: 3096KT - **£10.95**
Assembled Order Code: AS3096 - **£15.95**

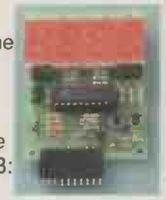
ATMEL AVR Programmer

Programmer for 20 and 40 pin DIP (AT90Sxxxx) "AVR" micro controllers. Uses PC serial port. No special software required. ZIF sockets not incl. 16VDC.
Kit Order Code: 3122KT - **£24.95**
Assembled Order Code: AS3122 - **£29.95**

Timers & Counters

These modules use a microcontroller and crystal for accurate and low-cost. 4 digit 14mm LED display used on all but 3141.

Presettable Down Counter



Starting count can be set. The 4-digit counter has four modes to control how the output behaves when it reaches zero. Max count rate of 30/sec or 30,000/sec. PCB: 51x64mm. 9-12VDC.
Kit Order Code: 3154KT - **£13.95**
Assembled Order Code: AS3154 - **£22.95**

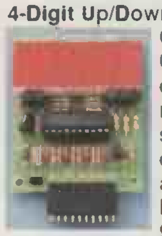
4-Digit Timing Module

The firmware included with this motherboard kit is a programmable down timer of 10,000 sec. Timing accuracy: 0.04%. PCB: 51x64mm. 9-12VDC Current: 50mA. 5 other firmware chips can be used with this motherboard. Each has a different timing mode and can be purchased as a pack.
Kit Order Code: 3148KT - **£9.95**
Assembled Order Code: AS3148 - **£18.95**
5 Piece Firmware Pack: F3148 - **£14.95**

Multi Mode Universal Timer

Seven different timing modes in one! Modes and delay ranges are set by DIP switches. Timing delays range between 255sec (1sec steps) and 42.5h(10min steps) Mains rated relay output. PCB: 48x96mm. 12VDC
Kit Order Code: 3141KT - **£14.95**
Assembled Order Code: AS3141 - **£21.95**

4-Digit Up/Down Counter



Count range is from 0000,1,2.. to 9999.It can also count down. Maximum count rate of about 30 counts per second. Two counters can be connected together to make an 8-digit counter. PCB: 51x64mm. 9-15VDC.
Kit Order Code: 3129KT - **£13.95**
Assembled Order Code: AS3141 - **£22.95**

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

No.1 for KITS

www.quasarelectronics.com

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

Biology spawns nano-substrate

NASA scientists have used biology to make a substrate which could be used for single-electron nano-electronics without lithography.

The scientists modified proteins found in microbes that live in near-boiling hot springs.

"We took a gene from a single-celled organism, sulfolobus shibatae, and changed the gene to add instructions that describe how to make a protein that sticks to gold or semiconductors," said NASA scientist Andrew McMillan.

The protein naturally self-assembles into a two-dimensional lattice. "We also designed it to capture metal and semiconductor particles at specific locations on the lattice surface," he said.

To produce large quantities of the protein, the modified gene was cloned into a rapidly multiplying form of E. coli bacteria.

Due to its history, the protein is heat-resistant and can be extracted from the E. coli mass by boiling.

It is then crystallised into its flat lattice, which consists of rings about 20nm across.

"We apply the crystals to a substrate such as a silicon wafer, and we add a gold or semiconductor slurry," said McMillan. "The tiny [1-10nm] particles of gold or cadmium selenide/zinc sulfide stick to the lattices."

These particles can then be used as quantum dots, the basic element of single-electron electronics.

The scientists see a regular array of quantum dots as a potential memory amongst other things.

Photo: Susanne Trent.

NASA scientists sampling an acidic hot springs in Yellowstone National Park for the microbes used to produce protein nanostructures.

UK broadband cheapest in Europe

Broadband prices in the UK are among the lowest in Europe, according to a report by the Broadband Stakeholder Group.

The BSG's second annual report said that UK costs were averaging about £26 per month, while some 30,000 people are connecting to broadband each week.

The UK has over one million users with always-on, broadband links mainly split between ADSL and cable. Around two-thirds of the population are in broadband capable areas.

"In the BSG's view, continued, concerted action is required to further extend the percentage of the population with access to broadband services. This is essential for both regional economic development and social inclusion," said the report.

Meanwhile the Government has announced plans to provide broadband access to primary and secondary schools, and connections for every GP surgery, hospital, primary care trust and health authority in the country.

Keyboards shuns QWERTY

For PC and Palm users that don't want to use conventional keyboards or Graffiti, there is CyKey (pronounced psyche).

The size of a postcard, it uses combinations of five keys to generate the alphabet, plus a couple of other keys for numbers and control characters.

The coded writing system was originally developed by Cy Endfield and Chris Rainey in the 1970s and was used in the innovative Microwriter one-handed word processor and its derivatives. The name is a tribute to Endfield who died in 1995.

Rainey is producing the new device and it is available now. Learning time is claimed to be under an hour.

Data transfer is via an infra-red link, battery life is several months and it also works with pocket Windows devices.

KeyPad is another QWERTY-free keyboard, this time a concept for PCs being developed by One Bamboo.

It has no markings, just a pattern of un-labelled keys.

Function is context-sensitive and the user is constantly guided by an on-screen display.

The current prototype is a membrane keypad with the markings as shown on the left and embossing to show key positions. It connects through a serial port. Sponsors are sought to fund further development of KeyPad.
www.cykey.co.uk
www.onebamboo.net

Chips are biggest polluter

Processing semiconductors is possibly the most wasteful process on the planet, using over 600 times the weight of the finished product in fossil fuels and chemicals.

This analysis comes from scientists in Japan, France and the US in a recently published paper.

Dr Eric Williams from the United Nations University in Tokyo claimed that making a single 256Mbit DRAM chip, weighing just 1.2g, uses up 1.2kg of fossil fuels and 72g of chemicals. In addition the fab requires 32kg of water and 700g of nitrogen for each device.

"The figure includes the chain of processes to produce silicon wafers from quartz, production of chemical inputs (but only their crude form, not semiconductor grade), fabrication and packaging," said Williams.

Moreover, these figures are a lower bound, he warned, as the energy he allowed to produce the chemicals only covers their commercial grade.

Electricity is the big fossil fuel user. For every cm^2 of finished silicon, 1.5kWh of electricity is used.

This is perhaps not surprising as the raw silicon boules are the purest material manufactured on Earth, and each kg takes up 2,100kWh.

Furthermore, during the chip's life it will typically consume another 440g of fossil fuel energy, just under 1kWh, Williams said.

The figures are for a single device, in this case just $1.6cm^2$ of silicon, so need to be multiplied by around 200 to give the amount per 200mm wafer.

In total around five million wafers (200mm equivalent) are processed every month by the chip industry.

Robot guards homes

This will be the first practical domestic robot, claims Sanyo.

Banryu, or guard-dragon, was originally developed as an earlier robot called 'guard dog' by small Japanese robotics firm tmsuk - pronounced 'temzack'.

Now Sanyo has joined the team and Banryu will go on sale next year if test marketing proves successful.

Acting as a fire-alarm is one of its key activities. Banryu includes an odour-sensor developed jointly by tmsuk, the Kanazawa Institute of Technology and New Cosmos Electric that "can sense a particular odour with practical accuracy", said Sanyo. With this the robot can smell the scent of smouldering before fire breaks out.

A whole bundle of other sensors are built-in, including a TV camera - with data compressor and radio link - and foot-mounted detectors which guide Banryu as it steps over obstacles.

The robot is large, at a metre long, 70cm tall and weighing in at around 40kg, but it moves at a rather slow 15m per minute. "More than fast enough for a home robot designed to travel in confined cluttered spaces," said Sanyo.

The robot partners are in talks with a Japanese security company on linking Banryu with more conventional security infrastructure.

www.tmsuk.co.jp

Digital valves run at 4kHz

A Cambridge firm has developed electronically controlled valves with operating speeds at least ten times faster than traditional electromechanical devices.

Camcon's digital valves are aimed at applications in industrial handling, engine fuel management, the oil industry, vehicle suspension and medical dosing.

"Applications are from jet engines to pipe organs," said Wladyslaw Wygnanski, founder of Camcon. He claims the electromechanical valves have reaction times of under 100μs and can run at frequencies up to 4kHz.

The valves are held by permanent magnets in the open or closed position, so no continuous power is needed. A spring attempts to pull the armature to the central position.

When a low impedance coil disrupts the holding magnet, the spring pulls the armature across, with the other magnet holding the armature before it settles in the middle position.

Thus energy needs are low - just 3mJ per switch - while the firm has devices in the lab that are still running after six billion cycles.

In order to push its technology to a wider audience, Camcon has appointed Danny Chapchal, former chief executive of Cambridge Display Technology, as its chairman. Chapchal will help to commercialise and license the technology.

"Camcon is a classic British invention that needs to be taken to a world stage. Its valve offers very precise high speed control of liquids and gases," said Chapchal. "By comparison all traditional designs of valve look clumsy."

"Camcon's digital valve has the potential to do for gas and liquid, something akin to what the transistor did for electronics," Chapchal added.

In the late 1990s he took Cambridge Display Technology through its initial start-up phase until it was sold to a consortium of investment firms.

Danny Chapchal

Colour holograms get real

Scientists from De Montfort University in Leicester have teamed up with a Russian research institute to improve their full colour holography. The group has the ability to show high definition three dimensional images.

Led by Professor Hans Bjelkhagen, the team from The Centre for Modern Optics already has links with firms such as Samsung, Nortel, Honeywell and De La Rue.

Bjelkhagen's holographs are stored in special emulsion plates, developed for the University by the Russian research institute, which has researchers in Leicester.

Writing data requires the use of three lasers; red at 647nm, green at 532nm and blue at 476nm. Via a relatively simple set of optics, the lasers are combined to form a white light which passes through the emulsion plate to strike the object being imaged.

The light reflected from the object interferes with the reference source inside the emulsion, so phase information is recorded as the emulsion is exposed.

Because the reference source passes through the emulsion, the plate must have very low light scattering properties, so silver halide grains are made very small, around 10nm across. This gives higher quality images than previous attempts at 3D colour imaging.

The exposure and fixing process is quite complex, but viewing the hologram is as simple as shining a halogen lamp on the plate. The 3D image will appear behind the plate.

"Marketing is a huge area for potential exploitation," says Brian Foxon, director of commercial partnerships at De Montfort. "If you want to show an audience your product, why restrict yourself to one dimension [presumably he means two] when you could use three?"

Although the technique currently works with still images, the team hopes to develop 3D video.

Plastic packages go military

Packaging specialist Apta Group has come up with an innovative way of avoiding obsolescence in certain military parts.

The Tyne and Wear-based firm is encapsulating plastic parts inside a military grade package.

Such a process could be useful when die are no longer available in military grades, said the firm.

The first device produced is a flash memory, although the encapsulation technique could equally apply to other memory or logic devices.

The commercial grade, 32-pit TSOP (thin small outline package) is sealed inside a co-fired ceramic package. The module is then tested and screened to military standards, said the firm.

The cost is not appreciably increased compared with buying the original military spec part, said Ian Robinson, Apta's sales manager: "Whether we bought TSOP or die, it's about the same price."

Colour display is 3D without glasses

A full-colour 3D display that can be viewed without special glasses has emerged from Sharp's laboratories in Cambridge and Japan.

The display, which can also be switched to a 2D mode, is actually a conventional active-matrix LCD with an unconventional backlight.

Getting the 3D effect involves making the image destined for the right eye appear black to the left eye, and vice-versa.

To do this, every second colour pixel is allocated to either the left or right eye.

Cunning geometry means vertical black stripes on the backlight align with pixels so that, from the left eye view, all the right eye pixels are black, and from the right eye view, all the left eye pixels are black.

The image is best observed from a certain distance - which is proportional to eye spacing. Correct head positioning is ensured by a simple indicator which can only be seen from the best distance for the user's eyes.

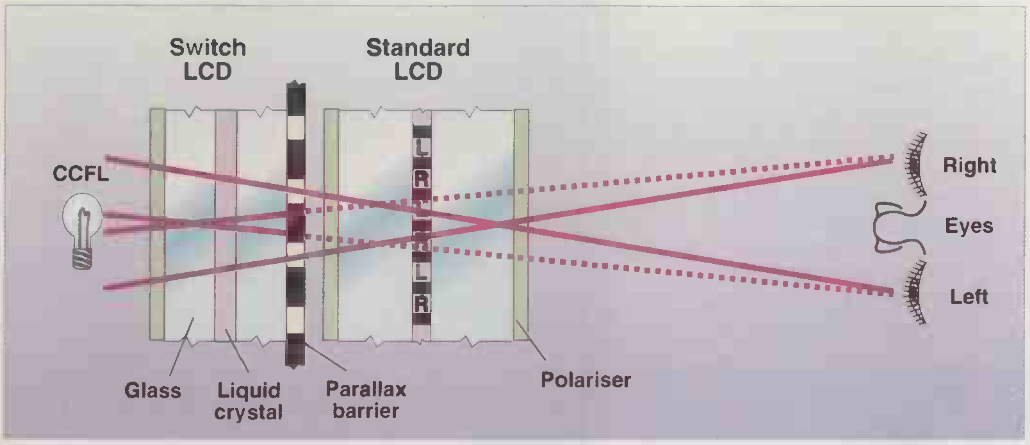
In 2D mode the backlight is switched to total transparency and the display is viewed as a simple colour LCD with twice the resolution it had in 3D mode.

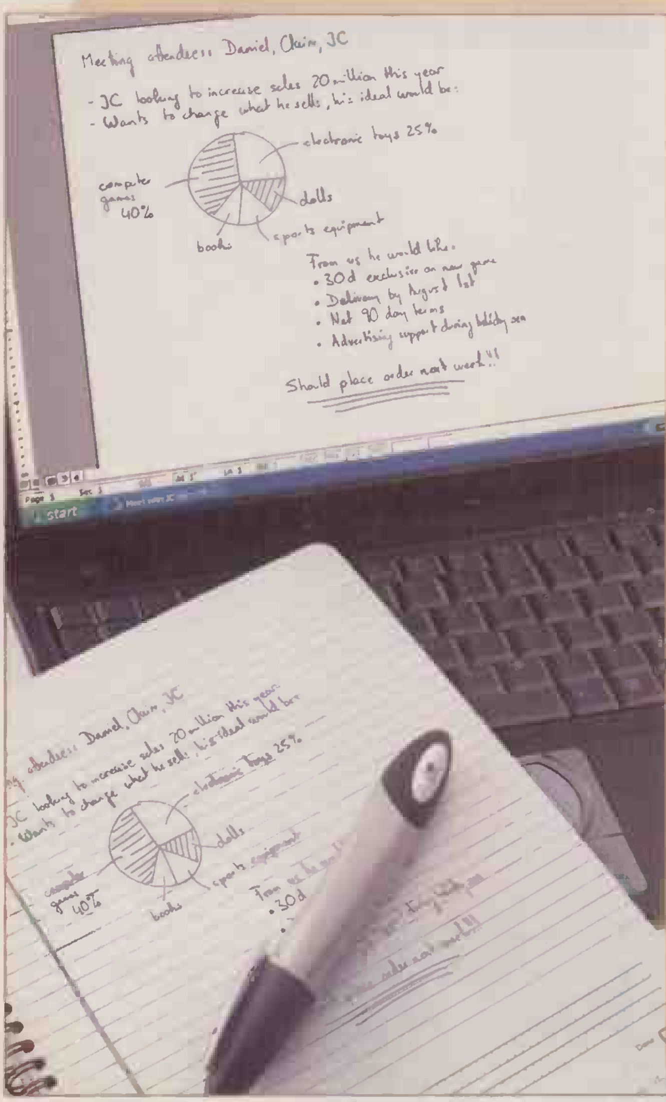
Although the exact way the backlight works is still a secret, it is known that it includes a single pixel-less LCD the same size as the main LCD and, between this and the main LCD, something Sharp calls a 'parallax barrier'.

This barrier is likely to consist of alternate stripes polarised vertically and horizontally.

The pixel-less LCD can then be used to rotate the polarisation of light approaching the barrier. When this light is polarised vertically, the barrier will appear to be a series of vertical black and light stripes. When the light is polarised diagonally, the whole backlight will appear evenly light, although at a diminished intensity.

A Sharp spokesman confirmed operation along these lines.





Pen records writing

This pen records what you write as you write it - but you need special pre-printed 'digital' paper.

An CMOS optical sensor embedded in the pen watches the micro-printed dots on the paper surface and records them every 10ms. This allows the Logitech io, as it is called, to deduce its position. Memory allows up to 40 pages of handwritten notes to be stored and these can be transferred to a PC through a USB cradle.

The proprietary non-repeating dot pattern, licensed with the pen technology from Anoto, has a nominal spacing of 0.3mm and gives the paper a slightly grey appearance. Position is encoded by slight deviations from the standard pitch.

The paper will be made by a number of companies and Anoto claims 60million km^2 of is can be produced before the pattern repeats.
www.anotofunctionality.com

DoCoMo has released a phone using a 5.6cm 65,536-colour switchable 2D-3D display from Sharp. Part of the i-shot range, the SH251iS allows users to receive or take 2D photos and translate them into 3D images for display. The on-board camera is a CCD with 310,000 pixels.

Novel serials shrink RF designs

Dielectric antennas could cut the size of portable and miniature RF equipment, claims Cambridge company Antenova, which has revealed its technology after several years development.

The antennas have no conductive parts except for a pcb track which acts as a feeder. All the rest is ceramic.

"You can make dielectric itself resonate," said Professor Simon Kingsley, the company's chief scientist. "It's displacement current. The electrons are not free to move, but they can vibrate."

Antenova claims two major advantages for its antennas.

Firstly they are smaller, because the dielectric constant is higher than free-space within the material and wavelength is proportional to the square root of dielectric constant, said Kingsley.

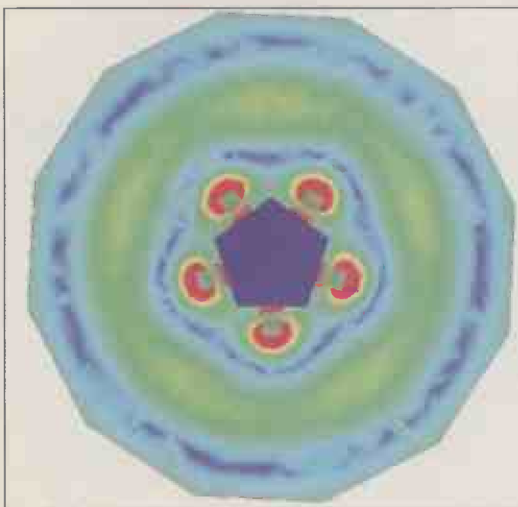
Secondly, almost all near-field effects are within the ceramic allowing the antennas to be placed close together with minimal interaction. "You can put two together at right angles and get little interaction down to a couple of millimetres separation," said Kingsley.

It is the second advantage that Antenova hopes will bring in customers.

Modern radios, for instance those used in wireless LANs, are increasingly using 'diversity' to improve performance.

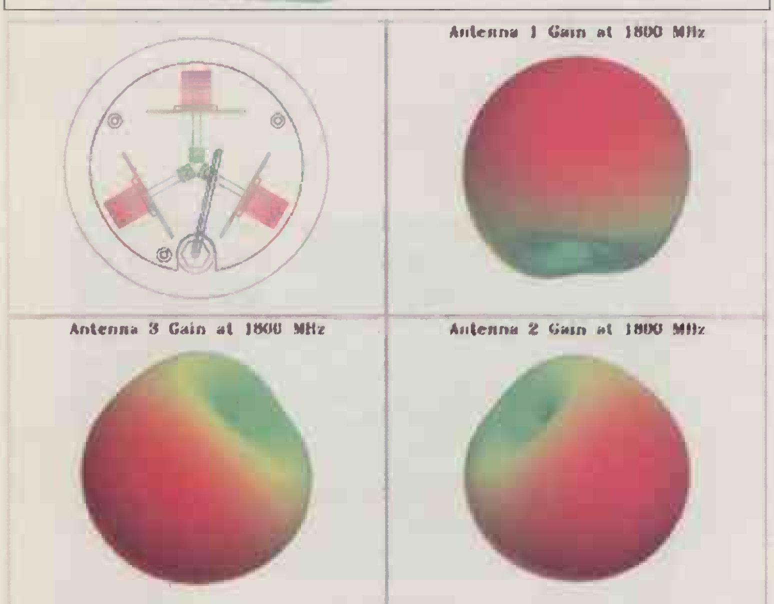
Diversity is using more than one aerial, then taking signals from both and combining them in such a way as to improve signal to noise ratio or

A five-sectored array for 5.8GHz wireless LAN infrastructure. The 72° sectors allow spatial diversity to increase in-room data rate. Four elements per sector produce a 20° vertical beam to increase gain. The array can also be set to omnidirectional mode.



Computer simulation shows a top view of e-field intensity from the 5-sectored router antenna shown in the laptop picture. The near field is almost completely contained within the dielectric antenna elements and the far field propagates omnidirectionally.

A dielectric Bluetooth antenna.



Gain plots for a tri-sectored antenna, showing the 3D gain pattern - with pattern length and deeper colour indicating higher intensity

some other important parameter.

Unfortunately, said Kingsley, near-field interaction means existing antennas frequently have to be placed so far apart that at least one has to be at the end of a flying lead.

Tight near fields allow dielectric antennas to be placed inside equipment without interaction, he said.

Even without a second antenna, low near-field radiation means nearby lossy materials, including plastic cases and human heads in the case of phones, have little effect.

Kingsley claims some miniature 2.4GHz antennas are actually tuned to 2.9GHz when that are made to allow for changes that will occur when they are installed. A good dielectric antenna will not. "With a hand near, the return loss may change but the frequency stays the same," he said.

Frequency transform beats FFT

An Anglia Polytechnic University lecturer has developed a frequency transform that can measure irregular signals.

Originally created for the MoD, the technique has been used to locate submarines using an array of towed hydrophones. Now its inventor, Dr Geoffrey Sweet, wants to commercialise the technology.

"I have a method that can decompose a signal in real time," said Sweet. "This is a real, real-time system for analysing signals."

Dubbed optimal phase binning (OPB), the technique avoids the massive amount of computation needed in techniques such as fast Fourier transforms.

"In radar we need to work these things out on the spot," said Sweet. "In an FFT you need to convolve two signals, and that means you have to multiply point by point. You've got to do an awful lot of multiplying."

FFT is also phase dependent, and relies on regular data.

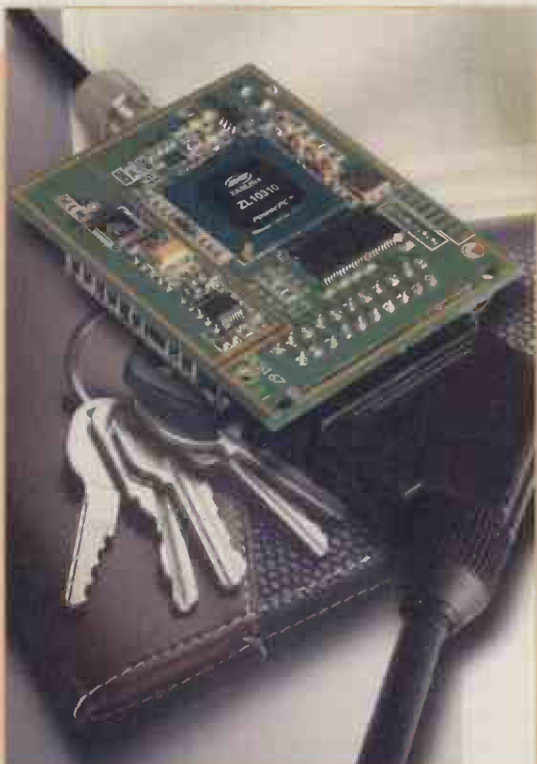
"My method is phase independent," Sweet added. "You convolve data with themselves and you don't do multiplies - you add the numbers together as they come in."

Using the data as it arrives also cuts the memory requirements of the processor - unlike FFTs which tend to require a large supply of SRAM.

Sweet says he has the interest of mobile phone firms among others, and hopes to push OPB into commercial use.

Possible applications include the location of underwater wreckage, heat sources in nuclear power stations, leaks from pipes, seismic activity and hearing aids.

OPB first originated in the analysis of signals from distant stars. Sweet's approach allowed irregular signals to be examined, without the aliasing that an FFT creates. OPB's first success was to show that a binary star system in fact included a third object.



TV in your wallet?

A single chip integrating all the functions for digital video broadcasting over terrestrial (DVB-T) has been designed by Zarlink Semiconductor in Swindon.

The firm has gone further by creating a reference design that is capable of receiving all free-to-air broadcasts such as Freeview in the UK. It takes the standard aerial signal in, and outputs direct to a Scart socket.

The main device, the ZL10310, combines a COFDM demodulator, MPEG2 A/V decoder and transport layer, PowerPC processor, memory controllers and power management circuits.

The wallet-sized reference design occupies just 90 x 55 x 25mm. Even with the tuner, memory and peripherals the whole design runs at less than 4W.

A total bill-of-materials for the design comes to less than $60, said the firm.

Low power radio gets simpler

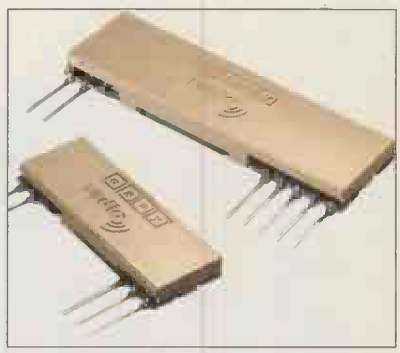
Low Power Radio Solutions has launched its own range of FM radio modules. The Witney-based firm said it was responding to a demand for easier access to short range radio equipment.

The easy-Radio devices cover the 433 and 434MHz European bands with 10 available frequencies, and the 860 to 920MHz band. The latter covers both Europe at 868-870MHz and the US at 902-920MHz.

Power output is set by the user, and data rate can be varied between 4.8 and 76.7kbit/s.

An on-board microcontroller carries out all encoding and decoding functions from standard sources including RS232 and TTL.

For orders of over 100 pieces the firm will customise software to the buyer's needs.



Pictured is the 433-4MHz FM SIL transmitter. It has 10 user selectable frequencies between 433-4MHz, user selectable power output up to 10mW, and range in excess of 250m line of sight. Price is £9.10 each for 100 off.

Seamless displays coming

UK-based Screen Technology has developed a way to 'tile' individual displays together with almost no visible join, and is looking to licence the method to display makers. The picture shows a hand-made prototype. Production joins will be even better, said the company.
www.screentechnology.com

DAB (Digital Audio Broadcasting) is slowly becoming the new radio. Much favoured by governments as it uses less bandwidth and of course, they can sell off the spectrum vacated by existing VHF/FM users. In this article, Roger Thomas reviews a PC based PCI card tuner.

DAB PCI tuner review

Modular Technology's digital radio receives band III (217.5 – 230 MHz) Digital Audio Broadcast (DAB) transmissions and is built on an internal PCI card with the receiver in a small low profile metal case on the card. The decoding is done by a Texas Instruments TMS320DRE200 DSP digital radio chip and PCI interface chip. Build quality of the board is good. The Windows software is written by RadioScape Ltd. and occupies around 18Mbytes of disk space. The supplied software has drivers for Windows 98, Me, 2000 and XP.

The indoor aerial supplied was a metal monopole aerial (half dipole) with a heavy base. The aerial stands 300mm (12 inches) tall and is designed especially for DAB signals which are transmitted using vertical polarisation. A sticker inside the box states that this is a 'Special introductory upgrade ..... this upgrade is only while stocks last after which ribbon dipoles will be supplied'. Attached to the aerial is approximately two metres of co-ax cable terminating in an 'F' type connector. The installation guide was a single page leaflet and there was little technical information supplied.

As the PCI card does all the DAB decoding, the minimum specification for the computer is rather modest, requiring only a Pentium 200MMX and 64Mb of memory. There are no configuration jumpers to set on the PCI card and thus the DAB radio tuner can be truly described as 'plug and play'.

DAB advantages

DAB has been designed to be immune from multi-path interference. This reliability is due to DAB incorporating error correction and the data being spread across 1536 carriers in each ensemble. If some of these carriers are impaired due to poor reception then the error correction can overcome any lost data.

Unlike VHF-FM, DAB will always provide hiss-free reception provided the signal strength is above a minimum threshold. If the signal strength drops below this threshold then the digital data decoder has too many errors and cannot recover the original transmitted data. Unlike analogue, digital radio does not show graceful degradation, the service is either there or not

As DAB is a digital transmission, as well as transmitting digital audio a DAB multiplex can also incorporate data and text.

Each DAB 'ensemble' occupies 1.536MHz and there is room for seven ensembles (channels 11B, 11C, 11D, 12A, 12B, 12C, 12D). The (small) portion of Band III that is used for UK's DAB was previously used for 405-line monochrome television broadcasts.

A DAB ensemble can transmit data at 2.34 Mbps (bits per second), but with error correction and other data overheads the useful data rate available for each ensemble is around 1.6 Mbps. A multiplex is the collection of audio and data services which is transmitted on an ensemble.

National and regional multiplexes

In the UK there are two DAB national multiplexes, one assigned to the BBC and the other assigned by the Radio Authority for commercial radio.

Channel 12B (225.648 MHz) is allocated to the BBC's national DAB radio network. Channel 11D (222.064 MHz) is allocated to the commercial national DAB network in England and Wales, and 12A (223.936 MHz) in Scotland. This commercial network is operated by Digital One. Channel 12D (229.072 MHz) is allocated to the commercial national network in Northern Ireland operated by Score Digital.

According to the BBC its national digital radio transmitters cover 70% of the UK population. Digital One has a slightly better coverage area and claim to switch on an average of two new DAB transmitters per month. The BBC hope to have reached 80% by the end of 2003.

Both national multiplexes are examples of a Single Frequency Network (SFN). Unlike analogue radio, a national multiplex is received on the same frequency irrespective of location or transmitter – so no need to re-tune if travelling. To work a SFN requires identical data to be broadcast by all the transmitters on that particular frequency. This explains why BBC local radio stations are not part of the national BBC multiplex.

For regional stations there are seven regional multiplexes currently in operation. These multiplexes cover north-east England, north-west England, west Midlands, Wales & the West, and Yorkshire. All these multiplexes are operated by MXR Digital and the Scotland Central multiplex is operated by Switch Digital (Scotland).

DAB coverage

If you are considering DAB then first check out web sites like the BBC, Digital One and DRDB to see maps of the coverage areas. On the Digital One web site coverage page, I entered my postcode and the result was '...... an excellent chance of receiving a strong digital radio signal in this area'.

If you primarily listen to a particular BBC local station then visit the BBC digital radio web site for a list of BBC local stations that are also being transmitted on DAB, currently the stations are –

Radio Bristol
Radio Cleveland
Radio Essex
GMR
Radio Humberside
Radio Lancashire
Radio Leeds
Radio London
Radio Merseyside
Radio Newcastle
Radio Sheffield
Radio Shropshire
Radio WM

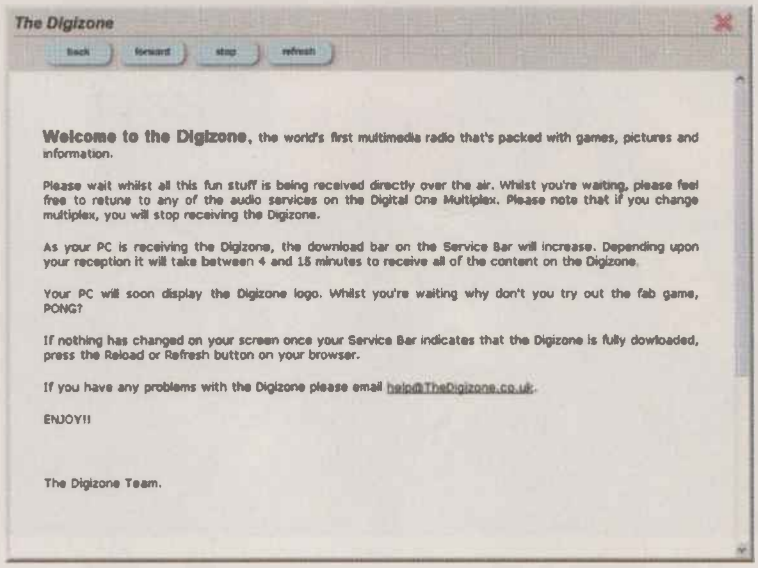


Figure 1: Digizone welcome page

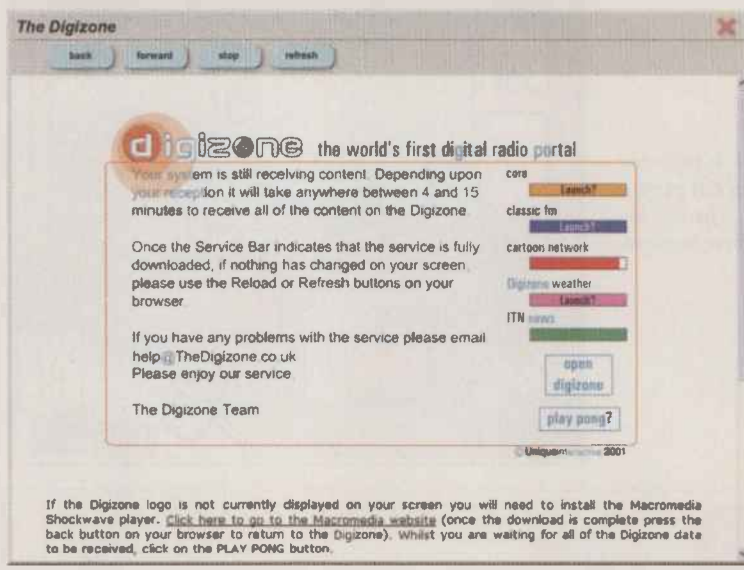


Figure 2: Digizone page showing progress of the five individual services being downloaded

The BBC has been allocated capacity for its local radio to be carried on commercial multiplexes licensed by the Radio Authority. The BBC's national radio stations - BBC Radio Wales, BBC Radio Cymru, BBC Radio Scotland, BBC Radio nan Gaidheal and BBC Radio Ulster are already broadcasting on the appropriate geographical multiplexes.

Check sites that list DAB stations to see if your regional or local multiplex transmits your favourite AM/FM radio stations. Coverage of the local multiplex is designed to be similar to the existing coverage of the commercial FM stations. Some areas are already in operation or the licencße has been awarded. However, there are some areas that have not yet been licensed or advertised by the Radio Authority.

DAB audio quality

In recent months there has been criticism of the BBC for

Figure 3: Digizone Cartoon Network menu page displaying various cartoon characters

Figure 4: Digizone Top Cat game – part of the Cartoon Network

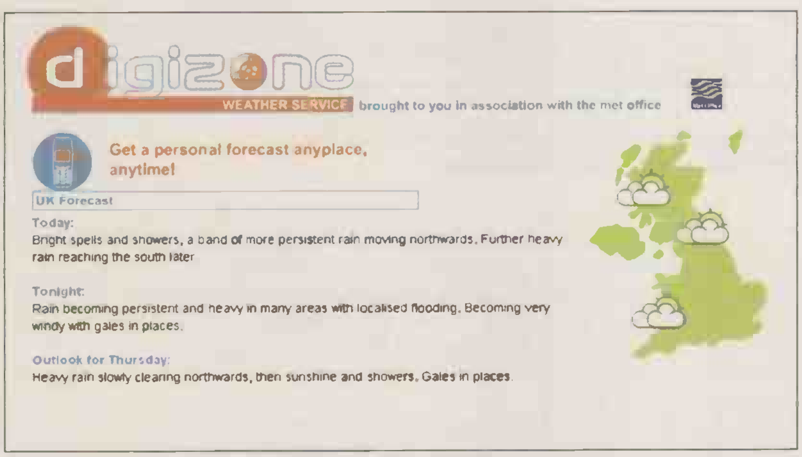


Figure 5: Digizone weather – unfortunately this forecast is three days old!

reducing the bit rate of its music stations on its national multiplex so that new radio stations can be introduced. The dichotomy is that to attract more digital listeners the BBC believes that it has to introduce DAB only stations (such as 6 Music, 1Xtra, 7) alongside radio stations already available on AM or FM. To make room for these new services the bit rate of existing radio stations has been reduced.

If you are considering an investment in DAB

Figure 6: BBC Vision Radio 'over the air' web site

technology on the basis of enjoying CD quality audio then you are in for a disappointment. The result of this bit rate reduction is that the audio quality can no longer be described as 'CD quality'. The DAB web sites now only claim that DAB produces 'crystal clear digital sound' or 'near CD quality'.

This aspect of DAB transmitting CD quality audio was heavily promoted when DAB was first proposed. It is doubtful that CD quality radio stations were ever an option given that a multiplex could only accommodate a maximum of six such radio stations. The required bit rate to achieve CD audio quality is 256 kbps. At present the highest data rate transmitted is Radio 3 at 192 kbps, and Virgin Radio and Classic FM at 160 kbps.

Whether this strategy helps or harms DAB take-up is debatable. Consider the quality of the majority of DAB music stations as being the equivalent of noise free VHF-FM (the majority of music stations transmit at 128kbps). There are some stations on DAB that are intended for (mono) AM transmission which have a lower bit rate. For example, BBC World Service operates at 64 kbps, talkSPORT at 80 kbps. The lowest bit rate I found was Bloomberg Radio at 48 kbps.

Radio data

A DAB multiplex can also transmit various data services as well as audio. Note that with this PCI radio card it is not possible to simultaneously download from a data service and listen to a radio station.

An example of a data service is 'The Digizone' transmitted on the national Digital1 Network multiplex that incorporates five different data services. They claim to be the world's first multimedia radio portal. It takes about 5-10 minutes to download, but with all data services DAB reception must be good.

These data services allow some of the content of internet web sites to be made available 'over the air', such as Core and ITN news. In the case of the Classic FM service, the display lists the music coming up. The Digizone weather page uses animated graphics. Within the Cartoon Network site there is an interactive game

Figure 7: EPG information for current programme being transmitted

Figure 8: EPG station information – click 'rec' to record any programme to disk

Figure 9: start of the digital radio adventure

called Top Cat in Alleycash. Extensive use is made of the Macromedia Shockwave player for the animated graphics and this web browser plugin needs to be installed and can be downloaded free from the internet.

The Digizone directory occupies around 700kbytes of disk space and contains over 100 small files. Once downloaded the Digizone is run from the hard disk so you can then change multiplex or select a radio station while browsing.

BBC Vision Radio provides an over the air web site for news, sport, business, weather and travel. These data services will change as improvements are made to the software and other services are added, but they demonstrate the multi-media potential of DAB.

EPG

The BBC transmits via the 'Test BBC Guide' channel an Electronic Programme Guide (EPG), showing a comprehensive listing of what's on BBC radio now and for the next few days, although, at present, there is no programme information for the new DAB only stations. It takes about 8-10 minutes to download this information. An EPG technical standard is expected to be agreed soon and hopefully this will be adopted by all the DAB broadcasters as EPG information adds greatly to the DAB radio experience.

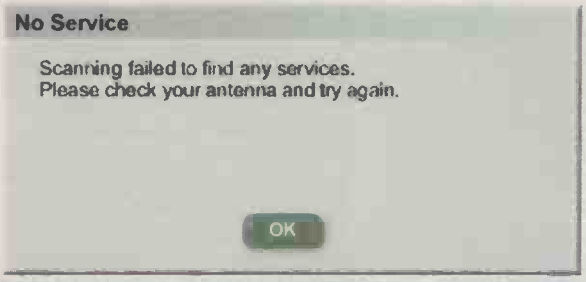
The 'Programme Guide' menu option offers several different ways to view the schedules and also offers a 'record this programme' icon. The software is intelligent enough not to offer this if the programme has already been transmitted.

The hard disk can be used to store the recorded radio programmes. Recording

DAB stations received

DRg London multiplex	
[11B - 218.640 MHz]	
The Storm-London	rock music
Choice	pop music
Liquid	pop music
AbracaDABra	children's programme
Purple Radio	varied
Mean Country	country music
Passion	varied
The Arrow	rock music
Tap	varied
Breeze	oldies music
Digital1 Network multiplex	
[11D - 222.064 MHz]	
PrimeTime Radio	easy listening
Life	pop music
Oneword	varied
D1 ten	currently testing
Classic FM	serious classical
TalkSPORT	sport
Virgin Radio	rock music
Core	pop music
Planet Rock	rock music
Bloomberg Radio	finance/business
DataServe	over the air web site
ntl-data	over the air web site
The Digizone	over the air web site
test_123	over the air web site
Switch London multiplex	
[12A - 223.936 MHz]	
The Groove	other music
MinistryOfSound	pop music
jazz fm	jazz music
WLON - The Mix	easy listening
Heart	pop music
Saga Radio	easy listening
Travel Now	travel
BBC London	varied
Spectrum Radio	other music
BBC National DAB multiplex	
[12B - 225.648 MHz]	
BBC Radio 5 Live	news
BBC 5LIVE SportX	secondary service
BBC Radio 1	
BBC Radio 2	
BBC Radio 3	
BBC Radio 4	
1Xtra – BBC	black music
BBC 6 Music	rock music
BBC 7	comedy, drama
BBCAsianNetwork	varied
BBCWorld Service	varied
Test BBC Guide	Electronic Programme Guide
BBC Vision Radio	over the air web site
BBC Travel	TPEG data service
CE London multiplex	
[12C - 227.360 MHz]	
Capital Disney	pop music
CAPITAL FM	pop music
CAPITAL GOLD	oldies music
Sunrise Radio	varied (Asian)
X F M	rock music
MAGIC	easy listening
KISS	pop music
News Direct	news
LBC	news/speech
Century London	pop music
SMASH HITS!	pop music
DAB Guide	Electronic Programme Guide

Figure 10: Welcome to the frustrations of finding the best indoor location for the DAB aerial



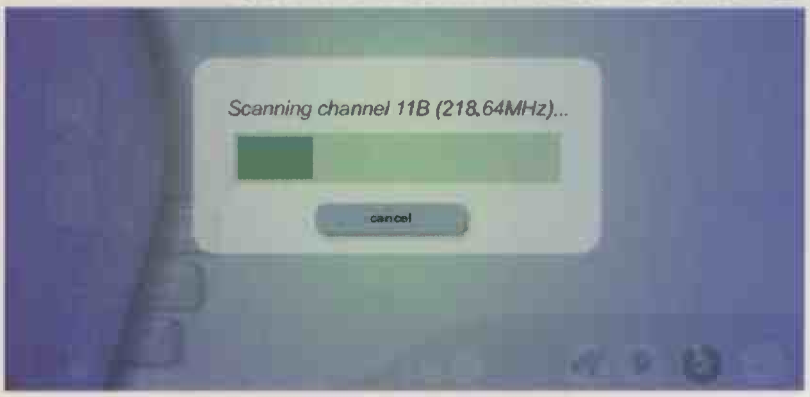


Figure 11: DAB scan in progress

DAB web sites

Modular Technologies
www.digitalradio.tv

Official DAB information
www.drdb.org
www.uk-dab.info
www.worlddab.org

National DAB
www.bbc.co.uk/digitalradio
www.bbc.co.uk/reception/radio_transmitters/digital_radio
www.thedigizone.co.uk
www.ukdigitalradio.co.uk (Digital One)

Regional/local DAB
www.capitalradiogroup.com
www.thedigitalradiogroup.co.uk
www.mxrdigital.co.uk
www.now-digital.co.uk (GWR)
www.oneradiodab.co.uk
www.scoredigital.co.uk

DAB licensing
www.radioauthority.org/radio-stations/digital

DAB stations available
www.drdb.org/stations.html
www.wohnort.demon.co.uk/DAB

DAB information
www.digitalradiotech.co.uk
www.rab-eye.co.uk
www.radio-now.co.uk
www.ukradio.com

Alternative DAB software
www.dabbar.co.uk
www.uk-dab.info/downloads.html

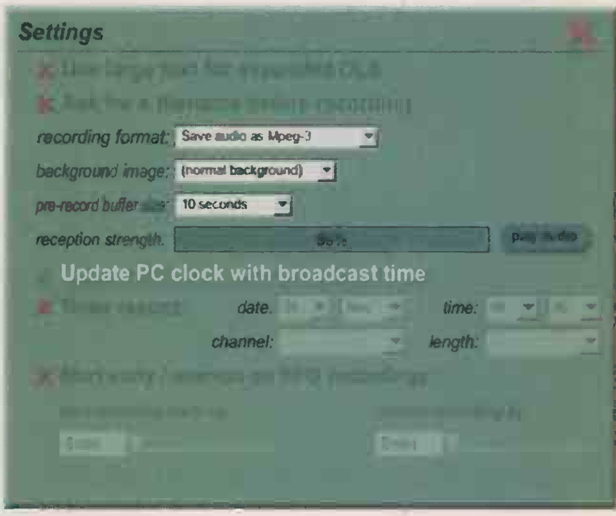


Figure 12: Pressing the 'spanner' icon on the main DAB screen displays this options page

requires about 1Mbyte of disk space per minute, but less for lower bit rate stations and the audio is stored in MP2 or MP3 format.

PCI card installation

My AMD Athlon 1.6GHz computer was opened up and the DAB tuner plugged into a spare PCI slot and the aerial connected. The computer was switched on and the Windows XP Home operating system, as expected, displayed the 'found new hardware' message on the task bar. The XP drivers where then installed from the supplied CD without any problems.

After a PC reset, the application software was installed from CD by a double mouse click on the CD drive icon. During installation the only user intervention required was to confirm which frequency range the receiver should tune. Scanning the UK DAB channel frequencies was the default option. However channel 11A (216.928MHz) is included in the scan, which is not, as far as I know, designated for DAB broadcasts in the UK. This is hardly serious as the file that contains the frequency information is a text file and can be edited.

DAB scan

Running the DAB software for the first time, the message 'there are currently no known channels to show - please click the 'scan' button ....'. A scan only takes around two minutes to complete and shows which multiplex frequency is being scanned.

The first scan produced a '.... failed to find any services – check antenna and try again' message, which was rather disappointing. I checked the connections and moved the aerial to a different location. Clicking the scan icon again produced the same result. Moved the aerial again and on my third scan attempt produced only the Digital1 Network multiplex.

Clicking the 'setting and preference' icon showed the signal strength at 0% and the led signal indicator on the radio station icons was red. Now I could re-position the aerial to find a better signal and watch the signal strength gauge move higher. Re-scanning found BBC National DAB multiplex, Digital1 Network multiplex and CE London multiplex.

I found that the position of the co-ax lead also had a significant influence on the signal strength. Eventually the best position for the aerial was found with the co-ax coiled up so that a minimum of cable was lying on the floor and the monopole placed on the window sill.

Different aerial and co-ax positions were tried and another scan found in addition the DRg and Switch multiplexes (London). A compromise on aerial position has to be achieved to find the best overall result as some positions favoured one multiplex over another. While DAB has been designed to be robust, a minimum signal strength is still required. An indoor aerial will not be as good as an aerial mounted externally.

All this confirms what the various coverage maps and web sites had indicated, basically that there is no local or regional multiplex for my area (Aylesbury, Bucks). The two national DAB multiplexes are available from the local Oxford transmitter and I am on the very edge of the London multiplexes, with CE London the strongest London multiplex signal. The DRg London multiplex is impossible to receive reliably.

The 'signal strength' percentage gauge changes all the time, it is more likely to be a combination of signal strength and the decoder calculating received bit errors. Listening to the Digital1 Network multiplex, the percentage constantly changes from 59% to 99%. Perhaps signal quality would be more appropriate label for this gauge.

More choice

Receiving these five DAB multiplexes produces over 50 radio stations and eight data services. When the cursor moves over a radio station icon, that icon opens up with the top showing the type of programme being transmitted (same as RDS on VHF-FM) and above that a volume control for each station. There is also a master volume control (wave), existing audio settings are not changed.

Next to each station is a green triangle that changes to a square when that station is selected and the red circle for recording to hard disk (in MP2 or MP3 format). The six 'LEDs' show the multiplex signal strength and any text transmitted by the radio station is also displayed. If the station is from the BBC multiplex then EPG information will automatically appear.

DAB v FM comparison

I have used for some time a VHF-FM GemTek Wizard Radio, cost £20. This radio device has a 25-pin serial connector that is plugged into one of the PC's serial ports via a serial cable and is controlled by the computer.

Audio from the GemTek radio is plugged into the line-input on my Soundblaster Live! sound card. Attached to the soundcard are two mains-powered Goodmans desktop loudspeakers with built-in amplifiers. The aerial is a ribbon wire dipole.

In terms of audio quality comparison there is little to choose between FM and DAB. The only audible difference is that there is no background hiss on DAB, unlike some of the more distant London FM stations.

Using the GemTek PC radio the following local stations are available on VHF-FM but not DAB. BBC local radio stations - Radio Oxford, Three Counties Radio, and my local commercial stations - Mix 96, Fox-FM, Chiltern FM. So I will not be removing my serial radio just yet, but I do feel that the days of national radio networks on VHF-FM are numbered.

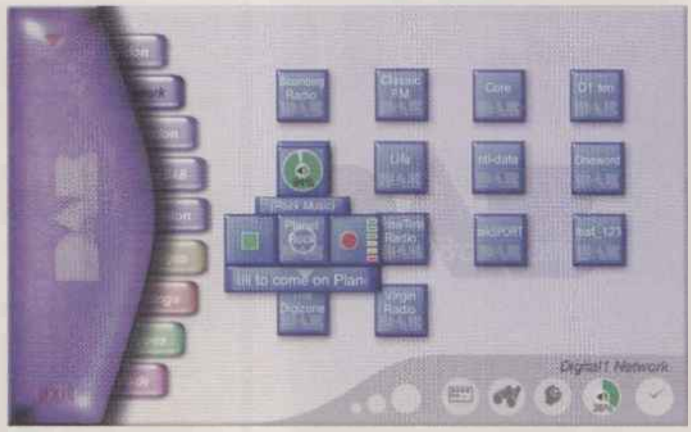


Figure 13: DAB stations on the Digital1 Network multiplex – listening to Planet Rock

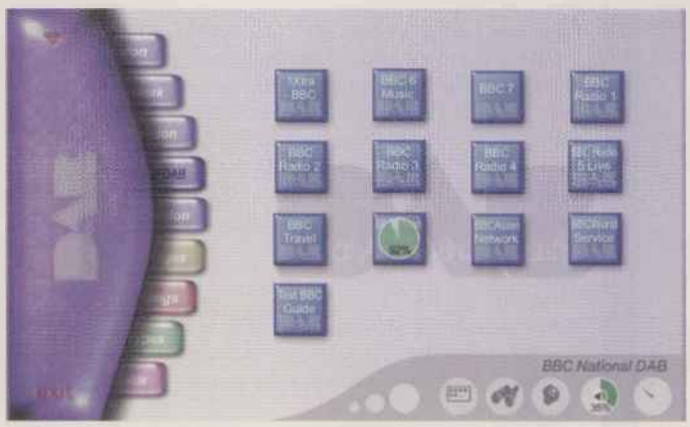


Figure 14: showing BBC National DAB multiplex and progress of downloading the BBC Vision Radio web site

Money well spent?

Overall I am pleased with the performance of the DAB radio. At present the cost of this DAB PCI tuner is £99.99. Competition will help to bring prices down as many companies have a stated aim of producing low cost DAB tuners and radios.

Personally, I prefer the software approach as an alternative to a normal radio. Using a PC gives access to all the multi-media features of DAB that none of the current generation of stand-alone radios can match.

The Windows software has a solid feel with sensible use of animation when features are selected. There were no problems encountered and the software was reasonably intuitive and easy to use. There is comprehensive help obtainable by left-click on the large DAB text. I would have liked to see more technical information provided for each multiplex, e.g. bit rate, mode, etc. This information has already been decoded by the software so should be easily available. Also an option to select an individual multiplex so that a good position for the indoor aerial could be found before the need to scan the whole band, rather than the serendipity approach for the initial scan. There is no provision to 'add channels' as each scan deletes all multiplex information. If the aerial is moved to a worse position then information on previously found multiplexes is lost. ■

Want to win it? Simply send us the answer to the question, "across how many carriers is the signal spread in each ensemble?" on a postcard together with your name and address and your entry will go into the hat. Address the postcard to Electronics World, Highbury Business Communications, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ. Please read the competition rules first though.

This competition is sponsored by **Modular Technology Ltd.,** the makers of the DAB PCI card. More information can be found on the product in Roger Thomas' review on page 12 of this issue and also Modular's web site at www.modulartech.com.

Win DAB digital radio

Competition rules

No purchase is necessary. Strictly one entry per household. Competition closing date 12th April 2003. No entries will be accepted after that date. The draw will take place within the next working week following the 12th April and the winner will be announced as soon as possible thereafter. The prize is not negotiable. No correspondence will entered into regarding this competition. No employee of Highbury Business Communications or Modular Technology Ltd. may enter the competition.

What is DAB

Until now, analogue radio signals such as FM or MW have been subject to numerous kinds of interference on their way from the transmitter to your radio. These problems were caused by mountains, high-rise buildings and weather conditions. DAB, however, uses these effects as reflectors creating multipath reception conditions to optimise receiver sensitivity. Since DAB always selects the strongest regional transmitter automatically, you'll always be at the focal point of incoming radio signals. The DAB system was developed by the Eureka 147 Project.

How do I get it?

DAB is broadcast on terrestrial networks, and you are able to receive it using solely a tiny non-directional stub antenna. You receive CD-like quality radio programmes even in the car without any annoying interference and signal distortion.

Aside from distortion-free reception and CD Quality sound, DAB offers further advantages as it has been designed for the multimedia age. DAB can carry not only audio, but also text, pictures, data and even videos - all on your radio!

You are able to listen to your favourite music programme and sing along with your idols, since the lyrics can be shown on your radio display, or you can contemplate the handsome face of the latest movie star, while a report is given on his current box-office hit.

Can I get it?

Over 285 million people around the world can now receive more than 585 different DAB services. Commercial DAB receivers have now been on the market since summer 1998. Furthermore, as well as all European countries, other non-European countries including Canada, Singapore, Taiwan and Australia have launched operational or pilot services. Countries like China and India have begun experimental services and Mexico and Paraguay among other countries have expressed their advanced interest in DAB.

DAB is available in the following countries: Australia, Austria, Belgium, Brunei, Canada, China, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hong Kong, Hungary, India, Ireland, Israel, Italy, Japan, Lithuania, Malaysia, Mexico, Namibia, Netherlands, Norway, Poland, Portugal, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, United Kingdom, USA.

Modular Technology DAB PCI card features

The Modular Technology DAB digital radio card fits into a PCI slot in a PC's mother board and the supplied driver works with Windows-98, Me, 2000 & XP.

The user interface provides full programme information on screen, displays text associated with programmes, allows recording at the click of a mouse, and gives users the ability to schedule recordings ahead of time from programme lists. Recordings can be stored as MPEG-2 files, or in MP3 format for high quality sound downloads to MP3 players.

Features include:

- Automatic service and programme seeking
- High quality distortion free reception
- Text displayed with programmes
- Recording at the click of a mouse

Apart from just listening to the radio, here are some other things you can do with the Modular Technology DAB PCI card...

- Look at the schedule for every station for the week ahead and select any programmes to be recorded (broadcaster's EPG permitting).
- E-mail a programme presenter at the click of a mouse.
- Download recorded programmes to most portable MP3 players for 'listening on the move'.
- Easily link to the web site of the station you're listening to.
- Show all radio stations broadcasting a particular genre e.g. Sport, News etc.
- Playback high quality recordings made on the PC.
- Set your PC's clock from the accurate signal broadcast as part of the DAB transmission.
- DAB is received through an antenna, it needs no connection to the internet.
- DAB is FREE just like AM/FM radio – there are no subscriptions or sign-ups

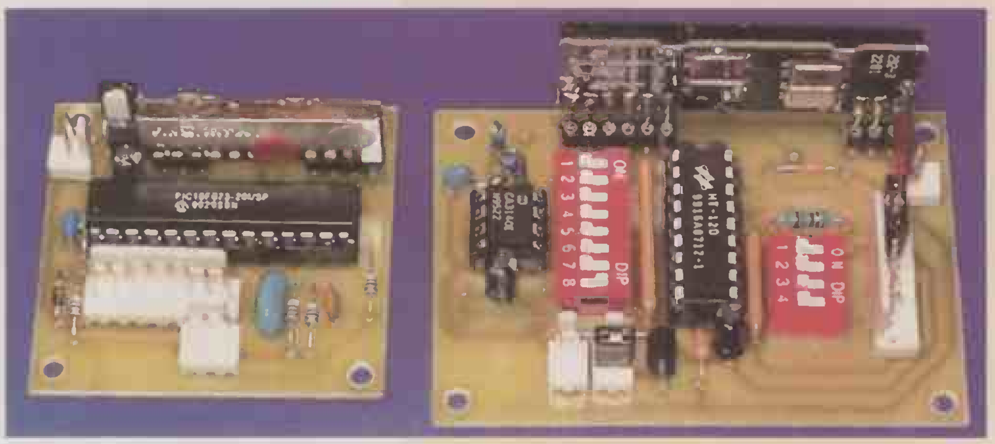
DAB content (music speech etc) is usually augmented by the broadcaster to include text information. This allows a receiver for example to display the current track and artists' name, or the presenter's e-mail address etc.

Minimum PC specification

Pentium-200MMX, 64Mb RAM, Spare PCI slot, antenna connection

Modular Technology Ltd designs manufactures and distributes Communications, Audio, Video and entertainment products, most of them for use with Personal Computers; selling through major retailers and OEMs in the UK and North America. Products are sold under the Modular Technology brand or in OEM livery as required. The company has extensive experience of selling Television and Radio products for PCs and their new DAB digital radio card gives users a glimpse of what they can expect from radio receivers in the future.

Long-range computer radio remote control



In this article, Pei An describes a PC-based remote control system using 173.250MHz license-exempt VHF radio linkers. A unique feature of the system is that its operation range is 500 metres in built-up areas and several kilometres in open ground.

A remote control system may consist of one transmitter and up to 1024 receivers. The transmitter is plugged into a standard RS232 port of a desktop or a laptop computer and is controlled by a program running on the PC. Each receiver can be configured into two modes. In the first mode, the receiver has an address of 8 bits (256 address combinations) with 4 digital output lines. In the other mode, the receiver has 12 bit address (1024 address combinations) with no digital output lines. In both cases, there is a digital line that pulses high to indicate a successful reception

Designed as building blocks, the system can be easily implemented into a digital system requiring a remote control capability.

Principle

The transmitter is built on a PIC micro-controller. The micro-controller receives data from a RS232 port of a PC and converts it into a serial data stream, the format of which is identical to that produced by a Holtek HT-12E encoder. The serial data is fed into a Radiometrix TX1 VHF radio transmitter that broadcasts the data to the surroundings via an antenna.

Inside the receiver, a Radiometrix RX1 VHF radio receiver demodulates the radio signal picked up by the antenna. The demodulated data is fed into a decoder (Holtek HT-12D or HT-12F). Inside the decoder, some data bits are treated as address bits and others as data bits. The decoder checks if the received address matches the pre-set address. If the two addresses match, data bits are latched to the output pins.

Radio linkers

The pin-outs of the TX1/RX1 radio linkers are shown in **Figure 1**. TX1 and RX1 are miniature 173.250MHz VHF radio transmitters and receivers that are suitable for extended range data link at a data rate up to 10kb/s[1]. A range of 10km can be achieved in open ground with a suitable data rate and antennae. They are type-approved to the EN300 220-1 for use at 173.250MHz in the UK and fully screened with extensive internal filtering to ensure EMC compliance to ETS 300 683. Other frequencies are available from the manufacture[1].

TX1 operates with a 2.2V to 10V supply at 9.5 mA. RX1 operates with a 2.7V to 10V supply at 12 mA. Both modules have a 'Disable' facility. By disabling the module, the current consumption can be reduced to less than 1μA. This feature is particularly useful for low-power portable or solar-powered applications.

Two types of antennas can be used with the TX1 and RX1 modules: the internal and external types. The internal antennas are small in size and suitable for portable applications. There are three versions: helical type, loop type and whip type (**Figure 2**).

External antennas are used for long-range links (**Ref** 2). They can be optimised for individual circumstances and may be mounted in good RF locations away from sources of interference. A 50 Ohm coax feeder can be used to connect the antenna to the module. The following types can be used: helical quarter-wave whip, half-wave whip and Yagi. The half-wave antenna is effective and is recommended where long range and all-round coverage are required. The Yagi is directional and exhibits gain. It is the ideal choice for links over fixed paths where maximum range is desired. In the UK, the Yagi can only be used with RX1. A good discussion of the use of antennae can be found in Reference 1.

Link range

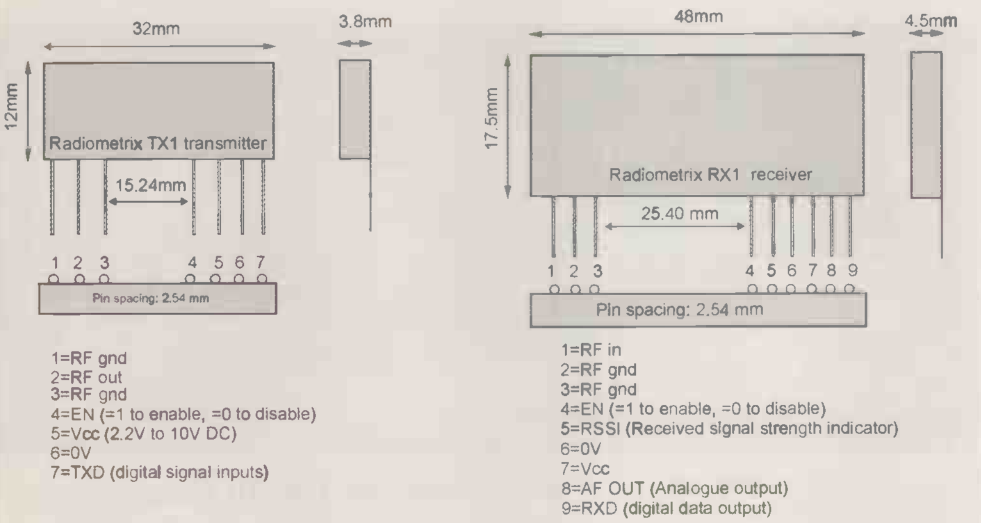
The modulation bandwidth @ -3dB for the TX1 is from 0 to 7kHz. This means that a square wave of 50:50

duty cycle up to 7kHz can be transmitted successfully by the TX1 module. The -3dB base band bandwidth for digital data reception of RX1 at pin RXD (pin 9) is 50Hz to 6kHz. The time between data transition varies from 0.1ms to 1.8ms. Any digital data that satisfies this timing requirement shall be received and output from the RXD line of the RX1 module.

The link range depends on data transfer rates and the type of antenna used. Th table shown left gives some examples. Range tests should be performed to establish the actual link range.

In most long-range applications, the data transfer rate is not of prime concern. For the digital data output line (RXD), the time between data transition should be between 0.1ms to 1.8ms, therefore, low frequency digital data can not be produced from the line. In this case, the analogue output (AF output) can be used. An external customised data slicer can be used to convert the analogue signal into digital data.

Data rate	TX antenna	RX antenna	Environment	Range
1.2kb/s	Half-wave	Half-wave	Rural/open	10 – 15km
10kb/s	Half-wave	Half-wave	Rural/open	3 – 4km
10kb/s	Helical	Half-wave	Urban/obstructed	500m -1km
10kb/s	Helical	Helical	In-building	100m – 200m



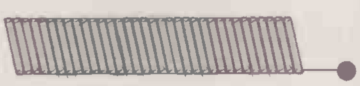
TX1 and RX1 are a licence-exempt miniature 173.250MHz VHF radio transmitter and receiver pair suitable for long-range data links. Link range of 10km is achievable with choice of data rate and antenna. They are completely screened with internal filtering to meet EMC requirements. Other frequency versions are available from the manufacturer.

Encoders and decoders

The HT-12E (Holtek) converts 12 data bits (0 or 1) into a serial data stream. In this stream, bit 0 or 1 is encoded in the manner as shown in **Figure 3.** Each transmission burst consists of a pilot period (12-bit length), a start marker (1/3 bit length) and 12 bits of data. A complete transmission takes 73 clock periods. The HT-12E transmits at least 4 bursts after it is activated.

A real example of the waveform of the burst is shown in **Figure 4** (note: oscillation frequency is about 3.2kHz). The address and data bytes are 254 decimal and 14 decimal respectively. Instead of using the encoder to produce such a data stream, a micro-controller can be programmed to reproduce it. Using micro-controllers, may more functions can be added to it. HT-12D and HT12F (see **Figure 5**) are decoders and are in pair with the HT-12E. The HT-12D has 8 address bits and 4 data bits. HT-12F has 12 address bits. For

Three types of internal antennas can be constructed and used with the TX1 and RX1 module. They are helical type, loop type and whip type.



35-40 turns wire spring. Length 120mm diameter 10mm. Trim length or expand coil for best results

a, Helical type

Wire, rod PCB track or combination

410mm @ 173 MHz

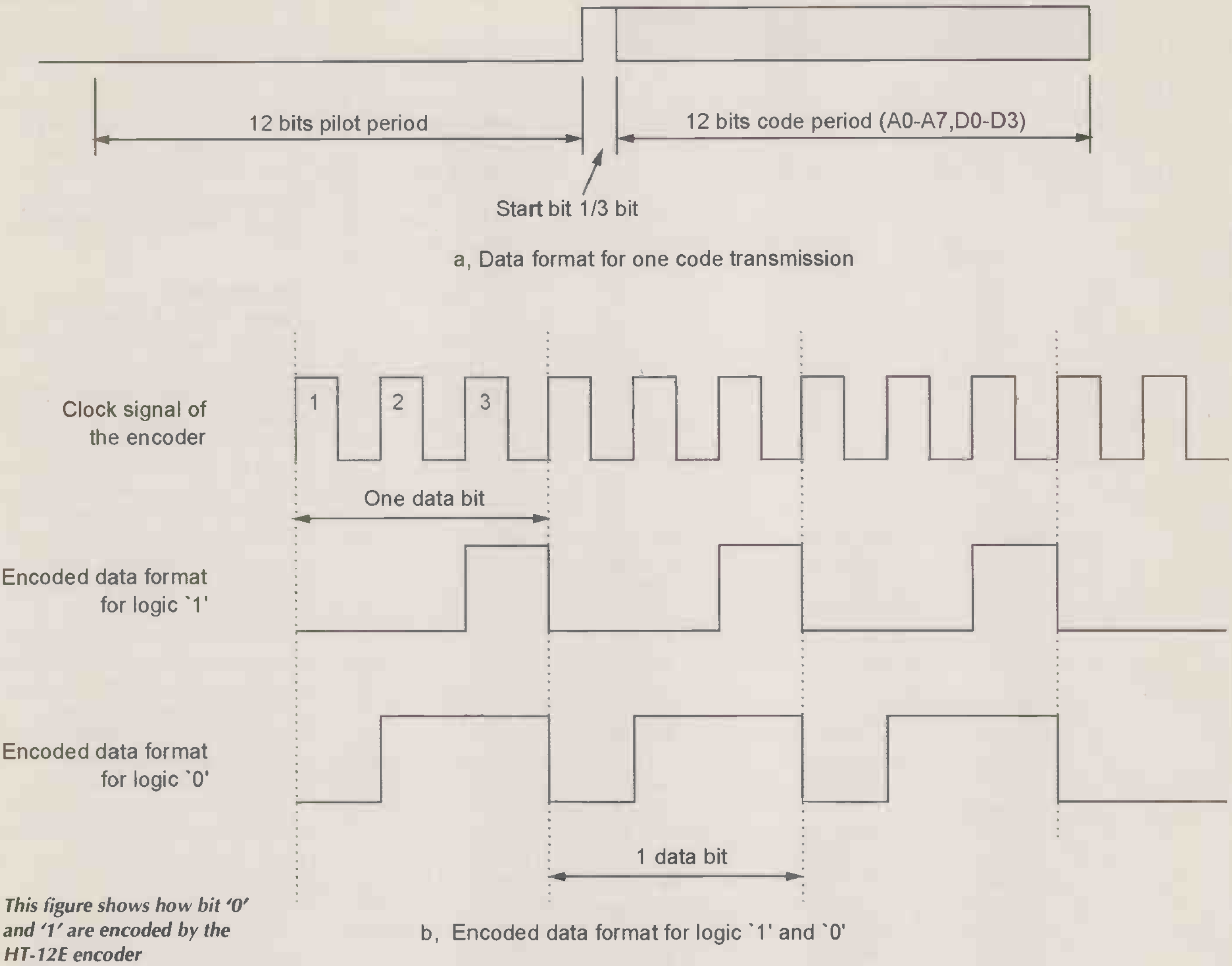
c, Whip type

1mm wide track

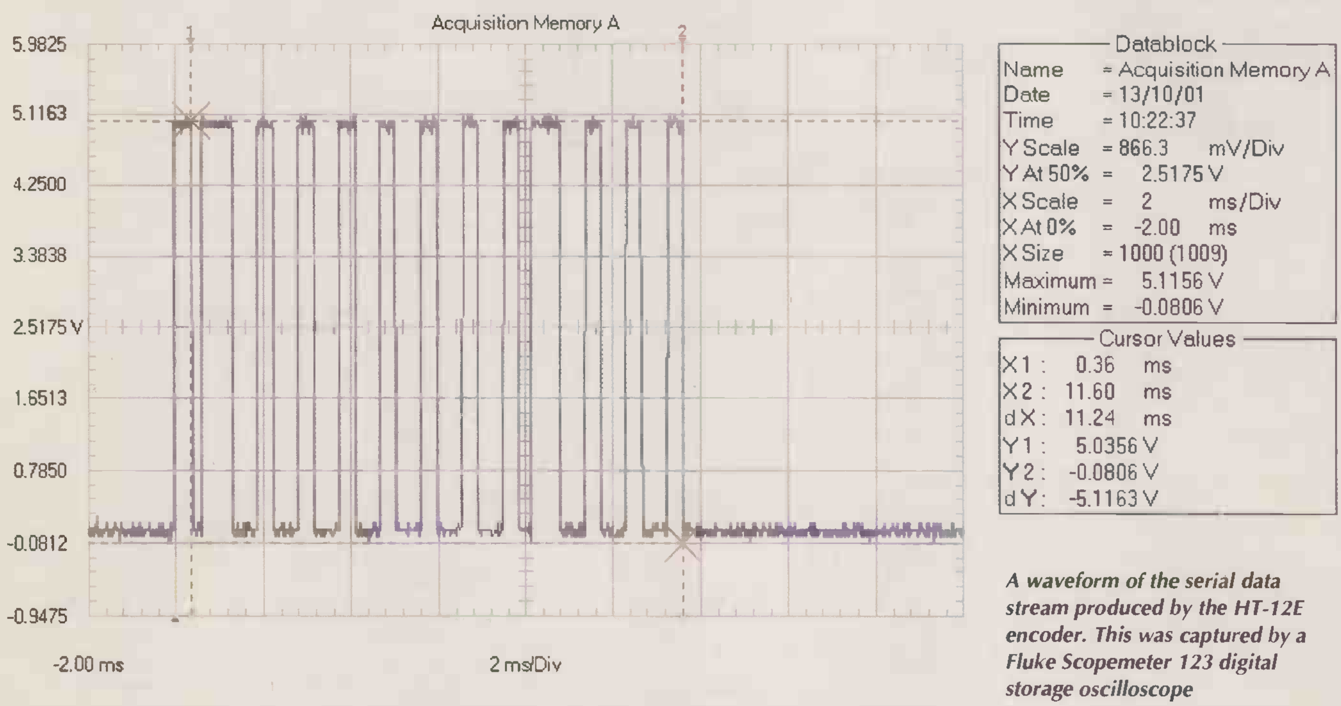
Capacitor 1.5 - 5 pf

b, Loop type

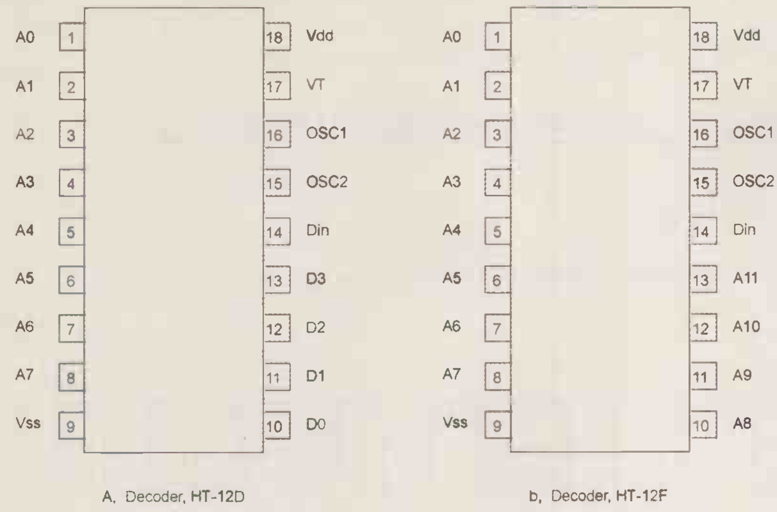
Antenna performance chart	Helical	Loop	Whip
Ultimate performance	√√	√	√√√
Ease of set-up	√√	√	√√√
Size	√√√	√√	√
Immunity to proximity de-tuning	√	√√√	√√



This figure shows how bit '0' and '1' are encoded by the HT-12E encoder



A waveform of the serial data stream produced by the HT-12E encoder. This was captured by a Fluke Scopemeter 123 digital storage oscilloscope



HT-12D and HT-12F. The HT-12D has 8 address inputs and 4 digital outputs. The HT-12F has 12 address inputs with no digital outputs. For both ICs, the Valid Transmission (VT) pin goes high after a transmission is received successfully.

both ICs, the VT pin (Valid Transmission) goes high after a valid transmission is received. An oscillation resistor shall be chosen to suit the frequency of the signal produced by the encoder (**Ref** 3).

The transmitter

Figure 6 shows the circuit diagram of the transmitter. It is built on a PIC16F873 micro-controller. The transmitter is connected to the RS232 port of a PC using three wires (TX, RTS and GND). The RTS line is used to reset the PIC. The computer sends RS232 data out via the TX line. The PIC receives the RS232 data and produces a serial data stream, which is identical to that produced by a HT-12E running at 3kHz. This stream is fed into the TX1 module.An antenna is connected to the TX1's RF output.The RS232 data format is fixed as 9600 Baud, 8 data bits, 1 stop bit with no parity check bit. To enable the controller to transmit data, firstly the computer issues a reset to the PIC by pulling the RTS line low for 100ms.

The computer then sends four bytes to the PIC. The 1st byte is the address byte (A1 to A8). The second byte is data byte (D1 to D4 for HT-12D or A9 toA12 for HT-12F). The 3rd byte tells the PIC the number of bursts to be transmitted (minimum value is 4). The final byte determines if the data transmission is single-shot or continuous. If the byte is set to zero, the PIC only produces one transmission. If the byte is not zero, the PIC will transmit intermittently and continuously. The interval between two successive transmissions is determined by the value of this byte (from 1 to 255 seconds). In this mode, the transmitter becomes a standalone device that transmits signals automatically at the pre-set rate.

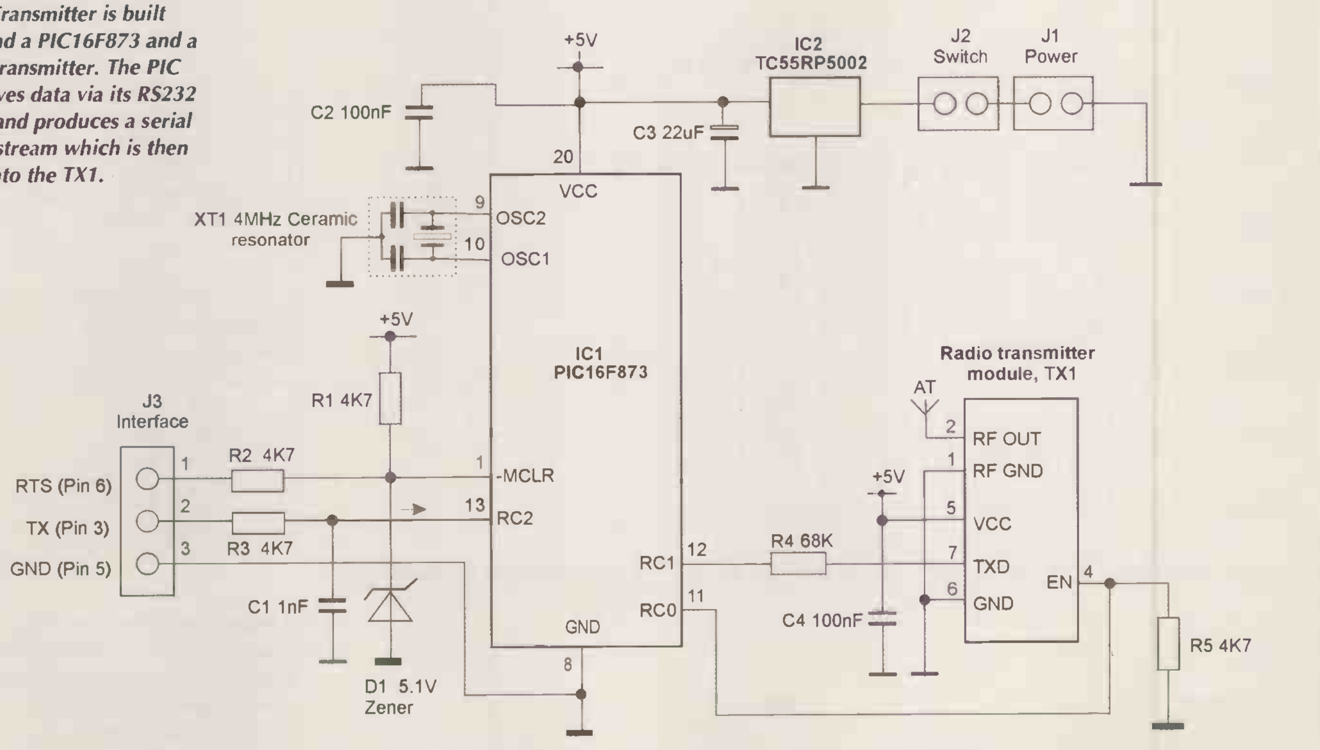
The receivers

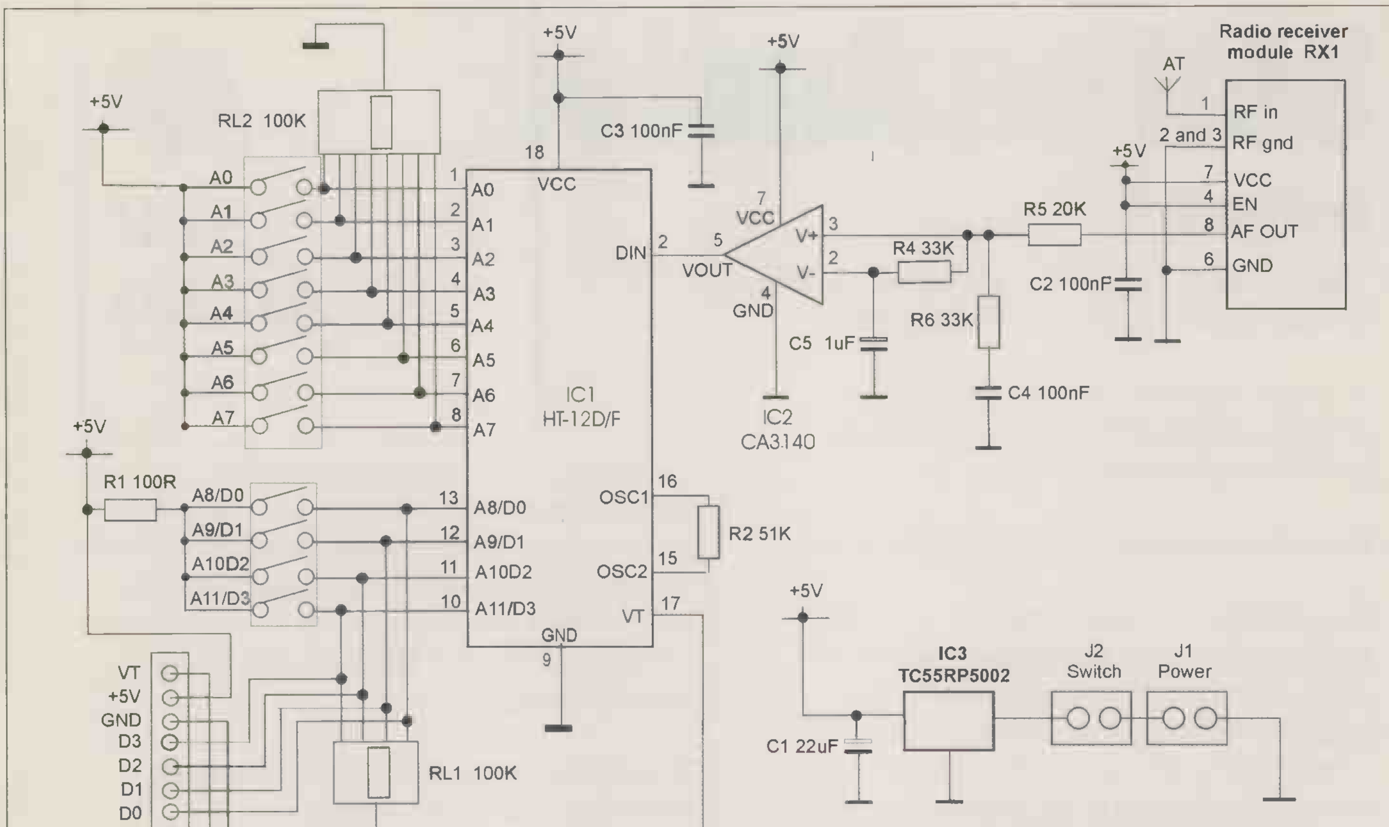
Figure 7 gives the circuit of a receiver. The RX1 demodulates radio signal into an analogue signal appearing at Pin 8 (AF out). This signal passes through a filter (R5, R6 and C4). The signal is fed into a CA3140 op-amp configured as a data slicer. From the op-amp, a digital data stream is produced, which is then fed into a HT-12D or HT-12F decoder. The frequency of the on-board oscillator is set at 150kHz as suggested by the datasheet.

HT-12D checks the received data (12 bits) three times. All the received data should be identical, otherwise the HT-12D ignores this data reception. If the 8-bit address matches the pre-set address, the 4 data bits are latched to its outputs. HT-12F checks if the received data (12 bits) matches its pre-set address (again 12 bits). For both ICs, VT goes high after a valid transmission is received.

All outputs are CMOS compatible and can source 1.6mA. To drive loads with high voltages at higher current, opto-isolated solid-state relays can be

The Transmitter is built around a PIC16F873 and a TX1 transmitter. The PIC receives data via its RS232 port and produces a serial data stream which is then fed into the TX1.





The receiver has a RX1 receiver, a data slicer built around a CA3140 and a HT-12D/F decoder. The local address is set by 8 (or 12) dip switches, SW1 and SW2.

used. Matsushita AQZ20* series PhotoMOS relays **(Ref 4)** are particularly suitable for this application. They are housed in a compact 4-pin 21×3.5×12.5mm SIL package. A current as small as 1mA is required to switch on the relays. The AQZ202 is capable of controlling a DC/AC voltage up to 40V at 3A. On-resistance is only 0.066 Ohm. The AQZ204 is capable of controlling a DC/AC voltage up to 400V at 0.5A. Transistor-type drivers or relay drivers can be also used with the receiver board.

Software for PIC and PC

The PIC software is developed in PIC Basic Pro compiler (List 1). The PC software is written in VB 6 (List 2), see box right. The screens of the VB6 program are shown in **Figure 8** and **Figure 9.**

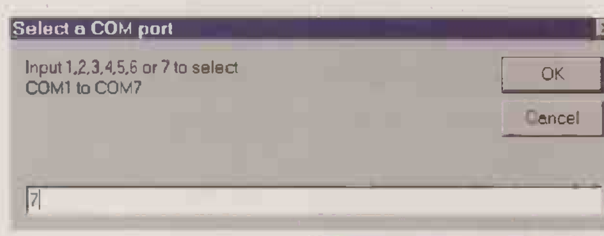
After starting the program 'TX1HT12', a screen shown in **Figure 8** appears. It asks the user to input the number of the COM port to be used. After clicking OK, the main screen appears **(Figure 9)**. In the Transmit pane, users should input the following parameters.

Address: Address of the receiver A1 to A8

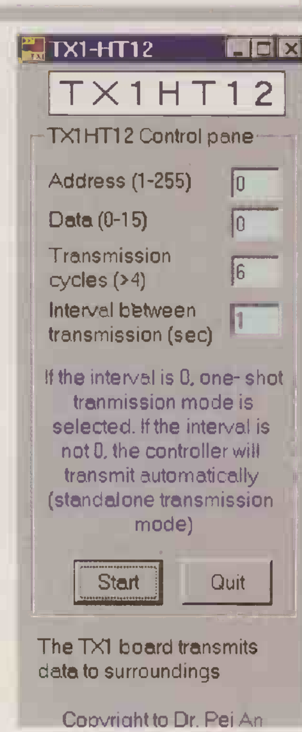
Data: Data byte if the receiver is HT-12D. Input A9 to A12 if the receiver is HT-12F

Transmission Cycles (>4): Number of words to be transmitted. The minimum value is 4

Interval between transmissions (>1): Delay seconds between two transmissions. If the value is zero, only one transmission is carried out (this is the one-shot mode). If the value is not zero, the controller transmits data intermittently (this is the standalone transmission mode). In this mode, the computer can be disconnected from transmitter. ■



The screen for users to input the number of the COM port to be used with this device. Input 1,2,3 or 4 to select COM1, COM2, COM3 or COM4.



The main screen of the software allows users to control the radio controller

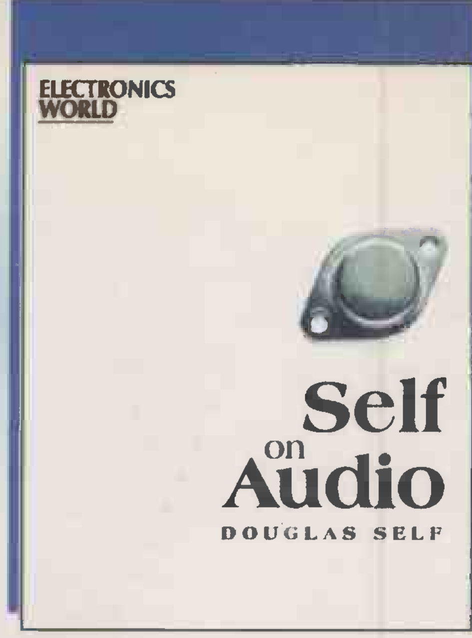
References

1. Datasheets for radio linkers are available from Radiometrix Ltd. Web site: www.radiometrix.com
2. Datasheets for external antennas: www.badland.co.uk
3. Data sheets for encoder/decoders are available from Holtek. Web site: www.holtek.com.tw
4. Datasheet for opto-isolated solid state relays are available from http://www.aromat.com/photomos.pdf

Lists of the PIC software can be obtained from
Jackie Lowe, Highbury Business Communications,
Anne Boleyn House, 9-13 Eweel Road, Cheam, Surrey SM3 8BZ

Self on Audio

Douglas Self



The cream of 20 years of Electronics World articles (focusing on recent material)

A unique collection of design insights and projects - essential for all audio designers, amateur and professional alike.

Scientific electronics based on empirical data

Douglas Self has been writing for Electronics World and Wireless World over the past 20 years, offering cutting-edge insights into scientific methods of electronics design.

This book is a collection of the essential Electronics World articles, covering twenty years of amplifier technology but with a very strong bias towards more recent material. The articles include self-build projects as well as design ideas and guidance for the professional audio designer. The result is a unique collection of design insights and projects - essential for all audio designers, whether amateur or professional.

Contents: Introduction; PRE-AMPLIFIERS: An advanced preamplifier MRPI; High-performance preamp MRP4; Precision preamp MRP10; Moving-coil head amp; Preamp '96 I; Preamp '96 II; "Overload Matters" (RIAA overload); Balanced line inputs and outputs, part 1; Balanced line inputs and outputs, part 2; POWER AMPLIFIERS: FETs less linear than BJTs; Distortion in power amplifiers 1-8; Distortion residuals; Trimodal part 1, 2; Load-invariant power amp INVAR.DOC; Common-emitter amps; Two-stage amplifiers; SPEAKERS: Excess speaker currents; Class distinction (amp classification); Relay control; Power partition diagrams; Audio power analysis.

Douglas Self has dedicated himself to demystifying amplifier design and establishing empirical design techniques based on electronic design principles and experimental data. His rigorous and thoroughly practical approach has established him as a leading authority on amplifier design.

Readership: Audio electronics enthusiasts; Professional amplifier designers; Power amp users

Paperback

Pages: 416pp

UK Price: £27.50 Europe £28.50 ROW £30.00

Return to Jackie Lowe, Highbury Business Communications Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey, SM3 8BZ

Please supply the following title:

SELF ON AUDIO

Total________

Name

Address

Postcode

Telephone

Method of payment *(please circle)*

Mastercard/Visa/Cheque/PO

Cheques should be made payable to Electronics World

Credit card no________________

Card expiry date

Signed

NEWPRODUCTS

Please quote *Electronics World* when seeking further information

Tackling "dull" green displays

The 'Cool Blue' range of STN modules from Tribox is being offered as an alternative to what the company calls "dull green or grey displays". Modules are available in all the industry standard packages and the supplier offers technical support,

design assistance and programming should this be required. The displays use STN glass with white LED backlighting. In reverse mode blue on white is also possible.
Tribox
Tel: +44(0) 1635 33209

LCD drivers aim for compact design

Three LCD driver ICs from Rohm are designed to reduce the component count of segment-type LCD displays in applications such as car audio systems, telephones, point of sale (POS) systems, multimedia terminals and home appliances. All of the ICs incorporate on-chip LCD driver voltages to minimise the need for external circuitry. The BU9728AKV 128-output and BU9735K 72-output segment drivers are designed to operate with a supply voltage of between 2.5V and 5.5V, and a duty cycle of 1/4. Operating from a 4.5 to 5.5V supply, the BU9716BKV is a 96-output segment driver with a duty cycle of 1/3 and a programmable bias of either 1/2 or 1/3. The BU9728AKV offers 32 segment outputs and four common outputs while the BU9735K provides 18 segment outputs and four common outputs. All devices incorporate a serial interface for direct connection to a host microcontroller.
Rohm
Tel: +44(0) 1908 282666
www.rohm.co.uk

Current-sense amplifier takes 76V

Maxim's latest high-side current-sense amplifiers handle voltages up to 76V and will monitor currents in automotive, telecoms, backplane high-voltage applications. The MAX4080 measures current flowing in one direction. The bi-directional MAX4081 measures charge and discharge currents, making it suitable for use with new 42V automobile batteries.
Maxim
Tel: +44(0) 118 9303388
www.maxim-ic.co.uk

FPGA design tool for big chips

Synplicity has enhanced its Synplify Pro FPGA synthesis software to further address the challenge of high complexity programmable logic devices (PLDs). As FPGA vendors incorporate more functionality and capacity onto a single device, the software tool supplier has extended its MultiPoint technology, including its difference-based incremental design methodology, to its Synplify Pro software, delivering scalable synthesis for current and emerging designs. In addition, it has added interactive timing analysis capabilities to allow designers to analyse critical paths in a design without re-synthesis.
Synplicity
Tel: +44(0) 1344 397212
www.synplicity.com

Reverse polarity SMA connectors for antennas

Vitelec Electronics has introduced a range of reverse polarity SMA and MCX connectors designed to provide a

matched connection between a GPS antenna and a system board. The SMA's are reverse threaded to prevent connection with standard connectors. Also available are snap-in, reverse polarity MCX connectors which employ female contacts in the plug connector, with male contacts in the jack connector. The SMA and MCX reverse polarity ranges are available in a variety of plug and jack formats, with connector bodies plated in gold or nickel, and central female contact designed in beryllium copper.
Vitelec Electronics
Tel: +44(0) 1420 488661
www.vitelec.co.uk

Chip switches 320,000 voice/data calls

Agere Systems is offering its fastest telecoms switching chip for wireless Internet data, video streaming files, and other types of communications signals through network systems. It switches voice, data, and video signals at an aggregated switching speed of 80Gbit/s. An aggregated speed of 80Gbit/s supports a minimum of 40Gbit/s of speed and bandwidth for current and future applications by users of switched voice, data, and video services. This means it will simultaneously switch 320,000 voice and data calls. It integrates multiple serdes (serialiser/deserialiser) input/output interconnect sub-circuits that can transmit data into and out of the chip at up to 2.5Gbit/s for each of the 32 serdes sub-circuit links to the chip. It uses a transmission standard encoding scheme that the supplier claimed is 20 per

Point of load converters use fixed frequency

Artesyn Technologies has launched three families of single-output, non-isolated point-of-load converters. Known as the SIL06, SIL15 and SIL30 series, these DC-DC converters are based on an open-frame single-board construction and use fixed-frequency switching technology. All three families are intended for through-hole board mounting. The SIL06 series is the smallest and can handle output currents up to 6A. The horizontal mounting version measures just 1.2 x 0.61in. (30.5 x 15.5mm), and has an above-board height of 0.53 in. (13.4mm). The 5V input model has a typical conversion efficiency of 89 per cent and provides an output that is trimmable from 0.9V to 3.3V. The 12V input model offers even higher conversion efficiency - typically 91 per cent - and an exceptionally wide output trim range,

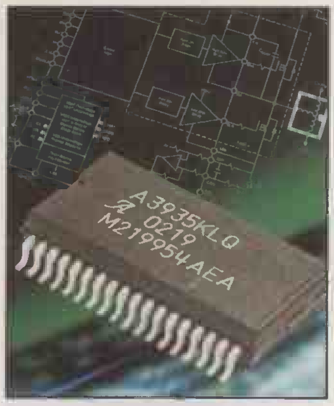
spanning 0.9V to 5.0V.
Artesyn Technologies
Tel: +44(0) 0353 242 5388
www.artesyn.com

Please quote *Electronics World* when seeking further information

cent more efficient than 8Bit/10Bit line encoding schemes used by other chips.
Agere
Tel: +44(0) 1344 296400
www.agere.com/micro

Demodulator for free-to-air DTV designs

Zarlink Semiconductor has added to its RF chips for the expanding terrestrial DTV market with the MT352 demodulator that allows terrestrial DTV signals to be received through existing analogue TV aerials. The demodulator incorporates COFDM technology which is designed to boost performance in the presence of low signal-to-noise ratios, and thus enhance reception while providing broadcasters with wider coverage. It also incorporates an active impulse noise filter that suppresses or blocks the disturbing effects of short and strong impulsive noise interference caused by domestic electrical devices, and even car traffic. It has an on-chip control engine that reduces the software overhead needed for automatic channel scan and acquisition. Power dissipation is 220mW.
Zarlink
Tel: +44(0) 1793 518128
www.zarlink.com



Mosfet controller has six outputs

A power Mosfet controller IC from Allegro MicroSystems is designed specifically for automotive applications involving the control of high-power motors. The A3935 provides six high-current gate-drive outputs capable of driving a range of n-channel Mosfets. Steady operation over a varying battery input range is achieved by an integral pulse-frequency-modulated boost converter which creates a constant supply voltage for driving the external Mosfets. Bootstrap capacitors are used to provide the supply voltage required, which is higher than the normal automotive battery supply. An internal low-dropout regulator is used for the gate-drive supply. Direct control of each gate output is possible via six TTL-compatible inputs. A differential amplifier is integrated to allow accurate measurement of the current in the three-phase bridge. A diagnostic output can be continuously monitored to protect the driver from short-to-battery, short-to-supply, bridge-open, and battery under/overvoltage conditions. Additional protection features include dead time, drive undervoltage, and thermal shut-down. The A3935 is available in the PQCC-44 or SOIC-38 packages, and has an operating temperature range of –40°C to +125°C.
Allegro
Tel: 0033 45051 2359
www.allegro.com

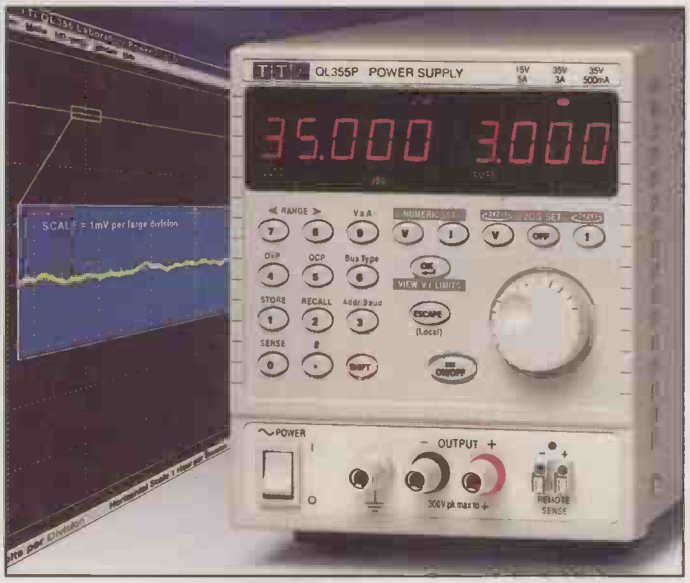
Category 6 cabling connection for Gigabit Ethernet

Tyco/AMP's category 6 cabling system plugs are designed to exceed all performance and component compliance requirements of the recently approved category 6 specification ANSI TIA/EIA 568B.2-1 and the class E requirements of the approved ISO/IEC 11801-2nd edition. To

achieve a mated jack and plug near-end crosstalk of 54dB at 100MHz in the 3,6 - 4,5 pair combination , the category 6 standard requires that the plug exhibit a de-embedded near-end crosstalk range of 36.4 to 37.6dB. The 100MHz frequency is also a benchmark for backwards compatibility with category 5e. To ensure backwards compatibility with 5e components, this mated jack/plug connection must test at 43dB at 100MHz with a de-embedded near-end crosstalk range of 34.4 to 37.6dB.
Tyco/AMP
Tel: +44(0) 800 2671111
www.ampnetconnect.com

Power supply with digital control

Thurlby Thandar has introduced the QL benchtop power supply. Setting resolution is 1mV up to 56V, and setting accuracy is 0.03 per cent. The unit's digital control uses what the supplier calls instrumentation-quality 16-bit D-to-A converters with low-drift, low-noise amplifiers. True linear power regulation is used, yielding output ripple and noise of less than 0.5mV. Single and triple-output modes are available with output from 105 to 215W. It can operate in constant-voltage or constant-current models with automatic crossover. Voltages can be set to 1mV resolution up to maximum output voltage, and currents can be set or measured down to 0.1mA. Switchable ranges on some models provide a maximum current of 3A up to 35V. A second range increases this to 5A, 15V.
Thurlby Thandar
Tel: +44(0) 1480 412451
www.tti-test.com



PICmicro with on chip 10-bit ADC

Microchip's family of PICmicro flash microcontrollers features integrated analogue-to-digital converter, precision internal oscillator, comparator and quick start-up. The PIC16F630 and PIC16F676 microcontrollers, use the firm's PMOS electrically erasable cell process technology for both program memory and on-chip data EEPROM. The 14-pin packaging is similar in size to 8-pin devices and considerably smaller than 18-pin devices. The microcontrollers are code-compatible with Microchip's current PIC12F629 and PIC12F675 8-pin flash devices. The devices offer a typical standby current of 100nA at 2.0V and operating voltage range from 2V to 5.5V. A quick start-up feature of 2μs and the ability to run a timer from an external crystal while in SLEEP mode will be useful in low

/isit our website
www.distel.co.uk

THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

GIANT 10" 7 SEGMENT DISPLAYS

Giant 10" / 254 mm DC driven 7 segment displays

bulk purchase enables us to bring to you these IANT 7 segment digital displays at a now **affordable** rice!! The **10" character size** gives **exceptional** readability at long distances and **enables** a host of applications including, **score** boards, **digital clocks**, coun**ters, event timers** etc. As the units are a simple lectromechanical device and operate from 12 V DC, mple switching via switches, relays, PIC or PC may e used to control single or multiple digits. **Units feature** integral 'Zero Power' memory which greatly simplifies design. For an **excellent DIY practical article**, see the May issue of **'Everyday & Practical Electronics' magazine**. Ideal School / College con**truction project**. Supplied in good RFE condition, complete with data sheet.

Less than 30% of makers price ! **Only £29.95**(B) **or 4 / £99.00**(D)
Order RW44 Order PH26

THE AMAZING TELEBOX

TV SOUND & VIDEO TUNER
*CABLE COMPATIBLE**

Converts your colour monitor into a QUALITY COLOUR TV!!

he **TELEBOX** is an attractive fully cased mains powered unit, containing all lectronics ready to plug into a host of video monitors or AV equipment which re fitted with a composite video or SCART input. The composite video output ill also plug directly into most video recorders, allowing reception of TV **channels not normally receivable on most television receivers*** (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully uneable 'off air' UHF colour television channels. **TELEBOX MB** covers virtully all television frequencies VHF and UHF **including the HYPERBAND** as sed **by most cable TV operators.** Ideal for **desktop computer video sys**ms & PIP (picture in picture) setups. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

ELEBOX ST for composite video input type monitors	£36.95
ELEBOX STL as ST but fitted with integral speaker	£39.50
ELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

For overseas PAL versions state 5.5 or 6 mHz sound specification.
For cable / hyperband signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

NEW State of the art PAL (UK spec) **UHF TV tuner module** with **composite** 1V pp video & **NICAM** hi fi stereo sound outputs. **Micro electronics** all on one small PCB only 73 x 160 x 52 mm enable full tuning control via **a simple 3 wire link** to an IBM pc type computer. Supplied complete with simple working program and documentation. Requires +12V & + 5V DC to operate.
BRAND NEW - Order as MY00. ***Only £39.95*** *code (B)*
See www.distel.co.uk/data_my00.htm for picture + full details

HARD DISK DRIVES 2fi" - 14"

2fi" **TOSHIBA** MK1002MAV 1.1Gb laptop(12.5 mm H) ***New***	£59.95
2fi" **TOSHIBA** MK4313MAT 4.3Gb laptop (8.2 mm H) ***New***	£105.00
2fi" **TOSHIBA** MK6409MAV 6.1Gb laptop (12.7 mm H) ***New***	£98.00
2fi" **TOSHIBA** MK1814GAV 18 Gb laptop (12 mm H) ***New***	£149.95
2fi" to 3fi" conversion kit for Pc's, complete with connectors	£15.95
3fi" **COMPAQ** 313706-B21 (IBM) 9 gb ULT/SCSI3 ***New***	£199.00
3fi" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95
3fi" **CONNER** CP3024 20 mb IDE I/F (or equiv.) RFE	£59.95
3fi" **CONNER** CP3044 40 mb IDE I/F (or equiv.) RFE	£69.00
3fi" **QUANTUM 40S Prodrive** 42mb SCSI I/F, New RFE	£49.00
5" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95
5" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95
5" **CDC** 94205-51 40mb HH MFM **I/F** RFE tested	£69.95
5" **HP 97548** 850 Mb SCSI RFE tested	£99.00
5" **HP C3010** 2 Gbyte SCSI *differential* RFE tested	£195.00
8" **NEC D2246** 85 Mb SMD interface. *New*	£99.00
8" **FUJITSU** M2322K 160Mb SMD I/F RFE tested	£195.00
8" **FUJITSU** M2392K 2 Gb SMD I/F RFE tested	£345.00

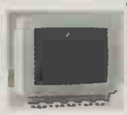
Many other floppy & H drives, IDE, SCSI. ESDI etc from stock, see website for full stock list. Shipping on all drives is code (C)

IC's -TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK
10,000,000 items EX STOCK
For *MAJOR SAVINGS*
CALL or see web site www.distel.co.uk

COMPUTER MONITOR SPECIALS

Legacy products
High spec genuine multysync.
CGA, EGA, VGA, SVGA



Mitsubishi **FA3415ETKL** 14" SVGA Multisync colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in **CGA, EGA, VGA & SVGA** modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE.** Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, in **EXCELLENT** little used condition. **Tilt & Swivel Base £4.75**
VGA cable for IBM PC included. **Only £129** (E) Order as CG73

External cables for other types of computers available - CALL

Generic LOW COST SVGA Monitors

We choose the make, which includes Compaq, Mitsubishi, IBM, etc. Supplied ready to run with all cables, Standard RTB 90 day guarantee.

14"	15"	17"
£59.00	**£69.00**	**£79.00**
order TD84	order TG21	order TJ66

Supplied in good used condition. Shipping code (D)

VIDEO MONITORS

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with <u>both</u> **RGB and standard composite** 15.625 Khz **video inputs via SCART** socket and separate phono jacks. Integral **audio power amp and speaker for all audio visual uses.** Will connect direct to **Amiga and Atari BBC** computers. Ideal for all **video monitoring / security** applications with **direct connection** to most colour cameras. High quality with many features such as front concealed **flap** controls, **VCR** correction button etc. Good used condition - fully tested - guaranteed **Only £99.00** (D)
Dimensions: W14" x H12fi" x 15fi" D.

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite** 15.625 Khz video input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13fi" D. 240 V AC mains powered. **Only £79.00** (D)

INDUSTRIAL COMPUTERS

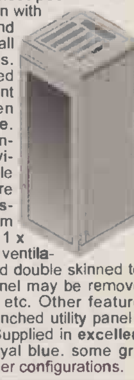
Tiny shoebox sized industrial 40 Mhz 386 PC system measuring only (mm) 266 w X 88 h X 272 d. Ideal for dedicated control applications running DOS, Linux or even Windows ! Steel case contains 85 to 265 V AC 50 / 60 hz 70 Watt PSU, a 3 slot ISA passive backplane and a Rocky 318 (PC104) standard, single board computer with 8 MByte NON VOLATILE solid state 'Disk On Chip' RAMDISK. System comprises: Rocky 318 (PC104) SBC ISA card with 40MHz ALi 386SX CPU, 72 pin SIMM slot with 16 Mbyte SIMM, AMI BIOS, battery backed up real time clock. 2 x 9 pin D 16550 serial ports. EPP/ECP printer port, mini DIN keyboard connector, floppy port, IDE port for hard drives up to 528 MByte capacity, watchdog timer and PC/104 bus socket. The 8 MByte solid state 'disk on a chip' has its own BIOS, and can be fdisked, formatted & booted. Supplied BRAND NEW fully tested and guaranteed. For full data see featured item on website. Order as QG36
100's of applications inc: firewall, routers, robotics etc **Only £99.00** (D)

19" RACK CABINETS

Save £££'s

Europe's Largest Stocks of quality rack cabinets, enclosures and accessories. Over 1000 Racks from stock

This month's special
33 / 42 / 47 U - High Quality
All steel Rack Cabinets
BIG £ SAVER



Made by **Eurocraft Enclosures Ltd** to the **highest** pos**sible spec**, rack features **all steel construction** with removable **side**, front and back doors. Front and back doors are **hinged for easy access** and **all** lockable with five **secure 5 lever barrel locks.** The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable **status** indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to **take the heaviest of 19" rack equipment.** The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A mains **distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket.** Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for **fitting of integral fans** to the sub **plate** etc. Other features include: fitted castors and floor levelers, **prepunched** utility panel at lower rear for cable / connector access etc. Supplied in **excellent,** slightly used condition with keys. Colour Royal blue. some grey available - CALL - Can be supplied in many other configurations.

33U	42U	47U
Order as BC44	Order as DT20	Order as RV36
External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23fi" W)	External dimensions mm=2019H x 635D x 603 W. (79.5" H x 25" D x 23fi" W)	External dimensions mm=2235H x 635D x 603 W. (88" H x 25" D x 23fi" W)
Only **£245**	Only **£345**	Only **£410**

Call for shipping quotation

COLOUR CCD CAMERAS

BIG £ SAVER

Undoubtedly **a miracle of modern technology** & our special buying power ! **A quality product** featuring a fully cased **COLOUR CCD** camera at a give away price ! Unit features full autolight sensing for use **in low light & high light applications.** A 10 mm fixed focus wide angle **lens** gives **excellent focus and resolution** from close up to long range. The **composite video output** will connect to any composite monitor or TV (via **SCART** socket) and most video **recorders.** Unit **runs from 12V DC** so **ideal for security & portable applications** where mains power not available.

Overall dimensions 66 mm wide x 117 deep x 43 high. Supplied BRAND NEW & fully guaranteed with user data, 100's of applications including Security, Home Video, Web TV, Web Cams etc, etc.
Order as LK33 ***ONLY £79.00 or 2 for £149.00*** (B)

SOFTWARE SPECIALS

NT4 WorkStation, complete with service pack 3 and licence - OEM packaged. ***ONLY £89.00*** (B)

ENCARTA 95 - CDROM, Not the latest - but at this price !	£7.95
DOS 5.0 on 3fi" disks with concise books c/w QBasic	£14.95
Windows for Workgroups 3.11+ Dos 6.22 on 3.5" disks	£55.00
Windows 95 CDROM Only - No Licence -	£19.95
Wordperfect 6 for DOS supplied on 3fi" disks with manual	£24.95

shipping charges for software is code B

SOLID STATE LASERS

Visible red, 670nm laser diode assembly. Unit runs from 5 V DC at approx 50 mA. Originally made for continuous use in industrial barcode scanners, the laser is mounted in a removable solid aluminium block, which functions as a heatsink and rigid optical mount. Dims of block are 50 w x 50 d x 15 h mm. Integral features include over temperature shutdown, current control, laser OK output, and gated TTL ON / OFF. Many uses for experimental optics, comms & lightshows etc. Supplied complete with data sheet.
Order as TD91 ***ONLY £24.95*** (A)

DC POWER SUPPLIES

Virtually every type of power supply you can imagine.Over 10,000 Power Supplies Ex Stock - Call or see our web site.

RELAYS - 200,000 FROM STOCK

Save ££££'s by choosing your next relay from our Massive Stocks covering types such as Military, Octal, Cradle, Hermetically Sealed, Continental, Contactors, Time Delay, Reed, Mercury Wetted, Solid State, Printed Circuit Mounting etc. , CALL or see our web site www.distel.co.uk for more information. Many obsolete types from stock. Save ££££'s

TEST EQUIPMENT & SPECIAL INTEREST ITEMS

Unless marked NEW, items in this section are pre owned.

MITSUBUSHI FA3445ETKL 14" Ind. spec SVGA monitors	£245
FARNELL 0-60V DC @ 50 Amps, bench Power Supplies	£995
FARNELL AP3080 0-30V DC @ 80 Amps, bench Suppy	£1850
KINGSHILL CZ403/1 0-50V @ DC 200 Amps - NEW	£3950
1kW to 400 kW - 400 Hz 3 phase power sources - ex stock	£POA
IBM 8230 Type 1, Token ring base unit driver	£760
Wayne Kerr RA200 Audio frequency response analyser	£2500
INFODEC 1U, 24 port, RJ45 network patchpanels. #TH93	£49
3COM 16670 12 Port Ethernet hub - RJ45 connectors #LD97	£69
3COM 16671 24 Port Ethernet hub - RJ45 connectors	£89
3COM 16700 8 Port Ethernet hub - RJ45 connectors NEW	£39
IBM 53F5501 Token Ring ICS 20 port lobe modules	£POA
IBM MAU Token ring distribution panel 8228-23-5050N	£45
AIM 501 Low distortion Oscillator 9Hz to 330Khz, IEEE I/O	£550
ALLGON 8360.11805-1880 MHz hybrid power combiners	£250
Trend DSA 274 Data **Analyser** with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£4500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
HP1650B Logic Analyser	£3750
HP3781A Pattern generator & **HP3782A** Error Detector	£POA
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£475
HP54121A DC to 22 GHz four channel test set	£POA
HP8130A opt 020 300 MHz pulse generator, GPIB etc	£7900
HP A1, A0 8 pen HPGL high speed drum plotters - from	£550
HP DRAFTMASTER 1 8 pen high speed plotter	£750
EG+G Brookdeal 95035C Precision lock in amp	£1800
Keithley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel voice recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batteries	£4500
Emerson AP130 2.5KVA industrial spec.UPS	£1499
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£945
HP6030A 0-200V DC @ 17 Amps bench power supply	£1950
Intel SBC 486/125C08 Enhanced Multibus (MSA) New	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
PHILIPS PM5518 pro. TV signal generator	£1250
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. New	£550
Fujitsu M3041R 600 LPM high speed band printer	£1950
Fujitsu M3041D 600 LPM printer with network interface	£1250
Siemens K4400 64Kb to 140Mb demux analyser	£2950
Perkin Elmer 299B Infrared spectrophotometer	£500
Perkin Elmer 597 Infrared spectrophotometer	£3500
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3250
LightBand 60 output high spec 2u rack mount Video VDA's	£495
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
B&K 2633 Microphone pre amp	£300
Taylor Hobson Tallysurf amplifier / recorder	£750
ADC SS200 Carbon dioxide gas detector / monitor	£1450
BBC AM20/3 PPM Meter (Ernest Turner) + drive electronics	£75
ANRITSU 9654A Optical DC-2.5G/b waveform monitor	£5650
ANRITSU ML93A optical power meter	£990
ANRITSU Fibre optic characteristic test set	£POA
R&S FTDZ Dual sound unit	£650
R&S SBUF-E1 Vision modulator	£775
WILTRON 6630B 12.4 / 20GHz RF sweep generator	£5750
TEK 2445 150 MHz 4 trace oscilloscope	£1250
TEK 2465 300 Mhz 300 MHz oscilloscope rack mount	£1955
TEK TDS380 400Mhz digital realtime + disk drive, FFT etc	£2900
TEK TDS524A 500Mhz digital realtime + colour display etc	£5100
HP3585A Opt 907 20Hz to 40 Mhz spectrum analyser	£3950
PHILIPS PW1730/10 60KV XRAY generator & accessories	£POA
VARIACS - Large range from stock - call or see our website	
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325
CLAUDE LYONS 100A 240/415V 3 phase auto. volt. regs	£2900

DISPLAY -ELECTRONICS-

ALL MAIL TO
Dept W, 29 / 35 Osborne Rd
Thornton Heath
Surrey CR7 8PD, UK
Open Mon - Fri 9.00 - 5:30

18 Million Items On Line Now !
Secure Ordering, Pictures, Information
VeriSign Secure Site
www.distel.co.uk
email = admin@distel.co.uk

ALL ENQUIRIES
0208 653 3333
FAX 0208 653 8888

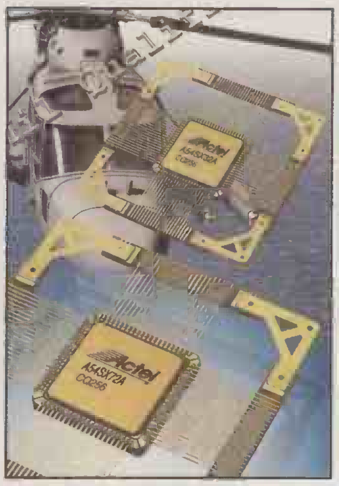
Est. 26 Years

Please quote *Electronics World* when seeking further information

power applications. The devices include 1,792 bytes of flash program memory, 64 bytes of RAM and 128 bytes of EEPROM. The PIC16F676 features a 10-bit ADC with 8 channels that can use either V_{DD} or an external voltage reference. Both devices include a precision internal oscillator that is ±2 per cent stable over a wide temperature and voltage range.
Microchip
Tel: +44(0) 118 921 5858
www.microchip.com

Antifuse FPGAs for mil spec

Actel is offering antifuse field-programmable gate arrays (FPGAs) qualified to military specifications. Featuring up to 72,000 typical gates, or 36,000 Asic gates, the military-qualified FPGAs deliver system performance of up to 250MHz



with guaranteed support for 33MHz PCI at case temperatures ranging from –55°C to +125°C. The devices are suitable for military, aerospace and avionics applications, including radar, command and control, ground-based communications and advanced weapon control systems. Antifuse FPGAs, such as these devices, offer levels of design security beyond SRAM-based FPGAs and conventional Asics. As there are no configuration boot PROMs or bit streams that can be intercepted and decoded, the SX72A and SX32A are secure, thereby preventing copying or reverse engineering of the design.
Actel
Tel: +44(0) 1256 305600
www.actel.com/eu

DOCSIS cable driver works at 5V

Analog Devices has announced its first +5V CMOS cable modem and set-top box designs. The AD8328 driver for DOCSIS 1.0, 1.1 and 2.0 compatible cable modems and OpenCable compatible digital set-top box designs is a digitally controlled, variable-gain amplifier optimised for upstream coaxial line driving. Available as industry standard pin-out 20-lead 4 x 4mm LFCSP package, which the suppliers said has better thermal characteristics than the QSOP package and a migration path to a lead-free package. It has a gain range of 59dB programmable in 1dB steps using an 8-bit serial word and accepts a differential or single-ended input. Its output is specified for driving a 75Ω load through a 2:1 transformer.
The worst-case distortion performance is ±54dBc at 65MHz across temperature with an output level of 60dBmV. Operating from a single +5V supply, the AD8328 has a transmit disable mode that reduces quiescent current to 2.6mA, and a sleep mode that further reduces the current to 299μA.
Analog Devices

022003

ELECTRONIC COMPONENTS

Station Road, Cullercoats, Tyne & Wear, NE30 4PQ

VISA

Prices Exclude Vat @17½%.
UK Carriage £1.50 (less than 1kg)
£3.50 greater than 1kg
Cheques / Postal orders payable to ESR Electronic Components.
PLEASE ADD CARRIAGE & VAT TO ALL ORDERS

See Next / Last Months Ad. for COMPONENT ACCESSORIES

4000 Series

4000B	£0.27
4001B	£0.16
4002B	£0.19
4007UB	£0.19
4008B	£0.23
4009UB	£0.23
4010B	£0.23
4011B	£0.16
4012B	£0.16
4013B	£0.19
4014B	£0.30
4015B	£0.32
4016B	£0.20
4017B	£0.23
4018B	£0.26
4019B	£0.25
4020B	£0.26
4021B	£0.31
4022B	£0.32
4023B	£0.19
4024B	£0.24
4025B	£0.20
4026B	£0.70
4027B	£0.22
4028B	£0.33
4029B	£0.33
4030B	£0.17
4035B	£0.31
4040B	£0.24
4041B	£0.31
4042B	£0.22
4043B	£0.35
4044B	£0.35
4046B	£0.35
4047B	£0.32
4048B	£0.34
4049B	£0.24
4049UB	£0.24
4050B	£0.20
4051B	£0.21
4052B	£0.32
4053B	£0.22
4054B	£0.56
4055B	£0.34
4060B	£0.25
4063B	£0.29
4066B	£0.20
4067B	£2.20
4068B	£0.16
4069UB	£0.19
4070B	£0.16
4071B	£0.20
4072B	£0.18
4073B	£0.17
4075B	£0.17
4076B	£0.30
4077B	£0.28
4078B	£0.20
4081B	£0.16
4082B	£0.21
4085B	£0.28
4086B	£0.33
4093B	£0.17
4094B	£0.29
4097B	£1.20
4098B	£0.22
4099B	£0.39
4502B	£0.32
4503B	£0.20
4508B	£1.40
4510B	£0.50
4511B	£0.33
4512B	£0.32
4514B	£0.77
4515B	£0.99
4516B	£0.44
4518B	£0.38
4520B	£0.34
4521B	£0.62
4526B	£0.40
4527B	£0.40
4528B	£0.40
4529B	£0.44
4532B	£0.24
4536B	£1.00
4538B	£0.37
4541B	£0.33
4543B	£0.47
4555B	£0.32
4556B	£0.40
4584B	£0.27
4585B	£0.47
4724B	£0.94
40106B	£0.20
40109B	£0.58
40174B	£0.46
40175B	£0.41

74HC Series

74HC00	£0.16
74HC02	£0.16
74HC03	£0.21
74HC04	£0.16
74HC08	£0.18
74HC10	£0.21
74HC11	£0.21
74HC14	£0.18
74HC20	£0.28
74HC27	£0.16
74HC30	£0.22
74HC32	£0.18
74HC42	£0.36
74HC73	£0.40
74HC74	£0.19
74HC75	£0.31
74HC76	£0.20
74HC85	£0.24
74HC86	£0.22
74HC107	£0.40
74HC123	£0.33
74HC125	£0.26
74HC126	£0.46
74HC132	£0.35
74HC133	£0.34
74HC137	£0.30
74HC138	£0.29
74HC139	£0.31
74HC151	£0.33
74HC153	£0.30
74HC154	£0.85
74HC157	£0.40
74HC158	£0.23
74HC160	£0.64
74HC161	£0.28
74HC162	£0.45
74HC163	£0.26
74HC164	£0.23
74HC165	£0.35
74HC173	£0.38
74HC174	£0.27
74HC175	£0.35
74HC192	£0.72
74HC193	£0.40
74HC195	£0.32
74HC240	£0.37
74HC241	£0.37
74HC244	£0.42
74HC245	£0.40
74HC251	£0.30
74HC253	£0.25
74HC257	£0.25
74HC259	£0.57
74HC273	£0.32
74HC299	£0.64
74HC365	£0.28
74HC367	£0.29
74HC368	£0.26
74HC373	£0.35
74HC374	£0.40
74HC390	£0.52
74HC393	£0.38
74HC541	£0.25
74HC563	£0.56
74HC564	£0.48
74HC573	£0.27
74HC574	£0.38
74HC595	£0.29
74HC688	£0.46
74HC4002	£0.31
74HC4017	£0.36
74HC4020	£0.36
74HC4040	£0.29
74HC4049	£0.31
74HC4051	£0.40
74HC4052	£0.43
74HC4053	£0.38
74HC4060	£0.44
74HC4075	£0.27
74HC4078	£0.32
74HC4511	£0.45
74HC4514	£0.84
74HC4538	£0.41
74HC4543	£0.90

74LS Series

74LS00	£0.22
74LS01	£0.14
74LS02	£0.22
74LS03	£0.29
74LS04	£0.22
74LS05	£0.14
74LS08	£0.22
74LS09	£0.15
74LS10	£0.27
74LS11	£0.17
74LS12	£0.20
74LS14	£0.33
74LS15	£0.24
74LS20	£0.27
74LS21	£0.20
74LS26	£0.21
74LS27	£0.25
74LS30	£0.20
74LS32	£0.21
74LS37	£0.31
74LS38	£0.18
74LS40	£0.14
74LS42	£0.42
74LS47	£0.48
74LS51	£0.24
74LS73	£0.36
74LS74	£0.18
74LS75	£0.30
74LS76	£0.40
74LS83	£0.38
74LS85	£0.48
74LS86	£0.25
74LS90	£0.37
74LS92	£0.45
74LS93	£0.42
74LS107	£0.30
74LS109	£0.21
74LS112	£0.24
74LS113	£0.23
74LS114	£0.36
74LS122	£0.31
74LS123	£0.31
74LS125	£0.28
74LS126	£0.25
74LS132	£0.26
74LS133	£0.36
74LS136	£0.23
74LS138	£0.33
74LS139	£0.26
74LS145	£0.56
74LS148	£0.64
74LS151	£0.29
74LS153	£0.38
74LS156	£0.36
74LS157	£0.22
74LS158	£0.21
74LS160	£0.48
74LS161	£0.32
74LS162	£0.44
74LS163	£0.32
74LS164	£0.43
74LS165	£0.48
74LS173	£0.24
74LS174	£0.24
74LS175	£0.30
74LS190	£0.60
74LS191	£0.24
74LS192	£0.60
74LS193	£0.43
74LS195	£0.24
74LS196	£0.24
74LS221	£0.41
74LS240	£0.32
74LS241	£0.32
74LS243	£0.30
74LS244	£0.32
74LS245	£0.32
74LS247	£0.60
74LS251	£0.24
74LS257	£0.24
74LS258	£0.24
74LS259	£0.45
74LS266	£0.14
74LS273	£0.32
74LS279	£0.24
74LS283	£0.47
74LS365	£0.21
74LS367	£0.21
74LS368	£0.21
74LS373	£0.32
74LS374	£0.38
74LS378	£0.62
74LS390	£0.53
74LS393	£0.33
74LS395	£0.26

74 Series

7407	£0.40

Linear ICs

AD524AD	£23.04
AD548JN	£2.48
AD590JH	£5.28
AD592AN	£4.80
AD595AQ	£13.92
AD620AN	£9.88
AD625JN	£16.20
AD633JN	£5.92
AD648JN	£2.57
AD654JN	£7.18
AD711JN	£1.46
AD712JN	£2.48
AD736JN	£7.98
AD797AN	£7.10
AD811AN	£6.24
AD812AN	£6.32
AD817AN	£3.19
AD820AN	£3.41
AD822AN	£5.20
AD829JN	£6.41
AD830AN	£5.44
AD847JN	£5.95
AD9696KN	£7.73
ADEL2020A	£5.06
ADM222AH	£3.55
ADM232AA	£3.55
ADM485JN	£2.97
ADM690AN	£5.13
ADM691AN	£6.48
ADM695AN	£6.48
ADM699AN	£3.58
CA747CE	£0.39
CA3046	£0.42
CA3080E	£0.60
CA3130E	£0.87
CA3140E	£0.57
CA3240E	£0.92
DG211CJ	£1.25
DG411DJ	£2.00
ICL7106CPL	£2.80
ICL7107CPL	£2.10
ICL7109CLP	£5.76
ICL7611DCP	£1.00
ICL7621	£0.84
ICL7660SCP	£0.80
ICL8038	£3.84
ICM7555	£0.41
ICM7556	£0.88
L165V	£2.36
L272M	£1.21
L293E	£4.03
L297	£5.12
L298N	£6.67
L4960	£2.81
L6219	£4.48
LF347N	£0.46
LF351N	£0.41
LF353N	£0.40
LF356	£0.84
LF411CN	£1.08
LM301AN	£0.40
LM311N8	£0.25
LM319N14	£0.90
LM324	£0.19
LM335Z	£0.94
LM339N	£0.19
LM348N	£0.36
LM35DZ	£1.90
LM358N	£0.17
LM380N	£0.81
LM386	£0.45
LM392N	£0.79
LM393N	£0.21
LM748CN8	£0.37
LM1881	£2.90
LM2901N	£0.15
LM2917N8	£2.34
LM3900N	£0.72
LM3914	£1.97
LM3915	£2.10
LM13600	£1.10
LMC660CN	£1.44
LMC6032IN	£1.55
LP311N	£0.74
LP324N	£0.72
LP339N	£0.75
LT1013CN8	£4.64
MAX202CPE	£1.97
MAX208CN	£6.99
MAX220CPE	£5.06
MAX222CPE	£5.06
MAX232CPE	£1.82
MAX483CP	£3.13
MAX485CP	£2.08
MAX631ACP	£4.99
MAX635ACP	£4.99
MAX1232CP	£2.80
MC1458N	£0.27
MC1488	£0.40
MC1489	£0.40
MC3302	£0.56
MC4558P	£0.33
MK484	£0.66
NE521N	£6.39
NE555N	£0.17
NE556N	£0.29
NE565N	£2.30
NE567N	£0.39
NE592	£0.62
NE5532N	£0.48
NE5534N	£0.45
NE5539N	£4.35
OP07CN	£0.90
OP27CN	£2.33
OP90GP	£3.11
OP97FP	£2.24
OP113GP	£3.44
OP176GP	£2.09
OP177GP	£1.86
OP200GP	£5.60
OP213FP	£5.20
OP275GP	£2.57
OP282GP	£2.27
OP283GP	£5.20
OP290GP	£4.28
OP297GP	£4.64
OP400GP	£11.81
OP495GP	£8.69
RC4136	£1.00
SG3524N	£0.70
SG3543	£6.88
SSM2141P	£3.21
SSM2142P	£6.16
SSM2143P	£3.78
TBA120S	£0.72
TBA800	£0.75
TBA810S	£0.64
TBA820M	£0.38
TDA1170S	£4.80
TDA2004	£2.21
TDA2030AV	£1.20
TDA2050V	£2.28
TDA2611A	£1.88
TDA2822A	£0.86
TDA2653A	£6.40
TDA7052A	£1.27
TED3718DP	£5.03
TEA5115	£3.11
TL061CP	£0.37
TL062CP	£0.60
TL064CN	£0.72
TL071CN	£0.32
TL072CN	£0.32
TL074CN	£0.40
TL081	£0.28
TL082CN	£0.32
TL084CN	£0.42
TL494CN	£0.68
TL7705ACP	£0.82
TLC271	£0.63
TLC272N	£0.60
TS274CN	£0.50
TS555CN	£0.34
TMP01FP	£5.60
UA741CN	£0.25
ULN2003	£0.40
ULN2004A	£0.44
ULN2803A	£0.42
ULN2804A	£0.39

EPROM's

24LC08BP	£0.73
24LC16BP	£0.69
24LC32AP	£1.14
2732	£5.51
27128-200	£3.99
27256-200	£3.99
27C64A-15F	£2.80
27C256B-15F	£2.34
27C512-15F1	£2.55
27C1001-15.	£3.17
27C2001-15.	£4.41
27C4001-120	£5.84
93C46N	£0.64

RAM

GM76C88.	£3.60
HM62128.-7	£9.14
U6264ADC7	£1.42
IS61C256-15	£3.20

A/D Converters Data Acquisition

AD420AN	£25.38
AD557JN	£7.08
AD7528JN	£11.42
AD7545AK	£14.04
AD7828KN	£20.33
DAC0800	£2.72
ICL7109CPL	£7.75
TLC549IP	£2.07

µControllers

AT89C2051	£6.38
12C508A04P	£0.78
12C509A04P	£0.85
16C54C04P	£1.49
16C54BJW	£7.60
16C56A-04P	£1.61
16F84-04P	£3.14
16F84-10P	£3.76
16F877-04P	£5.20
16F877-20P	£6.01

Voltage Regulators

7805	£0.24
7806	£0.24
7808	£0.24
7812	£0.27
7815	£0.27
78L05	£0.21
78L06	£0.32
78L08	£0.25
78L12	£0.18
78L15	£0.26
[illegible]	£0.39
78S05	£0.73
78S12	£0.70
78S15	£0.98
7905	£0.25
7912	£0.29
7915	£0.38
7924	£0.38
79L05	£0.18
79L12	£0.23
79L15	£0.28
79L24	£0.30
ADM666AN	£3.44
L200CV	£1.67
L296	£2.36
L387A	£2.72
LM2940CT5	£0.56
LM317LZ	£0.29
LM317T	£0.32
LM317K	£2.48
LM323K	£2.40
LM334Z	£0.96
LM337T	£0.67
LM338K	£5.47
LM338T	£1.18
LM723	£0.38
LP2950CZ5.0	£0.90
REF01CP	£2.40
REF195GP	£3.77
TL431CP	£0.20
ZN458B	£1.41

Diodes

1N914	£0.05
1N916	£0.05
1N4001	£0.05
1N4002	£0.05
1N4003	£0.04
1N4004	£0.04
1N4005	£0.04
1N4006	£0.04
1N4007	£0.05
1N4148	£0.03
1N4149	£0.07
1N5400	£0.08
1N5401	£0.08
1N5402	£0.08
1N5404	£0.09
1N5406	£0.10
1N5407	£0.10
1N5408	£0.10
6A05	£0.27
6A1	£0.27
6A2	£0.27
6A4	£0.28
6A6	£0.32
6A8	£0.30
6A10	£0.35
BA157	£0.10
BA158	£0.08
BA159	£0.13
BAT41	£0.12
BAT42	£0.10
BAT46	£0.20
BAT49	£0.36
BAT85	£0.12
BAV21	£0.07
BAW62	£0.07
BAX16	£0.05
BY127	£0.18
BY133	£0.10
OA47	£0.70
OA90	£0.33
OA91	£0.34
OA200	£0.56
UF4001	£0.08
UF4002	£0.09
UF4003	£0.09
UF4004	£0.09
UF4005	£0.10
UF4006	£0.10
UF4007	£0.14
Zeners 2.7 to 33V	
500mW	£0.06
1.3W	£0.10

New Catalogue Out Now
Free with all orders or via the internet.

Bridge Rectifiers

1A 50V	£0.35
1A 100V	£0.36
1A 200V	£0.39
1A 600V	£0.40
1.5A 50V	£0.19
1.5A 100V	£0.19
1.5A 200V	£0.19
1.5A 400V	£0.20
1.5A 600V	£0.24
1.5A 800V	£0.26
1.5A 1kV	£0.26
2A 100V	£0.34
2A 200V	£0.34
2A 400V	£0.35
3A 200V	£0.34
3A 400V	£0.40
3A 600V	£0.33
4A 100V	£0.78
4A 200V	£0.76
4A 400V	£0.86
4A 600V	£0.90
6A 100V	£0.49
6A 200V	£0.60
6A 400V	£0.53
6A 600V	£0.67
8A 100V	£0.98
8A 200V	£1.00
8A 400V	£1.04
8A 600V	£1.10
25A 100V	£1.47
25A 200V	£1.54
25A 400V	£1.98
25A 600V	£1.82
35A 50V	£1.67
35A 100V	£1.57
35A 200V	£1.80
35A 400V	£1.62
35A 600V	£1.90
35A 1000V	£1.98

Thyristors

2N5060	£0.19
2N5061	£0.19
BT151-500R	£0.65
C106D1	£0.36
PO102AA	£0.30
TIC106D	£0.49
TIC116D	£0.66
TIC126D	£0.77

Triacs

BT136-500	£0.58
BT136-600	£0.50
BT137-500	£0.65
BT137-600	£0.58
BT139-500	£1.00
BT139-600	£1.20
BTA08-600B	£0.84
BTA08-600BW	£0.76
BTA08-600C	£0.79
BTA08-600SW	£0.99
BTA08-600TW	£0.78
BTA12-600BW	£0.92
BTA16-600CW	£1.45
BTA16-600B	£1.28
BTA26-600B	£2.78
TIC206D	£0.70
TIC206M	£0.75
TIC226D	£0.80
TIC226M	£1.02
TIC246D	£1.00
TIC246M	£1.00
TIC236D	£1.12
ZO105DA	£0.53

Diac

DB3, 32V	£0.16

Transistors

2N1711	£0.26
2N2222A	£0.18
2N2369A	£0.43
2N2646	£1.02
2N2904A	£0.35
2N2905A	£0.30
2N2907A	£0.28
2N3053	£0.31
2N3054	£0.85
2N3055	£0.64
2N3439	£0.62
2N3440	£0.50
2N3702	£0.09
2N3703	£0.10
2N3704	£0.11
2N3705	£0.08
2N3771	£1.44
2N3772	£1.72
2N3773	£1.70
2N3819	£0.33
2N3820	£0.66
2N3903	£0.11
2N3904	£0.08
2N3905	£0.10
2N3906	£0.08
2N4036	£0.34
2N4401	£0.08
2N4403	£0.09
2N5245	£0.80
2N5296	£0.57
2N5401	£0.12
2N5551	£0.11
2N6491	£1.58
2SB548	£0.30
AC126	£0.74
AC127	£0.50
AC187	£0.68
AC188	£0.97
ACY17	£4.84
AD149	£1.29
AD161	£0.73
AD162	£0.92
BC107	£0.16
BC107B	£0.14
BC108	£0.18
BC108B	£0.14
BC108C	£0.18
BC109	£0.17
BC109C	£0.18
BC114	£0.19
BC115	£0.41
BC118	£0.41
BC132	£0.36
BC134	£0.36
BC135	£0.36
BC140	£0.75
BC141	£0.27
BC142	£0.34
BC143	£0.38
BC154	£0.36
BC157	£0.12
BC159	£0.17
BC160	£0.28
BC170B	£0.16
BC171B	£0.16
BC172B	£0.13
BC177	£0.23
BC178	£0.18
BC179	£0.18
BC182	£0.10
BC182L	£0.08
BC183L	£0.08
BC184	£0.09
BC184L	£0.10
BC204C	£0.72
BC206B	£0.72
BC208	£0.72
BC209A	£0.72
BC212	£0.10
BC212L	£0.08
BC213B	£0.10
BC213LC	£0.11
BC214	£0.08
BC214L	£0.10
BC225	£0.15
BC237B	£0.09
BC238B	£0.11
BC239C	£0.10
BC250A	£0.15
BC252	£0.13
BC261B	£0.30
BC262B	£0.24
BC267B	£0.30
BC307	£0.10
BC319C	£0.13
BC327	£0.08
BC327-25	£0.08
BC328	£0.09
BC337	£0.08
BC337-25	£0.08
BC338	£0.10
BC348B	£0.14
BC357	£0.25
BC393	£0.73
BC441	£0.40
BC461	£0.46
BC463	£0.29
BC477	£0.52
BC478	£0.45
BC479	£0.32
BC516	£0.21
BC517	£0.12
BC528	£0.20
BC537	£0.20
BC546A	£0.06
BC546B	£0.08
BC546C	£0.08
BC547A	£0.09
BC547B	£0.09
BC547C	£0.09
BC548A	£0.08
BC548B	£0.09
BC548C	£0.08
BC549B	£0.09
BC549C	£0.10
BC550B	£0.10
BC550C	£0.11
BC556A	£0.08
BC556B	£0.08
BC557A	£0.09
BC557B	£0.09
BC557C	£0.11
BC558A	£0.08
BC558B	£0.08
BC559A	£0.08
BC560A	£0.09
BC560B	£0.09
BC636	£0.10
BC637	£0.19
BC638	£0.21
BC639	£0.11
BC640	£0.13
BCY70	£0.22
BCY71	£0.29
BCY72	£0.20
BD124P	£6.86
BD131	£0.48
BD132	£0.46
BD135	£0.24
BD136	£0.21
BD137	£0.23
BD138	£0.24
BD139	£0.22
BD140	£0.25
BD150C	£0.82
BD201	£0.40
BD202	£0.70
BD232	£0.50
BD237	£0.32
BD238	£0.44
BD240C	£0.37
BD245C	£1.18
BD246C	£1.18
BD283	£0.61
BD284	£0.61
BD400	£0.79
BD437	£0.38
BD438	£0.27
BD442	£0.37
BD534	£0.47
BD535	£0.50
BD581	£0.62
BD597	£0.92
BD646	£0.52
BD648	£0.52
BD650	£0.53
BDX32	£1.78
BDX33C	£0.56
BDX34C	£0.50
BDX53C	£0.47
BDX54C	£0.50
BF180	£0.31
BF182	£0.31
BF185	£0.58
BF194	£0.31
BF194B	£0.19
BF244	£0.35
BF244B	£0.34
BF244C	£0.50
BF257	£0.33
BF259	£0.33
BF337	£0.40
BF423	£0.13
BF459	£0.33
BF469	£0.36
BFX29	£0.29
BFX84	£0.31
BFX85	£0.33
BFY50	£0.30
BFY51	£0.22
BFY52	£0.28
BS107	£0.21
BS170	£0.20
BU208A	£1.53
BU326A	£1.40
BU500	£1.54
BU508A	£1.30
BU508D	£0.98
BU806	£1.06
BUT11A	£0.57
BUT11AF	£1.14
BUX84	£0.78
BUZ11	£0.70
BUZ900P	£5.92
BUZ905P	£5.92
IRF530	£0.45
IRF540	£0.75
IRF630	£0.42
IRF640	£0.63
IRF740	£0.91
IRF830	£0.68
IRF840	£0.78
MJ2501	£1.60
MJ3001	£1.84
MJ11015	£2.45
MJ11016	£2.56
MJE340	£0.33
MJE350	£0.32
MPSA05	£0.14
MPSA06	£0.11
MPSA13	£0.09
MPSA42	£0.15
PHP69N03LT	£1.02
TIP29A	£0.32
TIP29C	£0.30
TIP30A	£0.47
TIP30C	£0.37
TIP31A	£0.27
TIP31C	£0.35
TIP32A	£0.26
TIP32C	£0.26
TIP33C	£0.74
TIP41A	£0.32
TIP41C	£0.35
TIP42A	£0.32
TIP42C	£0.43
TIP50	£0.31
TIP110	£0.28
TIP120	£0.30
TIP121	£0.34
TIP122	£0.33
TIP125	£0.31
TIP126	£0.31
TIP127	£0.36
TIP132	£0.68
TIP137	£0.64
TIP141	£0.93
TIP142	£0.91
TIP147	£1.07
TIP2955	£0.67
TIP3055	£0.63
ZVN3306A	£0.32
ZVN4306A	£0.74
ZVN4310A	£0.64
ZVP3306A	£0.42
ZTX300	£0.15
ZTX302	£0.17
ZTX450	£0.19
ZTX451	£0.19
ZTX453	£0.26
ZTX500	£0.16
ZTX502	£0.17
ZTX550	£0.22
ZTX551	£0.22
ZTX600	£0.33
ZTX600B	£0.35
ZTX605	£0.36
ZTX651	£0.35
ZTX653	£0.36
ZTX689B	£0.36
ZTX690B	£0.37
ZTX705	£0.39
ZTX750	£0.25
ZTX751	£0.34
ZTX753	£0.34
ZTX789A	£0.41
ZTX790A	£0.41
ZTX851	£0.50
ZTX853	£0.50
ZTX951	£0.54
ZTX1048A	£0.48
ZTX1051A	£0.46
ZTX1053A	£0.48

Quality Components
No surplus or redundant stock. All from leading manufoctures.

Quality Service
Sameday despatch on all stock items. Friendly helpful staff.

Fast Delivery
Nextday service for all small (<1kg) orders at no extra charge. 3 day service for orders >1kg

No Minimum Order
Order what you need, no pack quantities or min order value.

Quantity Discounts Available
We offer discounts for all items subject to quantity required, phone, fax or email for a quote.

We carry a large range of capacitors in stock, including:
Ceramic Mini Disc, Dipped Ceramic Multilayer, Dipped & Boxed Polyester, Mylar Film, Polystyrene, Plastic Film, MKT Polyester, Tantalum Bead, Sub-miniature Radial, 105°C Radial, Low Leakage Radial, Non Polarised Radial & Axial, PCB Can Electrolytics, Polypropylene & Ceramic Trimmers and Tuning capacitors. Full technical details available.

Resistors - Please State Value Required

			per 100 of one value only
1/8W Carbon Film 5%	E12 Series	10• -1M0	£0.02 Each, £0.80 per 100
¼W Carbon Film 5%	E12 Series	1• -10M	£0.02 Each, £0.60 per 100
¼W Metal Film 1%	E24 Series	10• -1M	£0.04 Each, £1.72 per 100
½W Carbon Film 5%	E12 Series	1• -10M	£0.02 Each, £0.95 per 100
2.5W Wirewound 5%	E12 Series	0• 1-220•	£0.23 Each

1W, 2W, 5W, 20W, 25W & 50W also in stock - selected values only, contact sales dept.

Preset Resistors - Please State Value Required

Enclosed, 10mm Square Horz / Vert.	100• - 1M0 0.15W	£0.12 Each
Skeleton, 10mm Dia. Horizontal.	100• - 1M0 0.1W	£0.09 Each
Sub-min, 6mm Dia, Horizontal	E3 200• -1M0 0.1W	£0.12 Each
Multiturn, 10mm Square, Top Adjust.	E3 100• -1M0 0.5W	£0.81 Each
Multiturn, 19mm Long, End Adjust.	E3 50• -1M0 0.5W	£0.59 Each

Potentiometers - Please State Value Required

Single Gang ¼" Shaft, 25mm Dia.	470• -2M2 Linear	£0.56 Each
Single Gang ¼" Shaft, 25mm Dia.	4k7,10k,47k,100k,1M,2M2 Log	£0.56 Each
Dual Gang ¼" Shaft, 20mm Dia.	1k0-2M2 Linear	£1.54 Each
Dual Gang ¼" Shaft, 20mm Dia.	10k-470k Logarithmic	£1.54 Each
Switched ¼" Shaft, 20mm Dia.	1k0-2M2 Linear	£1.92 Each
Switched ¼" Shaft, 20mm Dia.	4k7-2M2 Logarithmic	£1.92 Each
PCB Mount, Splined Shaft, 16mm Dia.	470• -1M0 Linear	£0.48 Each
PCB Mount, Splined Shaft, 16mm Dia.	470• ,4k7,100k,1M0 Log	£0.48 Each
Dual PCB, Splined Shaft, 16mm Dia.	10k,50k100k,500k Lin	£0.84 Each
Dual PCB, Splined Shaft, 16mm Dia.	10k,50k,100k,500k Log	£0.84 Each

Tel: 0191 2514363 Fax: 0191 2522296 Email: sales@esr.co.uk http: //www.esr.co.uk

Please quote *Electronics World* when seeking further information

Chip antennas are for mobile comms

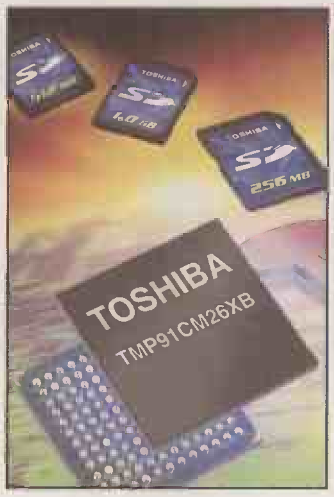
Furukawa Electric Co has released two chip antennas for mobile communications devices: one for IEEE 802.11b wireless LAN and bluetooth devices in the 2.4GHz band. the other for CDMA-ONE cell phones in the 900MHz band. The company claims the 2.4GHz model, which offers high gain and a wide bandwidth of over 200MHz for the required bandwidth of 80MHz, is claimed to be the world's smallest at 8.8mm x 2.9mm x 0.7mm. It uses Furukawa's two-dimensional radiation circuit to produce a non-directional radiation pattern. The 900MHz chip antenna (17.4mm x 4.8mm x 1.5mm) uses a three-dimensional radiation circuit, which the company says provides performance equivalent to that of a whip antenna. Both types of chip antennas are manufactured by injection moulding, enabling mass production. Lead terminals are used to provide high heat resistance, and the terminal plating is suitable for leadfree soldering. Rather than a ceramic dielectric, the designs use a thermoplastic high-dielectric material which ensures high-frequency stability, as well as small size and high resistance to change in temperature and humidity.

Furukawa Electric Co
Tel: +44(0) 207 313 5333
www.furukawa.co.uk

16-bit micro with SD host and USB 1.1

Toshiba's latest 16-bit micro-controller includes an on-chip SD memory card host controller (SDHC) and integrated USB 1.1 interface for use in digital SD memory card applications. The TMP91CM26XB's on-chip SDHC can transfer data at up to 2Mbyte/s, while the built-in USB controller provides a serial connection for data transfer at up to 12Mbit/s. It is supplied in a 144-pin FBGA package and will operate at voltages down to 3.0V and frequencies up to 36MHz. Minimum instruction time is 111ns at the maximum clock speed. In addition to the SDHC and USB controller, the microcontroller incorporates 32kbytes of ROM and 16kbytes of RAM, a 10-bit ADC, a two channel UART, three independent timers, and functionality for addressing external flash memory. Connectivity options include an 12C interface and 100 I/O ports.

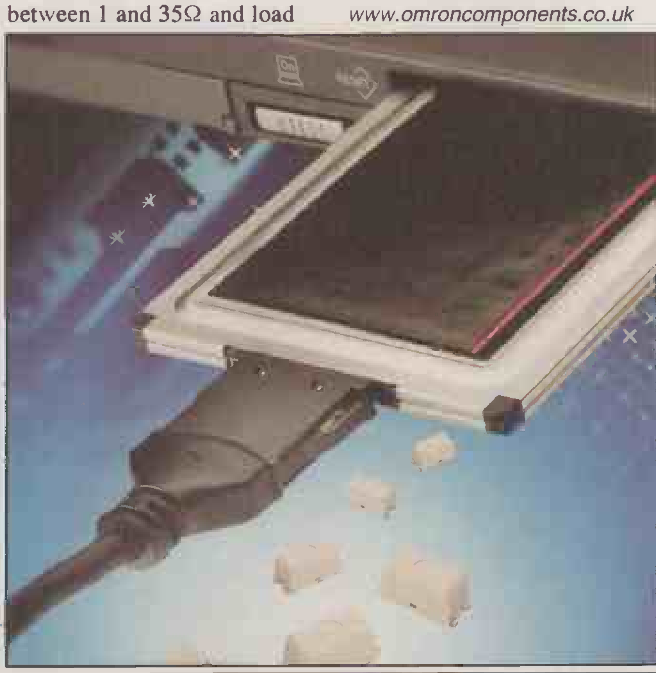
Toshiba
Tel:+44(0)49 211 5296 254
www.toshiba-europe.com



Mosfet relays make smallest bid

Omron has introduced its smallest high performance 20V and 40V Mosfet relays, based on SSOP packaging. With a claimed 67 per cent board space saving, the G3VM-21LR, LR1, and G3VM-41LR3-LR4 relays offer similar performance to their larger counterparts, in a form factor of 4.2 x 2.04 x 1.8mm (L x W x H). Specifications include 1,500VAC input to output isolation, ON resistance of between 1 and 35Ω and load current switching capabilities of between 80 and 300mA, depending on model. The SSOP relays are intended for use where high-density single pole normally-open (SPNO) switch functions are required. Applications include bare board/functional PCB test equipment and ATE carrying out product quality assurance of semiconductor components.

Omron
Tel: +44(0) 870 7505661
www.omroncomponents.co.uk



LCD controller with 4Mbit memory

OKI Electric has an LCD graphic display controller with on-chip display memory of 4Mbit DRAM or a maximum of 1,024 horizontal and vertical dots, which can be configured to suit the application, for example 1,024 x 1,024 dots or 2,048 x 512 dots. The ML87V3104 is available in a 100-pin TQFP package. The device manages display data and control information and communication via an 8 or 16-bit wide bus. Operating frequency is 15MHz maximum and power supply voltage is 3.3V Display size is a maximum of 1,024 dots horizontal and vertical with 16/256 colours out of 4,096 colours (pseudo colours) and 4,096/6,5536 (direct colours). Output data complies with STN 4/8-bits parallel or TFT 12-bits (R4, G4, B4) or 16-bits (R5, G6, B5). An extended temperature version is available (–45 to 85°C).

Oki Electric
Tel: +44(0) 1753 787700
www.oki-europe.com

802.11g wireless chipset for 54Mbit/s

Intersil is sampling its PRISM GT 2-chip wireless LAN for wireless networking to the latest 802.11g WLAN standard. The device combines the 802.11g draft standard's mandatory modulation schemes complementary code keying (CCK) used in 802.11b, and orthogonal frequency division multiplexing (OFDM) used in 802.11a with its ZIF (zero IF) architecture in designing the PRISM GT chipset. CCK ensures backward-compatibility with the installed Wi-Fi base, while OFDM provides 54Mbit/s operation.

Intersil
Tel: +44(0) 1276 686 886
www.intersil.com

PCI controller for encryption processing

RadiSys has a PCI/ISA system controller targeting applications such as unified messaging systems, network and encryption processing systems. Based on the Intel 815 chipset with C-ICH communications controller, the EPC-2325 is a single board computer with dual 10/100 Ethernet and an optional Ultra 160 LVD SCSI interface.
It is available with processors ranging from 850MHz Celeron

Please quote *Electronics World* when seeking further information

through to the 1.26GHz Pentium III. It features integrated VGA, dual 10/100 Ethernet ports, an optional single channel Ultra160 LVD SCSI interface, system monitoring and a dual programmable watchdog timer. It supports a maximum of 512Mbyte using industry-standard PC133 SDRAM. The board also offers a full set of I/O interfaces including 64mA ISA bus drive capability, a 32-bit/33MHz PCI bus interface, dual USB, dualATA/100IDE, dual serial, a parallel port, an SMbus interface and a PS/2 port for keyboard and mouse.
RadiSys
Tel: +44(0) 1527 588810
www.radisys.com

Emulator downloads at up to 2.2Mbyte/s

Analog Devices (ADI) has added a PCI-based emulator for its JTAG DSPs (which include all Blackfin, SHARC, TigerSHARC and ADSP-219x devices) to its Crosscore family of development tools. The emulator offers code download speeds of up to 2.2Mbyte/s with the JTAG interface clocked five times faster than its predecessor. It is integrated with the firm's VisualDSP++ integrated development environment, offering programmers a quicker transition from development in a simulation environment to target hardware debugging. A background telemetry channel feature enables data exchange using a shared group of registers to which both the host and the target have read/write access while the application is running. This removes the need to halt the target application, obtain the desired information, and then restart. The emulator consists of a small shielded pod and cable, allowing for a non-intrusive debug interface to all of the ADI JTAG DSPs. It auto-detects voltages for 1.8V, 2.5V, 3.3V and 5.0V targets, which is indicated by dispay LEDS.
Analog Devices
Tel: +44(0) 1932 266000
www.analog.com

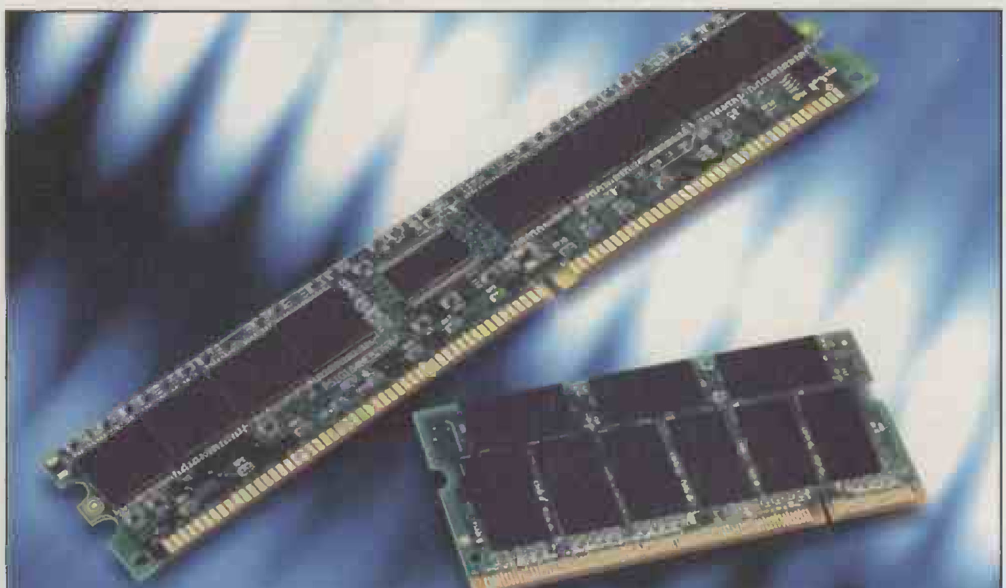
N-channel Mosfets work up to 150°C

The RK7002A and SM6K2 surface mount Mosfets from Rohm are miniature 60V devices offering single- and dual-transistor configurations. The devices can operate with junction temperatures of up to 150°C and are suitable for a variety of switching designs including automotive applications, said the company. The RK7002A provides a single N-channel transistor and the SM6K2 integrates two N-

channel devices that are totally independent to avoid interference. Both of the Mosfets incorporate a protection diode between gate and source to protect against static electricity during operation. Capable of operating with a continuous drain current of 300mA and a pulsed current of 1.2A, the RK7002A features a typical on resistance (RDS(ON) down to just 0.7Ω. Maximum power dissipation for the device is 200mW. The 5M6K2 can handle a continuous drain current of 200mA and a pulsed current of 800mA and has typical RDS(ON) down to 1.70. Supplied in Rohm's SST3 (SOT-23) package, the RX7002A measures 2.9 x 1.3 x 0.95mm and can be used in parallel for applications requiring higher ratings.
Rohm
Tel: +44(0) 1908 282666
www.rohm.co.uk

1Gbyte DDR memory in low profile

Smart Modular Technologies is offering two high-density DDR (double data rate) modules in its low-profile DDR and SDR (single data rate) family of products. The 1Gbyte 184-pin 1.0in. DIMM supports a peak bandwidth of 2.128Gbyte/s and a data transfer rate of 266MHz/s/pin meeting emerging high-end networking requirements. Typical applications for this module include wireless base stations, gigabit routers, VoIP, servers, edge routers and web server switches. Part number is SM5722885D-8ELCH01 (PC2100 CL2.5). The 1.25in. 512Mbyte PC2700 ECC SO-DIMM is designed to meet common memory requirements for embedded computing applications and networking applications. For single board embedded computing applications, such as firewalls and fibre channel switch blades, one or two 512MB SO-DIMMs mounted horizontally to meet sub-0.5in. height limitations are usually required. Concurrently, the ECC function is required for detecting and automatically correcting errors of one bit per word. The 512Mbyte SO-DIMM is configured as 64Mx72 and can process data at a rate up to 333MHz.
Smart
Tel: +44(0) 1782 543 348
anthony.carter@smartm.com



Driver for rugged performance

Dy 4 Systems has introduced a VxWorks/Tornado board support package and driver suite for its SVME/DMV-181 ruggedised single board computer, Compatible with Tornado 2.2, the latest version of Wind River's development environment, the BSP provides a set of libraries and drivers enabling developers to integrate the SVME/DMV-181 into defence and aerospace applications running on the widely adopted VxWorks real-time operating system. Based on the 500MHz Power PC 7410 processor, the board offers a set of I/Os including six serial and dual Fast Ethernet and USB interfaces.
Dy 4 systems
Tel: +44(0) 1613 599 9199 ■

Fact: most circuit ideas sent to *Electronics World* get published

The best circuit ideas are ones that save time or money, or stimulate the thought process. This includes the odd solution looking for a problem – provided it has a degree of ingenuity. Your submissions are judged mainly on their originality and usefulness. Interesting modifications to existing circuits are strong contenders too – provided that you clearly acknowledge the circuit you have modified. Never send us anything that you believe has been published before though.

Don't forget to say why you think your idea is worthy.

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly. Where software or files are available from us, please email Jackie Lowe with the circuit idea name as the subject.

Send your ideas to: Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8BZ email j.lowe@highburybiz.com

Novel power flasher

This simple circuit uses a flashing LED to turn a power MOSFET on and off as the LED flashes. Resistive loads taking up to 10 amps at 12 volts may be driven depending on the MOSFET drain/source resistance and I_{dss}.

The LED can also be used as a local indicator if the load is located away from the on/off switch. A small heat sink is required for the MOSFET.

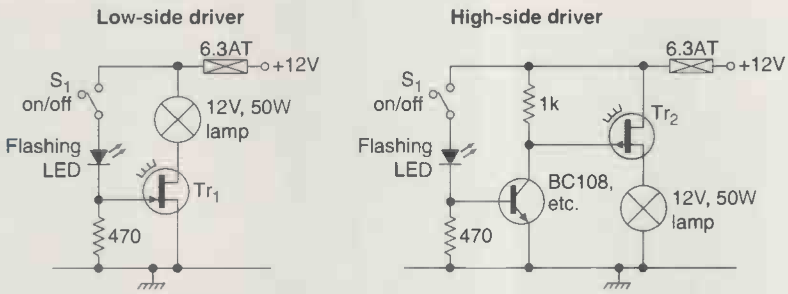
Two circuits are described; first the low-side driver. A voltage of around 6V is developed across R_1, which turns on Tr_1 when the LED is in conduction. Almost any n-channel 30V 20A TO 220 MOSFET with an R_{dss} greater than 0.2Ω will do.

The second circuit is the high-side driver. Again around 6 volts is developed across R_1 when the LED is on. Voltage across R_1 does not go sufficiently low to turn on the MOSFET when the LED is off so a simple inverter is introduced to enable the MOSFET to be fully turned on.

The bipolar transistor is fully saturated when the LED is on, causing the gate of the MOSFET to approach zero volts, turning the device fully on. Almost any p-channel MOSFET with similar specifications to the one mentioned above will work.

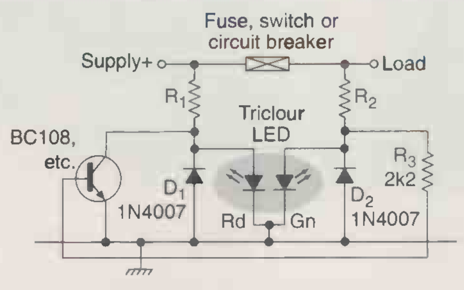
Note that the flash rate is around 2Hz and the duty cycle of the LED is 40:60. The circuit may not conform to local traffic regulations if it is installed in a vehicle.

Alistair Borthwick
Edinburgh



Power flasher with low-side or high-side driver options. Fet Tr_1 is a 30V, 20A n-channel type while Tr_2 is a 30V, 20A p-channel device.

Blown fuse indicator



Under normal conditions, this monitor circuit indicates the powered-up state via green light from a three-colour LED. If the fuse blows, the LED turns red.

In this idea, a combined red/green LED is used to indicate an open circuit fuse or circuit breaker. If the fuse is substituted for a switch or security loop, it can also indicate switch position or loop continuity, giving the status of both closed and open circuit conditions.

In normal operation – i.e. fuse OK – the green LED is illuminated and Tr_1 is held in the conduction state by the potential across the LED, shorting out the supply to the red LED. If the fuse is open circuit, the supply to the green LED is lost, Tr_1 ceases conduction and the red LED is now allowed to illuminate.

Diodes D_1 and D_2 are required for AC operation and can be omitted if a DC version is required. For 12V DC operation, R_1 and R_2 are around 1kΩ. For 240V operation, R_1 and R_2 should be 22kΩ, 4 watt minimum. Any safety and hazard regulations regarding circuitry working with mains voltage must be observed.

Alistair Borthwick
Edinburgh

Electronics World reader offer:

x1, x10 switchable oscilloscope probes, only £21.74 a pair, fully inclusive*

*Additional pairs as part of the same order, only £19.24 each pair.

Seen on sale for £20 *each*, these high-quality oscilloscope probe sets comprise:

- two x1, x10 switchable probe bodies
- two insulating tips
- two IC tips and two sprung hooks
- trimming tools

There's also two BNC adaptors for using the cables as 1.5m-long BNC-to-BNC links. Each probe has its own storage wallet.

To order your pair of probes, send the coupon together with £21.74 UK/Europe to ***Probe Offer, Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey, SM3 8BZ***

Readers outside Europe, please add £2.50 to your order.

Please supply the following:

Probes

Total__________

Name____

Address______________________________________

Postcode________________ Telephone________________

Method of payment *(please circle)*

Cheques should be made payable to ELECTRONICS WORLD

Access/Mastercard/Visa/Cheque/PO

Credit card no____________________________________

Card expiry date Signed

Please allow up to 28 days for delivery

Specifications

Switch position 1	
Bandwidth	DC to 10MHz
Input resistance	1MΩ – i.e. oscilloscope i/p
Input capacitance	40pF+oscilloscope capacitance
Working voltage	600V DC or pk-pk AC
Switch position 2	
Bandwidth	DC to 150MHz
Rise time	2.4ns
Input resistance	10MΩ ±1% if oscilloscope i/p is 1MΩ
Input capacitance	12pF if oscilloscope i/p is 20pF
Compensation range	10-60pF
Working voltage	600V DC or pk-pk AC
Switch position 'Ref'	
Probe tip grounded via 9MΩ, scope i/p grounded	

PRBS-generator with optional binary-to-MLT-3 converter

The pseudo-random binary sequence generator described here conforms to the ITU O.151 standard and produces a 2^{23}–1 random bit sequence before repeating the bit patterns. It is based on the principle of clocking a long shift register with feedback from different register stages as shown in the principle diagram in **Fig. 1**.

Although the principle is well known, I have not found a simple implementation with conventional logic. So I developed the simple but effective circuit depicted in Fig. 2.

At the core of the PRBS Generator core are registers $IC_{2,3,4}$ and the XOR-gate, IC_5. As the feedback is taken from stages 18 and 23, only the last register, IC_4, needs to be one that has all of its shift stage outputs available externally. I used a 74HC164.

The other two registers, IC_2 and IC_3, are 74HC165 types which have an output from the last stage only. However, they have preload inputs, which are very important in this application. The reason is that the bit pattern 000 0000 0000 0000 0000 0000 is not allowed for this PRBS generator. It would result in all stages sticking in a continuous zero-state, so the device will not generate it.

To prevent the pattern, a short negative pulse is applied to the reset input (CLR) of IC_4 and to the load inputs (SH/LD) of IC_2 and IC_3. This initial pulse is generated by the network R_2/C_3. As a result, all stages of IC_4 are initially loaded with zeros and all stages of IC_2 and IC_3 are loaded with "1", as the A-H inputs are tied to the positive supply rail. So the initial bit pattern is 000 0000 1111 1111 1111 1111 and the device will not stick in the forbidden state.

Via selector S_1, the user is given the choice of using the internal 10MHz clock generator, built around $IC_{1A/B}$, or to clock the shift registers with an external clock fed in via J_1. As the design was constructed as a laboratory project for the students at the Department of Electronics of Sofia University, it incorporates a binary data-to-MLT-3 converter.

MLT-3 stands for multi-level transition and was developed by Cisco for driving Ethernet data over UTP Cat. 5 cables as a part of bandwidth efficient encoding scheme. It has a lower frequency content

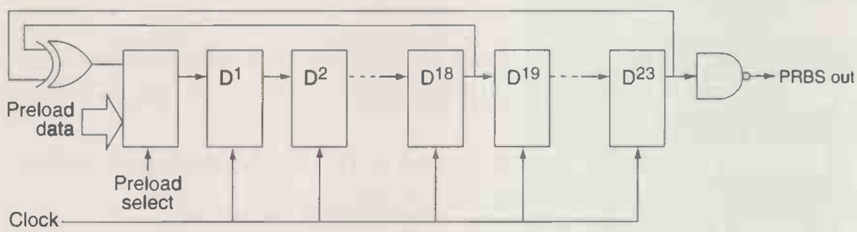


Fig. 1. Outline of a pseudo-random binary sequence generator using shift registers and feedback.

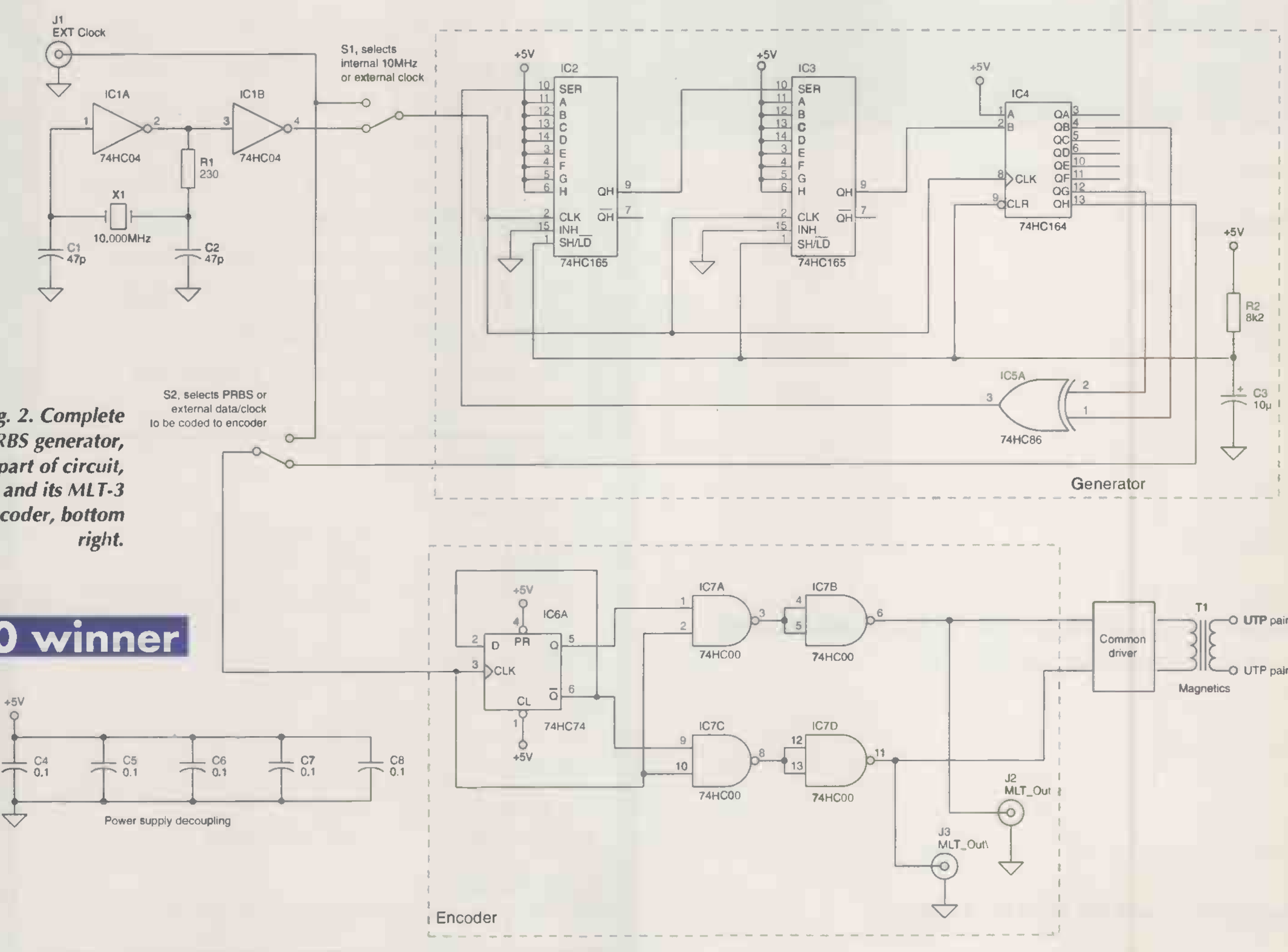


Fig. 2. Complete PRBS generator, top part of circuit, and its MLT-3 encoder, bottom right.

£50 winner

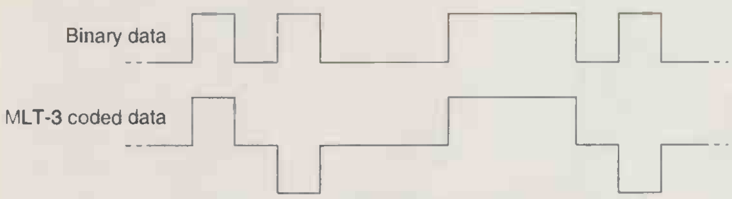


Fig. 3. A standard binary serial stream, top waveform, and an MLT-3 stream, bottom.

compared to the binary data. The typical conversion mechanism is depicted in Fig. 3.

In the circuit this function is accomplished by IC_6 latch and IC_7 gates, which are alternately enabled by the Q and Q\ outputs of the latch. I found this type of converter in the data sheet of National Semiconductor's DP83843 PHYTER 802.3 physical layer device[1].

Binary data feeding the encoder can be either the PRBS data from the first part of the circuit or external data available through J1-input. Data source selection is carried out using S_2.

The MLT-3 signal can drive an optional transformer, T_1, to interface to UTP-cable. Alternatively, it can be viewed via two channels of an oscilloscope, set in the 'channel-1-minus-channel-2' mode, for which connectors J_2 and J_3 are provided.

Emil Vladkov
Sofia, Bulgaria

Reference

1. National Semiconductor Corporation, DP83843BVJE PHYTER data sheet, July 1999, http://www.national.com.

Low-distortion audio-range oscillator

Producing low-distortion sine waves, this oscillator operates over the range 16 to 22000 Hz. The circuit is based on two articles that have appeared earlier in *Wireless World* – Roger Rosens' 'Phase-Shifting Oscillator', February 1982 pp. 38-41, and J. L. Linsley Hood's 'Wien-Bridge Oscillator with low harmonic distortion' from May 1981 pp. 51-53.

This design features the simplicity of the Rosens' circuit but avoids the use of a thermistor. Instead, oscillator stability is controlled by means of a common photo-resistor driven by a LED, as suggested in the Linsley Hood article.

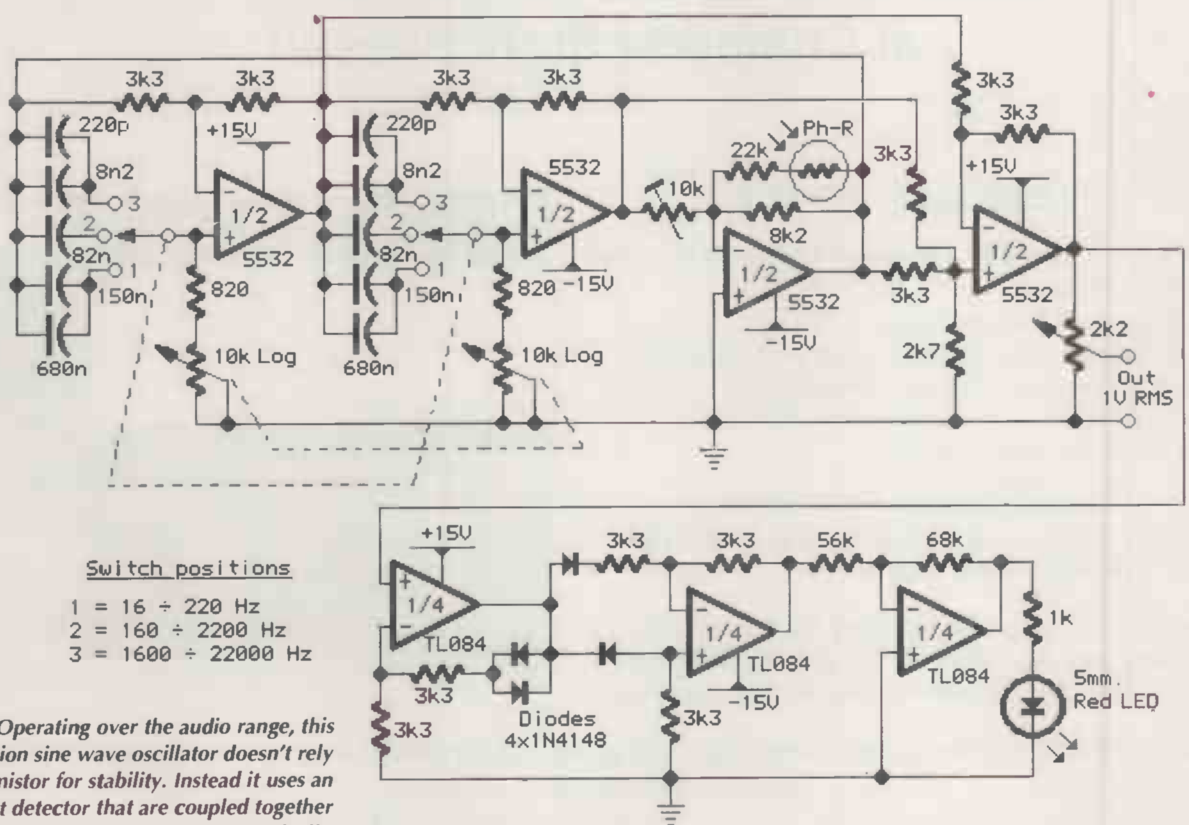
There is no settling time when the oscillator's frequency is changed and no bouncing of the output waveform. Use of an expensive and sometimes difficult to obtain thermistor is avoided.

Any common photo-resistor and 5mm red LED can be used, provided they are in close contact and enclosed in a light-proof small box. For this purpose, I used the metal screen of a small IF transformer for AM transistor radios sealed with black insulating tape.

The 10kΩ trimmer must be set to obtain a 1V RMS output. THD measured with a home-made distortion meter described in *Wireless World* (J. L. Linsley Hood: Spot-Frequency Distortion meter, July 1979 pp. 62-66) was as follows:

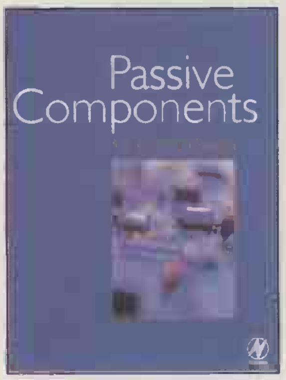
Frequency	Reading
100Hz	0.0035%
300Hz	0.0028%
1kHz	0.002 %
3kHz	0.002 %
10kHz	0.001 %

Flavio Dellepiane
Italy



Operating over the audio range, this low-distortion sine wave oscillator doesn't rely on a thermistor for stability. Instead it uses an LED and light detector that are coupled together optically.

BOOKS TO BUY



PASSIVE COMPONENTS FOR CIRCUIT DESIGN

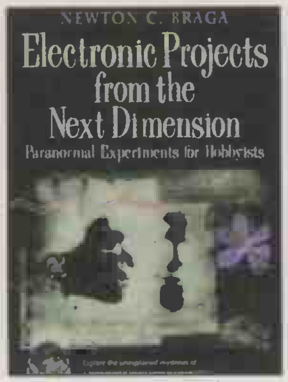
Passive Components for Circuit Design is a unique introduction to this key area of analog electronics designed for technician engineers and anyone involved in circuit design. The coverage encompasses all component types capable of power amplification: resistors, capacitors, transformers, solenoids, motors and transducers. The behaviour of the components is explored along with the different types available and the principles of circuit design. Tolerances, stability, variation with temperature, reliability and manufacturing standards are all covered. Reading this book will improve your skills in component selection and analog circuit design. These are essential skills not only for the analog designer, but for all circuit designers, professional or amateur.

Contents: Preface; Fundamentals; Fixed resistors; Variable resistors, potentiometers and diodes; Capacitors; Inductors and inductive components; Inductive devices; Transducing components; SMT; Hardware; Index

Readership: Technician engineers, circuit designers, advanced hobbyists

Pages: 304pp

Price: UK £23.00
Europe £24.00
ROW £27.00



ELECTRONIC PROJECTS FROM THE NEXT DIMENSION

For years paranormal scientists have explored the detection and documentation of spirits, auras, ESP, hypnosis, and many more phenomena through electronics. Electronic Projects from the Next Dimension provides useful information on building practical circuits and projects, and applying the knowledge to unique experiments in the paranormal field. The author writes about dozens of inexpensive projects to help electronics hobbyists search for and document their own answers about instrumental transcommunication (ITC), the electronic voice phenomenon (EVP), and paranormal experiments involving ESP, auras, and Kirlian photography.

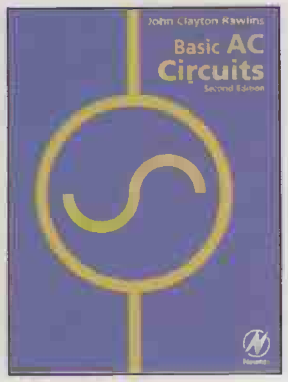
Although paranormal studies are considered esoteric, Electronic Projects from the Next Dimension teaches the technical skills needed to make devices that can be used in many different kinds of experiments. Each section indicates how the circuit can be used in paranormal experiments with suggestions about procedures and how to analyze the results.

Contents: White noise generators for use in instrumental transcommunication (ITC) and electronic voice phenomenon (EVP) experiments; Practical circuits for image experimentation, such as a wireless sparkling image generator, horizontal bar generator, brontophic sound, magnetic field generator, high-voltage generators (Kirlian Machine's I & II); Paranormal skills experiments with temperature change, polygraph, electro-shock, random number generation, UFO detection, and ghost-finding.

Readership: Hobbyists, Electronics Enthusiasts

Pages: 256pp

Price: UK £28.00
Europe £30.00
ROW £37.00



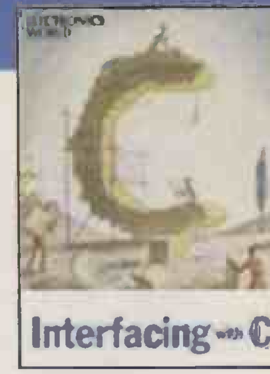
BASIC AC CIRCUITS

This is the step-by-step approach for beginners. This self-paced individualized learning tool covers concepts, terms, and the mathematics required to understand AC circuit problems. It has been designed to improve analysis techniques for prediction and control development.

Readership: Beginners meeting AC circuits for the first time: students; technicians

Pages: 921pp

Price: UK £34.00
Europe £36.00
ROW £38.00



INTERFACING WITH C

A practical and painless way of becoming an expert C programme New edition also covers C++ and the Windows environment Get up to speed with the essential maths needed for C without having to buy a university maths text!

Price: UK £20.00
Europe £22.00
ROW £24.00

Post your completed order form to:-

Jackie Lowe,
Highbury Business Communications,
Anne Boleyn House, 9-13 Ewell Road,
Cheam, Surrey, SM3 8BZ

How to order

Book Title ____________________

❑ I enclose a cheque/bank draft for £__________
(payable to ELECTRONICS WORLD)

Please charge my credit/charge card
❑ Mastercard ❑ American Express ❑ Visa ❑ Diners Club

Credit Card No: Expiry Date:

____

Signature of Cardholder____________________

Cardholder's statement address: (please use capitals)

Name____________________

Address____________________

____

____

Post Code____________________Tel:____________________

Personal computers have become so fast and convenient that they are appropriate platforms for digital signal processing of long data files or real-time signals. DSP design can be mathematically daunting, but it needn't be. This article describes the straightforward design of a finite impulse response (FIR) filter that can be tailored to specific needs without the consultation of a mathematician. Christopher Kuni explains.

FIR Filter on a PC

The filter's response is arbitrary, within reasonable limits, even beyond the classical lowpass, highpass, and bandpass characteristics. Windows WAV sound files or raw 16-bit PCM data files can be processed.

The design involves several bedrock DSP concepts, including the discrete Fourier transform, convolution, block convolution, the convolution theorem, aliasing, the Gibbs phenomenon, and window functions. Although the article is intended as an introductory tutorial and briefly explains these subjects, the reader should have either a passing familiarity with them or a good entry-level DSP textbook at hand; see the reference list. Software development is in C, and at least a basic understanding of this language is assumed.

Central to this design is the discrete Fourier transform (DFT). A particular implementation of the DFT, the fast Fourier transform (FFT), speeds computation very significantly. Writing one's own version of the FFT is pointless, given that many excellent published versions are available. I use four1() from Reference 1, a book that I believe should be in the library of anyone who does scientific programming in C. The code cannot be reproduced here because of copyright restrictions, but you can find it at www.nr.com; follow the links to Numerical Recipes Books On-line, and go to Chapter 12. Be sure to read the copyright information carefully, as willy-nilly reproduction of text from the book is not permitted.

I chose the FIR approach because FIR filters have three advantages over infinite impulse response (IIR) filters. First, they are absolutely stable; there is no feedBack (or recursion, in DSP parlance) so no possibility of instability. Second, they are robust; computational imprecision has less effect on frequency response than in the IIR case. Third, they have linear phase response if their impulse response is symmetrical or antisymmetrical, an easy design criterion to meet. On the other hand, for some response requirements, IIR filters are simpler and therefore faster.

Figure 1 shows the topology of an FIR filter of length 5. In general, the number of unit delays is determined by the design requirements. Narrow transition bands require long filters.

A moment's reflection will reveal that Figure 1 represents a convolution in which the gains h_0-h_4 constitute the convolution kernel. This observation is important because we can implement our filter as a convolution using the FFT at considerable savings in computation time as compared with brute-force multiplication and adding of data samples as they march along a digital bucket brigade[1].

The discrete series formed by the h's is the impulse response of the filter. This can be seen intuitively by imagining a sample of unit amplitude travelling through the delay line formed by the unit delays. The filter output will then be the series h_0, h_1, h_2, h_3, h_4.

One of the most powerful tools in DSP is the

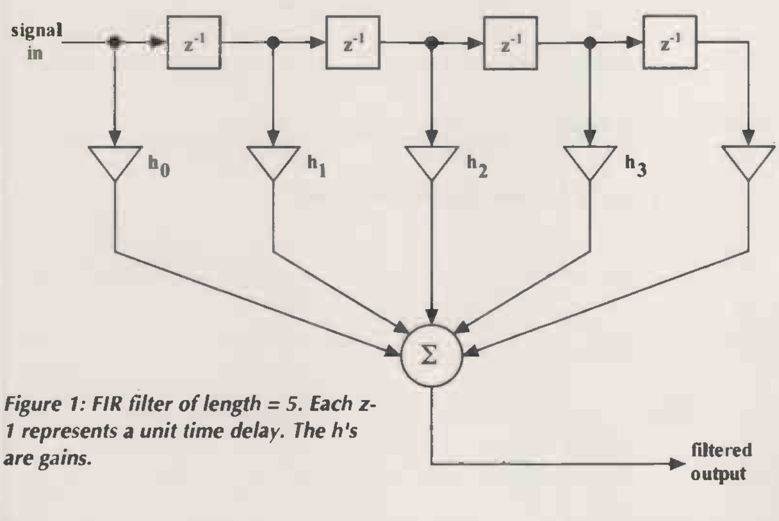


Figure 1: FIR filter of length = 5. Each z-1 represents a unit time delay. The h's are gains.

convolution theorem, which in words states that convolution in the time domain can be accomplished by simple multiplication in the frequency domain. So our filter can be accomplished by multiplying the Fourier transforms of the impulse response and the input data, **Figure 2.** For a particularly clear discussion of this concept, see Reference 2, another must-have.

To calculate the h's we make use of the fact that the frequency response of a digital system is periodic in frequency with a period equal to f_s, the sampling frequency[2]. This periodicity suggests that we might use the Fourier transform to derive the impulse response of our filter from the frequency-domain response specification. The Fourier coefficients obtained from the transform of a single cycle of the periodic frequency response would specify an infinitely long impulse response. This series is in effect truncated to some manageable length N if we sample the specified frequency response at N equally spaced points and then perform the DFT on these samples; if we use the FFT, N must be a power of 2. It turns out that this intuitive approach has a sound mathematical basis, but, as usual in engineering design, the devil is in the details.

Given a frequency response specification, say a low-pass characteristic with a cutoff at a quarter of the sampling frequency, the DFT yields a wrapped-around version of the desired impulse response **Figure 3.** The time-domain values must be unwrapped to give the h's in the necessary order for convolution. Note that the zero-frequency[3] and negative frequency values of the response must be specified in wrap-around order; the response at a given frequency is specified the same at that frequency and at its negative counterpart. The middle non-zero time value is duplicated at the ends of the impulse response to yield a symmetrical function with an odd number (i.e. N+1) of values. The procedure is simple, but mathematical purists may roll their eyes in despair at this explanation; they can find a lucid mathematical explanation of why this approach works in Reference 3.

A rough estimate of the required length of an FIR filter can be obtained from

$$N_{est} = \frac{2}{3}\log\left(\frac{1}{10\delta_1\delta_2}\right)\frac{\omega_S}{\Delta\omega}$$

where N_{est} is the estimated filter length, δ1 is the peak passband ripple, δ2 is the amplitude of the highest stopband ripple lobe, ω_s is the sampling frequency, and $\Delta\omega$ is the width of the narrowest transition band in the design. δ_1 and δ_2 are fractions of unity rather than dB. So for a 1dB peak passband ripple and a -40dB stopband, δ_1=0.12 and δ_2=0.01. If the sampling frequency is 44.1kHz and the narrowest transition band is 500Hz, then N_{est} = 113. This estimate does not take into account the window function (described presently), so it is indeed rough, but useful as a starting point. N must be one greater than a power of 2, so we would choose a first-guess filter length of 129.

So far, so good. But now we wonder how well the filter's actual response matches the specified response, given that we calculated an impulse response of only length N+1; that is, we discarded an infinite number of points! The actual response will always be only an approximation to the specified response. There are two ways to check this. A quick and dirty method, and one that is frequently sufficient, is to subject the filter to a chirp (swept frequency) input and inspect the output with a sound file editor. The second, more precise way is to calculate the exact response from

$$H(\omega) = e^{-jM\omega T}\left[h_M + 2\sum_{n=0}^{M-1} h_n \sin(M-n)\omega T\right]$$

$$M = \frac{N-1}{2}$$

where H(ω) is the complex filter gain, ω is frequency in radians/second, N is the filter length, and hM is the central point around which the impulse response is symmetrical.

The calculated response can be viewed with plotting, spreadsheet, or mathematics software[4]. If adjustments are needed, these are made, and the process is repeated until the response meets design requirements. This iterative process is formalized in the Remez exchange algorithm (Reference 4), into which we will not delve further, but the

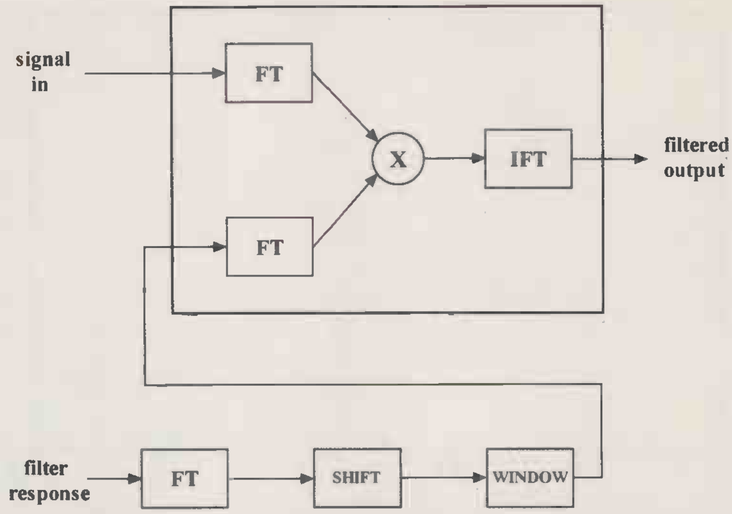


Figure 2: FIR filter implemented by inverse FFT of product of FFTs of impulse response and input signal. Operations within the box constitute convolution. The shift operation re-orders the wrapped data.

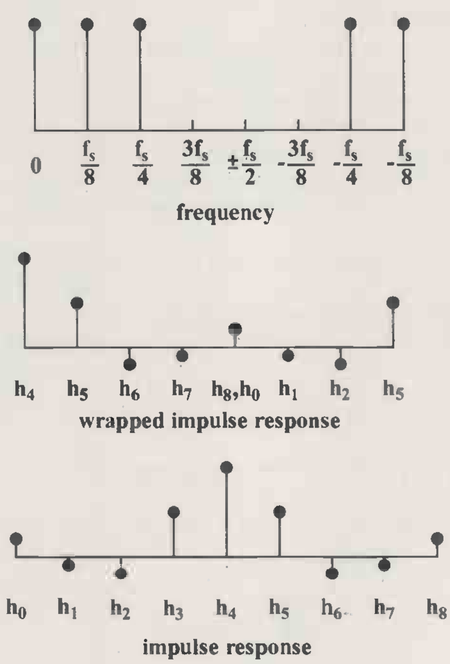


Figure 3: Generation of the impulse response for a lowpass filter having a cutoff 0.25fs. fs is the sampling frequency. Note wrapped order of frequencies in which the positive frequencies increase to the right of 0 to fs/2, which is also the magnitude of the highest negative frequency (top). Negative frequencies decrease to the right of fs. Both positive and negative frequency amplitudes of the desired response must be specified. The wrapped transform (middle) of the specified response is re-ordered to give the impulse response (bottom).

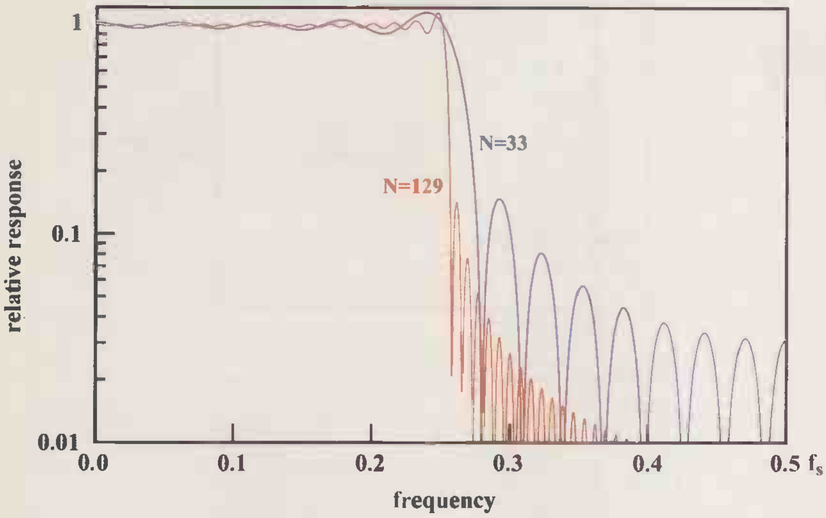


Figure 4. Frequency responses of lowpass filters of lengths 33 and 129.

informal cut-and-try approach is usually surprisingly fast. The only changes that are made in each iteration, other than to the original filter specification, are to filter length and to the window function.

A few examples will clarify the preceding ideas. Figure 4 shows the calculated frequency responses for N=33 and N=129 of a low-pass specification having a cut-off frequency of $0.25f_s$. Two defects plague the results. First, the passbands have significant ripple. Second, the stopbands also have ripple lobes, the largest of which has an amplitude of only about 17dB below passband gain in both filter lengths.

These defects result from the Gibbs phenomenon, which is the non-uniform convergence of the Fourier series near a discontinuity. This bugaboo of FIR design affects the present result because we determined the impulse response

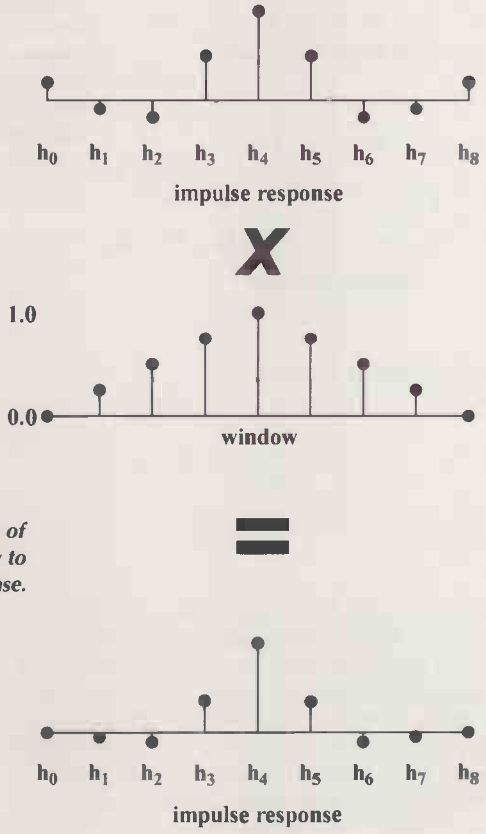


Figure 5. Application of triangular window to impulse response.

from the Fourier transform of a response specification that has a discontinuity and we were forced to truncate the impulse response to a finite length, in this case 33 or 129 (that is, we calculated only 33 or 129 values of the infinite series).

Increasing the filter length will not significantly decrease the passband ripple or the amplitude of the stopband ripple lobes near the discontinuity. However, Gibbs effects can be minimized by specifying a gradual rather than discontinuous transition between the passband and stopband, or, equivalently, by gradually tapering the ends of the impulse response toward zero. This tapering is accomplished by applying a window function to the impulse response. The simplest[5] is the triangular or Bartlett window, in which the tapering function is linear, shown for a filter of length 9 in **Figure 5**.

The effect of the Bartlett window is to reduce the passband and stopband ripple amplitude but at the cost of a widened transition band, **Figure 6.** The tapering of the impulse response can obviously follow any number of functions. Among the most widely used windows are the Bartlett, Hamming, Von Hann (frequently corrupted to "Hanning" in the literature), Blackman, and Kaiser. In general, these windows offer different trade-offs between reduction of Gibbs effects and widening of the transition band; the Kaiser window allows the designer to specify this trade-off. Mathematical descriptions of these windows are in almost any DSP text.

Although increasing filter length does not reduce Gibbs effects near a discontinuity, it does narrow the transition band, Figure 6. The cost of an increased filter length is increased computation time. In the present application, this cost is not as great as one might think at first glance. Blocks of data are processed serially, so larger blocks mean fewer blocks. The overall result is only a modest increase in computation time for a long input data set when filter length is doubled; the details depend on the local computer, compiler, hard drive, i/o overhead, etc.

As convolution of the whole data file would in general be impractical, sequential blocks of data are convolved with the impulse response. If the convolution results were simply spliced together, the output file would be spoiled by end effects of convolution. One solution to this problem is the overlap-save method of block convolution, in which overlapping blocks of data are convolved with the impulse response, and in which only a portion of the right-hand end of the convolution result is saved and moved to the output file. The amount of overlap used here is 50%, and this is also the fraction of the convolution result that is saved. Reference 5 contains an excellent discussion of this method of block convolution.

The program is written in ANSI C. The input/output details are kept as simple as possible; you may need to modify these for your compiler and operating system. Windows WAV files are accommodated by copying the input file header to the output file. For this manoeuvre to work, the program insures that the lengths of the input and output files are identical. For raw PCM files, simply omit the for loop that copies the header.

Next, the specified filter response is synthesized. Both the negative and positive frequencies must be specified, as must zero-frequency, in wrap-around order as shown at the top of Figure 3. The array spectdat[] is complex: the zeroth and even-numbered elements are real and the odds are imaginary. All imaginary elements must be set to zero (done here when spectdat[] is declared). A lowpass filter is specified in this example.

The amplitude correction sets the overall gain of the filter to 1.0. The program then calls four1() to do the DFT on the response specification. Note that the pointer to spectdat[] is decremented by 1 in this call so that the elements of spectdat[] can start at 0 rather than 1. (This oddity of four1() is presumably left over from an earlier Fortran incarnation.) The transform replaces the previous values stored in spectdat[]. Because the specified frequency response is a symmetrical function, the calculated imaginary elements of the array remain zero (or nearly zero). This result is then re-ordered for convolution.

Both sides of the impulse response are then subjected to the window function. The middle value is left unchanged. The right N-1 real elements of the array are padded with zeroes.

The first step of the convolution is to perform the DFT on the windowed impulse response. The program performs this operation once, and the result is used repeatedly as blocks of data are read and convolved.

The while-loop reads blocks of data into the right half of an array having twice the number of complex elements as the block length; this block is moved to the left half of the array before the next block of data is read. The complex product of the transform of a copy of this array is taken with the transform of the zero-padded impulse response. The product is inverse transformed by four1(), and the right-hand half of the result is sent to the output file; the left-hand half of the result is discarded.

The if-else control statements and associated code insure that the length of the input and output files will be equal. Up to 2(N-1) samples at the end of the input file may not be processed in this scheme, but a series of 2(N-1) or more zeroes appended to the end of the input file would cure this trivial problem. Most sound files end with far more silence than this.

This bare-bones program will prove useful for many practical filtering problems but for the sake of clarity is uncluttered by niceties that will be presented in a subsequent article. Features that are excluded for the time being are the calculation of the frequency response, and importing/exporting the specified and calculated frequency responses.

Because four1() operates on complex data, some (nearly half) of its calculations are redundant when the input files are real. This redundancy can be eliminated by clever manipulation of the data arrays on which four1() operates, for a significant gain in computation speed. This subject will also be taken up later.

The impulse response is always symmetrical and one greater than a power of 2 in this design. These restrictions, imposed here for simplicity, are in general not necessary, so other more efficient designs may sometimes be possible. Consult the literature and experiment. A good compiler debugger will serve as a bank of DVMs, and sound editing or data plotting software as an oscilloscope.

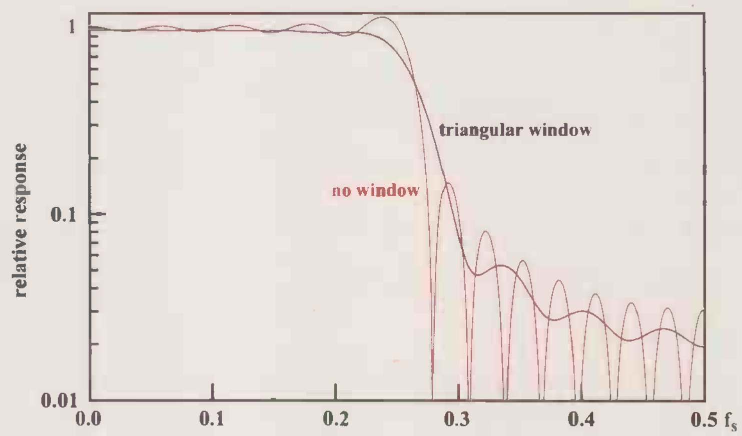


Figure 6. Effect of window function.

Notes

1. Note that the operations in Figure 1 need not be digital. An analogue delay line, analogue multiplications by the h's, and analogue addition will in theory accomplish the same result as the digital implementation. If you are put off by DSP and want to ease the transition from analogue design, you can set up a series of clocked analogue sample-and-holds, op-amp gain blocks, and a summer, and explore the signal flow through the filter with an oscilloscope. I once spent an enjoyable and enlightening Sunday afternoon doing exactly that.

2. This periodicity means that input frequencies above half the sampling frequency will appear in the output as lower frequencies. For example, if the sampling frequency is 44.1kHz, then an input frequency of 23.05kHz will appear at the output as 23.05 - 44.1/2 = 1.0kHz. This phenomenon, known as aliasing, leads to very disturbing audio distortion unless the input signal is effectively band-limited to exclude frequencies above half the sampling frequency. Inexpensive PC sound cards that I have used for analogue to digital conversion band-limit surprisingly well.

3. I prefer "zero-frequency" to "D.C." or "direct current," as there is no current - just a series of 1s and 0s.

4. I use Psi-Plot plotting software, which includes a spreadsheet, and Mathematica, which has flexible plotting capabilities.

5. One could argue that the rectangular window is the simplest. Such a window multiplies within its bounds all values of the impulse response by unity, and all values outside its bounds by zero. This is the function that truncated the infinite series of Fourier coefficients.

References

1. Press WH, et al: Numerical Recipes in C, 2nd ed. Cambridge University Press, 1992, pp 496-536.
2. Brigham EO: The Fast Fourier Transform. Prentice-Hall, 1974, pp 58-64.
3. Bozic SM: Digital and Kalman Filtering. Edward Arnold, 1979, pp 33-44.
4. Baher H: Analogue and Digital Signal Processing. John Wiley and Sons, 1990, pp 316-338.
5. Shynk JJ: Frequency-Domain and Multi-rate Adaptive Filtering. IEEE Signal Processing Magazine, January 1992, pp 14-37.

The Program

```
/*      FIRFIL.C

READS A .WAV FILE, CONVOLVES IT WITH FFT OF SYNTHESIZED
SPECTRUM. UP TO 2(N-1) SAMPLES AT END OF OUTPUT FILE ARE
SET TO ZERO, SO INPUT & OUTPUT FILES ARE SAME LENGTH. 44
BYTE HEADER IS COPIED. POINTER TO data[] IS DECREMENTED IN CALLS
TO four1() SO ARRAYS CAN START AT 0 INSTEAD OF 1. */

#include<stdlib.h>
#include<stdio.h>
#include<math.h>
```

```
#define N 257 /* length of FIR filter */
#define SWAP(a,b) tempr=(a);(a)=(b);(b)=tempr /* for four1()
*/

main()
{
   void four1();

   int outt, p=0, q=0, i=0, tempdat, isign, m, m2, m4;
   static float ddata[4*(N-1)]={0}, spectdat[4*(N-1)]={0},
   dout[4*(N-1)]={0}, datin[4*(N-1)]={0};

   short int inn;

   FILE *in;
   FILE *out;

   in=fopen("c:\\temp\\input.wav","rb");
   out=fopen("c:\\temp\\output.wav","wb");

   m=N-1;
   m2=2*m;
   m4=4*m;

   /* Copy .wav header: */

   for(q=0;q<22;q++)
   {
     fread(&inn,sizeof(inn),1,in);
     fwrite(&inn,sizeof(inn),1,out);
   }

   /* Synthesize spectrum of lowpass filter having cutoff
    frequency = sampling freq/4: */

   for(i=0;i<(N-1)/2;i+=2)
   {
     spectdat[i+2]=1.0;  /* Sets positive freqs to 1.0 */
     spectdat[(N-1)*2-i-2]=1.0; /* Sets negative freqs to
1.0 */
   }

   spectdat[0]=1.0;  /* Sets zero-freq to 1.0 */


   /* Amplitude correction: */

   for(i=0;i<m2;i+=2) spectdat[i]=spectdat[i]*m2;


   /* Do fft on filter spectrum to get filter kernel: */

   four1(spectdat-1,m,1);

   /* Move 0-time to middle of left N/2+1 complex elements,
i.e.
    N+1 array elements. Arrange negative times to left of
middle
    and positive times to right. Duplicate at each end the
real value
    that was originally in the middle. Kernel will then have
the
    correct form for convolution: */

   for(i=0;i<m+1;i+=2) spectdat[m2-i]=spectdat[m-i];
   for(i=0;i<m;i+=2) spectdat[i]=spectdat[m2-i];


   /* Apply triangular window to kernel: */

   for(i=0;i<m+1;i+=2)
   {
     spectdat[i]=spectdat[i]*i/m;
     spectdat[m2-i]=spectdat[m2-i]*i/m;
   }

   /* Take fft of kernel for convolution: */

   four1(spectdat-1,m2,1);

   while(1)
   {

     /* Read a block of m samples into
       right half of array: */

     for(q=m2;q<(m4-1);q+=2)
        {
          fread(&inn,2,1,in);
          if(feof(in)) break;
          datin[q]=inn;
        }

        /* Copy input array to ddata[] for fft because
four1()
         corrupts input array: */

        for(p=0;p<m4;p+=1) data[p]=datin[p];

        /* If end of file was not reached,
         do fft on ddata[]: */

        if(q==m4)
        {
          four1(ddata-1,m2,1);

          /* Take the complex product of the transformed
signal and the
            transformed kernel: */

          for(i=0; i<(m4-1); i+=2)
          {
             dout[i]=spectdat[i]*ddata[i]-
             spectdat[i+1]*ddata[i+1];
             dout[i+1]=spectdat[i+1]*ddata[i]+
             spectdat[i]*ddata[i+1];
          }

          /* Take the inverse fft of the product to complete
            the convolution: */

          four1(dout-1,m2,-1);


          /* Write m right-hand output values
            and discard m left-hand values: */

          for(p=m2;p<(m4-1);p+=2)
          {
             tempdat=dout[p];
             fwrite(&tempdat,2,1,out);
          }

          /* Copy m right values to left half of array: */

          for(p=0;p<(m2-1);p+=2) datin[p]=datin[p+m2];



        }


        /* Set left-over fraction of last block to 0: */

        else
        {
          for(p=0;p<((q-m2)/2);p++)
          {
             tempdat=0;
             fwrite(&tempdat,2,1,out);
          }
        }

      if(feof(in)) break;

    }

    fclose(out);
    fclose(in);
    return(0);
}

void four1(float data[],int nn,int isign)
/* Replaces data by its DFT if isign is 1 or by nn times its
  inverse DFT if isign is -1. Data are a complex array of
length
  nn, input as a real array data[1..2*nn]. Odds Re, evens
Im.
  nn must be an integer power of 2.*/
{ /* four1() code goes here */ }
```

Wim de Jager

Improved hybrid power amplifier

In the November 1996 issue of Electronics World, I described a hybrid power amplifier based on a solid-state phase splitter driving the push-pull valve output stage.

A main feature is the avoiding of dc-offset problems in the toroid output transformer by an op-amp based integrator. Dominant pole frequency compensation limits the bandwidth to 35kHz. To be able to deal with today's high performance audio sources, such as super audio CDs, we need bandwidth improvement. Apart from frequency compensation the output transformer has a HF –3dB cut-off frequency of 188kHz. It is therefore a challenge to enlarge the circuit's bandwidth and exploit a larger part of the transformer's bandwidth. Minor circuit changes result in a closed-loop HF –3dB cut-off frequency of 170kHz and a slew rate of 15V/µsec. The corresponding Full Power Bandwidth amounts to 100kHz.

Modifications

To achieve a slew rate of 15V/µsec (without the use of frequency compensation) the tail-current of the differential input stage (Q3,Q4), see **Fig.1**, must be enlarged from 2mA to 5.5mA. This leads to the following modifications: R8 = R12 = R13 = 100Ω, R5 = R6 = 10Ω and R10 = R11 = 47kΩ. Note that by this actions the open-loop HF –3dB cut-off frequency has been increased from 6kHz to 30kHz. At full drive, the output signal of the preamplifier is clipped at –50V in the first design, which does not affect the performance adversely. This phenomenon results in switching distortion at high frequencies in the improved version. Note that for an operating point of the cathode

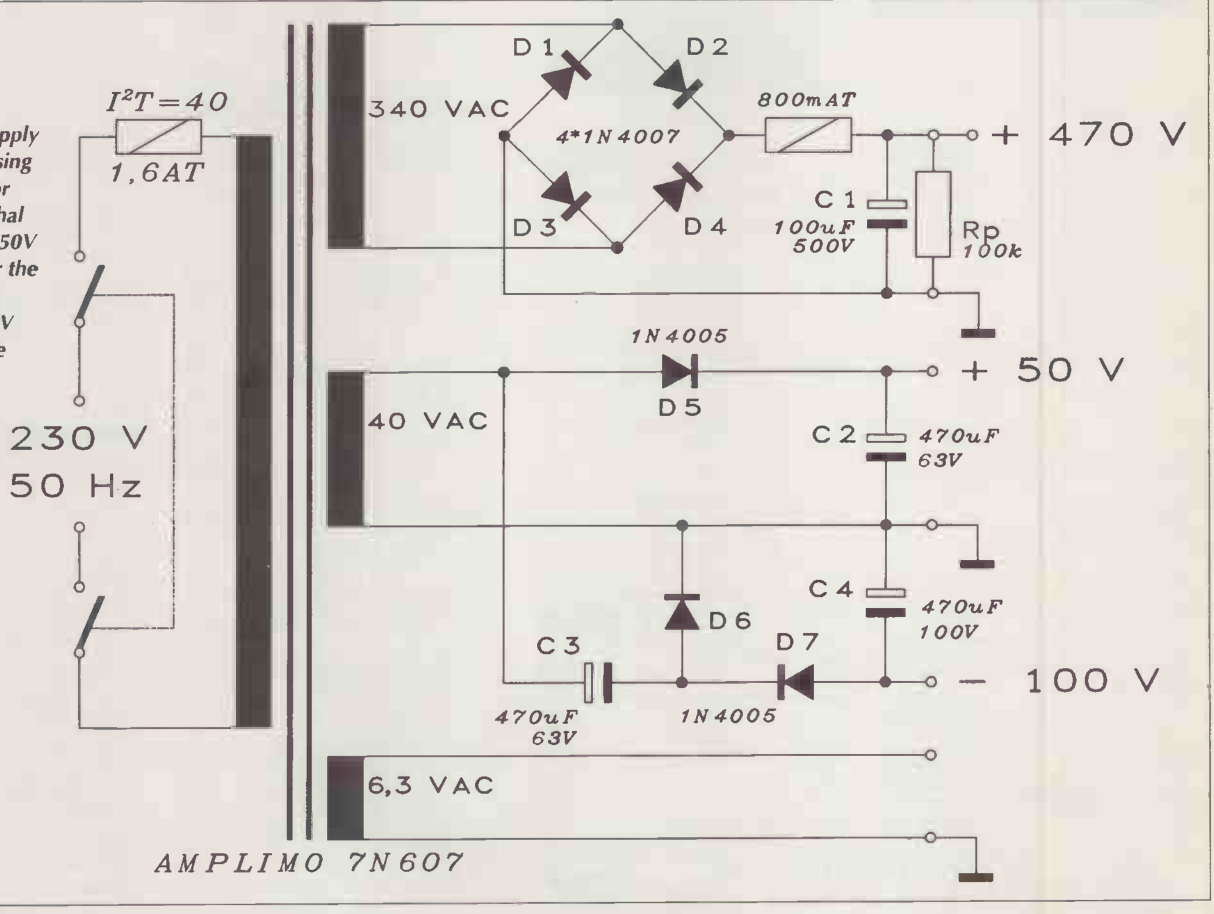


Fig.2 Power supply circuit comprising ht at the top for the valves –lethal don't forget- +50V and –100V for the phase splitting circuit and 6.3V for the cathode heaters.

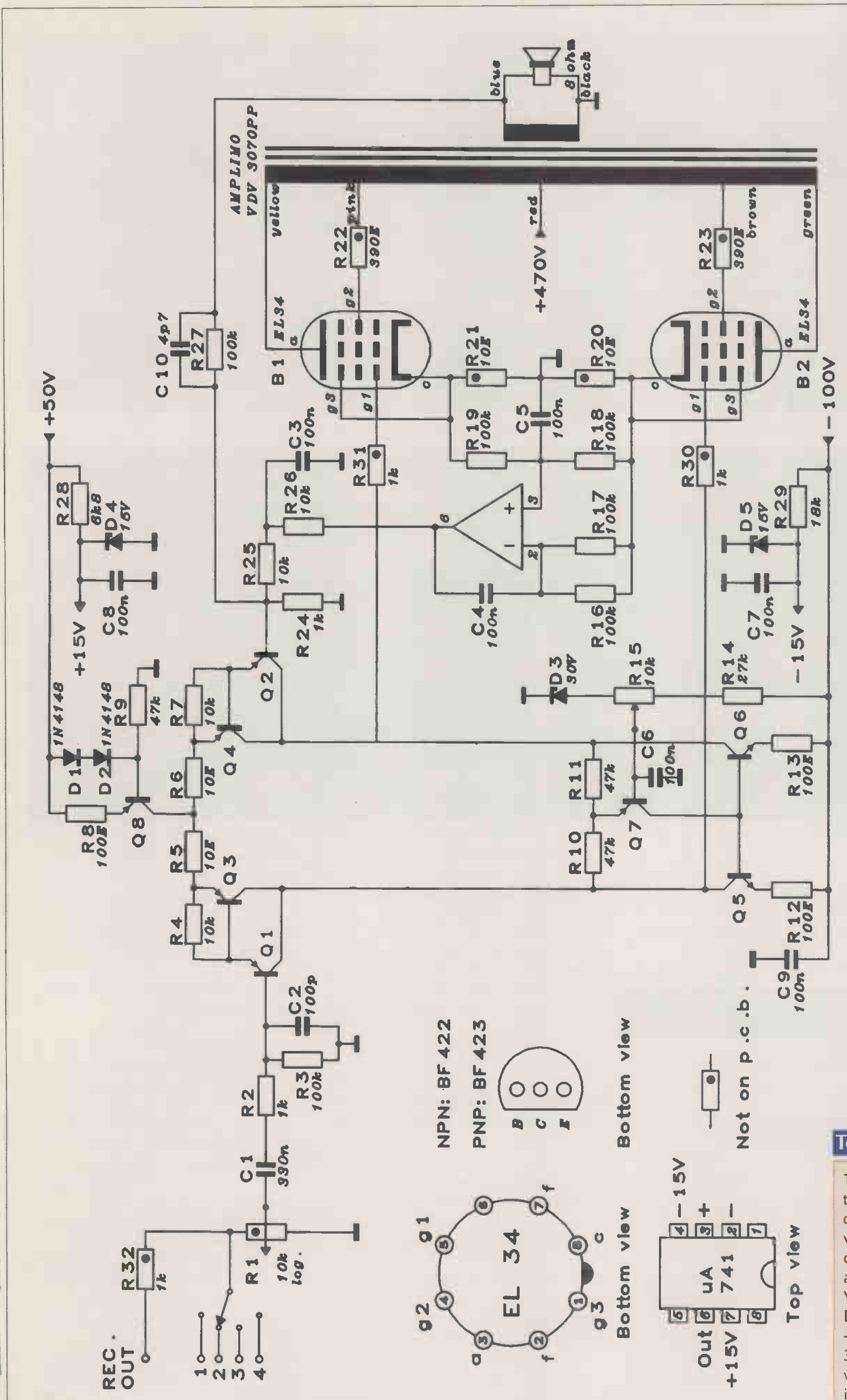


Fig.1 The improved hybrid 40W power amplifier uses transistors for phase splitting, an IC integrator for dc feedback and valves for power driving and features a 30Hz-100kHz Full Power Bandwidth.

Technical support

The output and power-supply transformers, special fuses, ht capacitors, matched EL34 valves, valve bases and printed circuit boards are all obtainable from Amplimo, Vossenbrinkweg 1, 7491DA, Delden, The Netherlands, Tel. +31-74-3763765, Fax +31-74-3763132, Internet: www.amplimo.nl, E-mail: info@amplimo.nl.

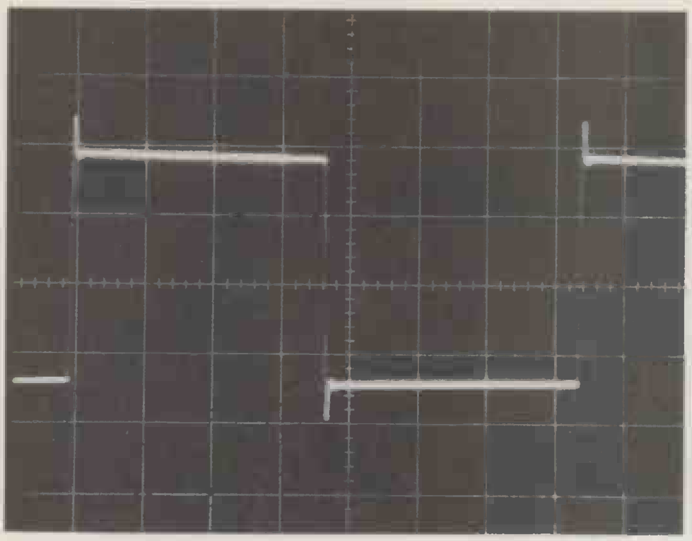


Photo 1 Square-wave response (2kHz) with open output

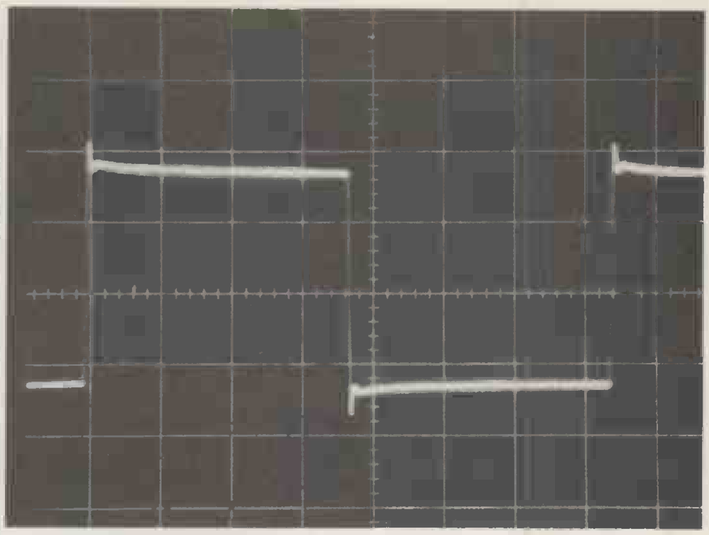


Photo 2 Square-wave response (2kHz) at RL=8Ω

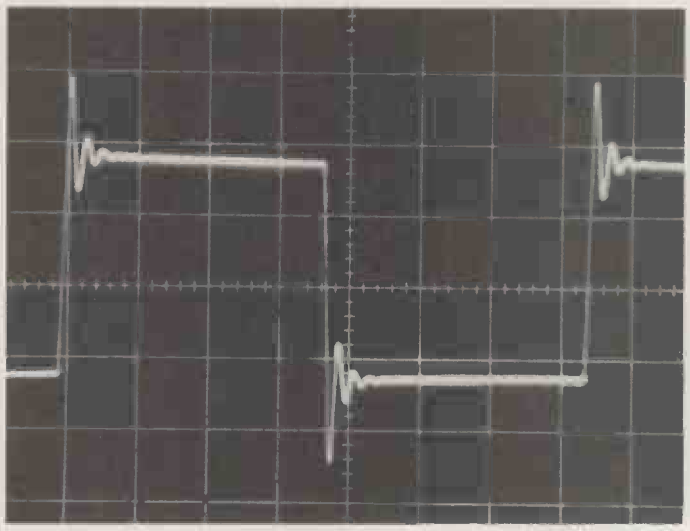


Photo 3 Square wave response (2kHz) at CL=1µF

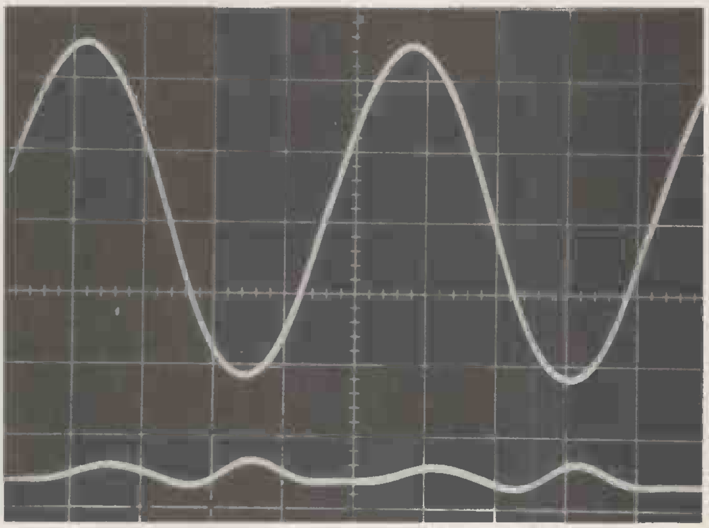


Photo 4 Waveform resulting from driving the amplifier at 40W, 8Ω with a 100kHz sine-wave illustrates the absence of switching distortion.

current of 40mA, the setting of the grid voltage is about –35V. The dynamic range of the grid voltage is 0V to –70V. By using a –100 V supply voltage in the improved amplifier, see the voltage multiplier in Fig. 2, no clipping occurs.

As a consequence of increasing the supply voltage from –50V to –100V the transistors BC639 and BC640 (max. CB voltage = 80V) are replaced by BF422 and BF423 respectively (max. CB voltage = 250 V). Resistor modifications: R14 = 27 kΩ, R29 = 18 kΩ.

Frequency compensation

In the first design, 100pF capacitors at the high impedance nodes of collector Q3 and collector Q4 accomplish frequency compensation, whereas a capacitor (15pF) connected across R27 improves the stability further. However, dominant pole frequency compensation decreases the slew rate and is therefore too disadvantageous for the improved amplifier. The closed-loop characteristic of the improved amplifier, without the use of frequency compensation, showed a +2.2dB peak at 130kHz. A capacitor C10 = 4.7pF connect across R27 eliminates the peak and does not affect the bandwidth adversely.

About volume control setting and bandwidth

The improved bandwidth urges corresponding figures for the high frequency performance of the input circuit. The input capacitance is mainly determined by CB capacitance of Q1 multiplied by the pre-amp voltage gain. (Miller effect) The voltage gain is very high – about 700 – and therefore the input capacitance is in the order of magnitude of 1nF. R1=50kΩ and Q1=BC640 are used in the first design and as a result the HF –3dB cut-off frequency at centre position (worst case) of R1 is only 12kHz. By using R1=10kΩ and Q1=BF423 (low CB capacitance) in the improved version the HF –3dB cut-off frequency at centre position of R1 is 130kHz. ■

Performance of the improved hybrid power amplifier

Control range of the cathode current is 10-90mA. The operating point was chosen at 40mA at which the negative grid voltage is about 35V.

• DC offset at the cathode resistances <2.8mV (<0.6%)
• Negative feedback factor = 5.6 (15dB)
• Output impedance = 0.9Ω
• Input voltage at 40W output power = 170 mV
• THD at 40W,8Ω = 0.35% (100Hz), 0.26% (1kHz), 0.78% (10kHz), 2.6% (100kHz)
• Bandwidth (–3dB) at 1W, 8Ω=10Hz-170kHz
• Slew rate=15V/µsec
• Full Power Bandwidth at 40W, 8Ω=30Hz-100kHz
• Signal-noise ratio=88dB (95dB “A” weight)

The stability obtained is illustrated in the measured square-wave response with open output, **photo 1**, at 8Ω, **photo 2**, and at 1µF, **photo 3**. In the THD waveform at 40W, 100kHz **(photo 4)** no switching distortion occurs.

Modern impedance measurement techniques III

In his third in-depth article covering modern methods of measuring impedance, Alan Bate* investigates which methods of data conversion best suit modern DSP-based impedance measuring bridges.

Digital signal processing, or DSP, is now widely used in DVB, CD audio, mobile phones, medical, oceanography, space data acquisition and where ever high performance filtering and signal extraction from noise is required. The main advantages of DSP are;

- Its ability to process signals as digital data with the benefits of stability with time and temperature. High accuracy is obtainable, limited only by the word size and speed of the computer's architecture.
- It allows the signal to be processed in the time or frequency domain. Complex signals are often easier to analyse in the frequency plane.
- Very-high-order filters can be designed with frequency and phase responses unobtainable via analogue hardware methods.
- Very linear mixing is possible by digitally multiplying signals, enabling, for example, high-order quadrature amplitude modulation and detection.
- DSP allows the capture all harmonic detail within one period of the signal.
- Very narrow band detection systems of less than 1Hz bandwidth can be designed, particularly at low frequencies where analogue active filters components would neither have sufficiently tight component tolerances or stability.
- Once digitised, a signal can be processed without farther degradation in signal-to-noise ratio by using a sufficiently large word size in firmware.
- Precision waveform synthesis is possible by converting from frequency to time domain and using digital-to-analogue conversion to generate the signal in real time.

Alias who?

The first consideration with any DSP system is the possibility of aliasing.

When a signal is sampled it is being multiplied – or mixed – with a stream of sample pulses. In the frequency plane, this becomes the product of the two signal frequencies giving the original signal channel, i.e. base band, plus its image at either side of the sample frequency. These aliases repeat at all harmonics of the sample frequency, **Fig. 1**.

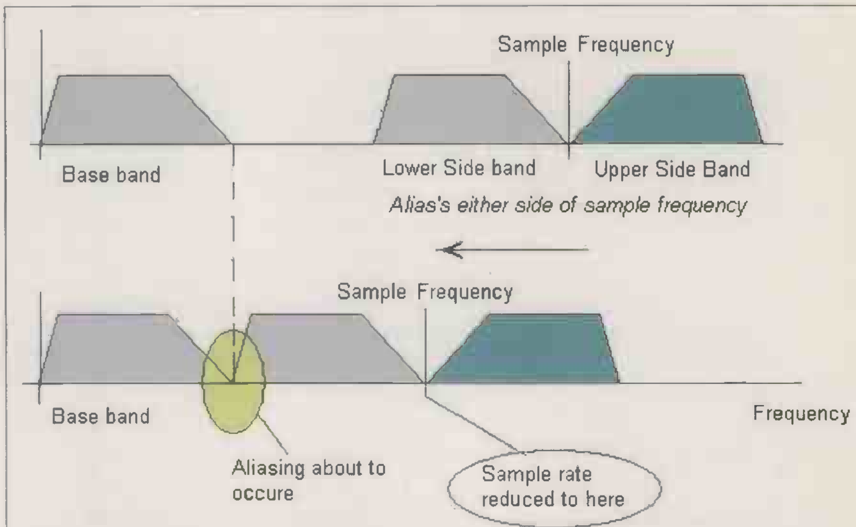


Fig. 1. Aliasing occurs when the sample rate is reduced below twice the base-band maximum frequency.

Looked at another way, at each sample harmonic (or harmonic carrier frequency), upper and lower side bands are formed, just like in AM radio. As long as the sampling frequency is much higher than the original signal channel bandwidth (base band in RF parlance) then the lowest side band, will also remain well above the base band and no interference will occur.

If the sample rate is now progressively reduced, all the aliased components (side bands), will progressively move down the frequency plane. Eventually, the lower side band will over lap with the base-band upper limit, Fig. 1. When

*Alan Bate BEng (Hons) MIEE

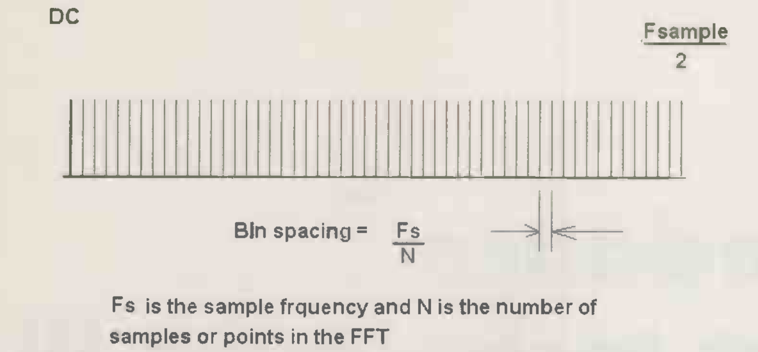


Fig 2 The FFT will output the frequency spectrum at discrete sample points or "bins" from zero to the half sample frequency. Above the half sample frequency the data is only mirrored in amplitude and frequency.

this occurs aliasing sets in and the signal will no longer relate to the original information: information in the original signal will be lost.

Whether there is information loss or not is determined using Shannon's sampling theorem. This basically states that if the sample rate is not less than twice the frequency of the highest frequency component in the original base band signal, then no information is lost through the sampling process.

The maximum signal frequency before aliasing occurs will be half the sample rate. This is known as the Nyquist frequency, or Nyquist rate. Beware though that the Nyquist frequency is not standardised, as S. W. Smith points out in his book, 'The Scientist and Engineers Guide to Digital Signal Processing' (http://www.dspguide.com/).

In DSP speak, the region between DC and the Nyquist frequency is known as the Nyquist bandwidth. This can be readily understood by inspection of the frequency plane discussed above. Aliasing will be referred too later.

Now that very high-resolution 24 bit A-to-D converters with sample rates above 20ksample/s have become available, it is worth investigating the possibilities of a DSP approach to impedance measurement.

Basically, the analogue phase-sensitive detector, or PSD, discussed earlier is replaced by digital multiplying

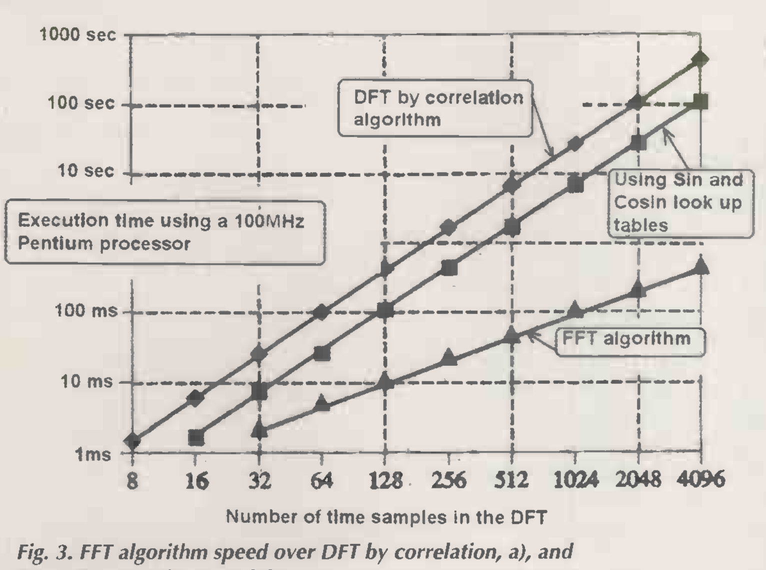


Fig. 3. FFT algorithm speed over DFT by correlation, a), and FFT/DFT execution speed, b).

software to extract the real and quadrature information in the unknown and standard signals E_u and E_s discussed previously.

Extracting the information can be achieved by using the fast Fourier transform (FFT) algorithm. This algorithm is derived from the discrete Fourier transform, or DFT, which is a time-sampled version of the well known Fourier transform of classical mathematics. It deals with translating continuous wave forms in time into their corresponding frequency components.

From DFT to FFT

As a DSP tool for spectral analysis, discrete Fourier tranforms without using the FFT algorithm are no use on their own in this application. To visualise why, assume a 20Hz bandwidth, which is comparable to the analogue PSD approach for high-accuracy measurements. Assuming a maximum measurement frequency of 10kHz, then the minimum theoretical sample rate to meet the Nyquist requirement is 20kHz.

For efficient computer calculation, the number of time samples N must be a power of two. Now the DFT outputs a spectral frequency response at discrete frequencies with a frequency spacing – called bin spacing in DSP speak – of;

$$\textit{Bin Spacing}\ \Delta f = \frac{f_{sample}}{N}\,(\mathrm{Hz})$$

where N is the number of time samples, **Fig. 2**. In other words, the resolution of the transformed signal in the frequency domain is directly related to the longest observable period in the time domain. This in turn is a function of both the time between samples (Δt), and the number of samples N, used in the FFT computation. The spectral frequency range is from DC or zero frequency to half the sample rate, or Nyquist frequency;

$$\frac{N}{2}\Delta f = \frac{1}{2\Delta t}$$

since there are $N/2$ samples in the DFT spectral output, computed from N time samples.

Ignoring the DC component, for 10kHz to be at a bin frequency with a bin or spectral line spacing of 10Hz requires 10kHz/10Hz, which is the thousandth bin. It is necessary to make the maximum DFT frequency the next higher frequency above 10kHz that is also a power of two, which is 10.24 kHz. Double this to get the minimum sample frequency to meet the Nyquist criterion. Sampling frequency f_{sample} is thus $2\times f_{Nyquist}$, or 20.48kHz.

Now we need a block of 2048 time samples with a sample period of 1/20480Hz, which is 48.828μs. Block length is 2048×1/20480 Hz, which is $^1/_{10}$Hz or 100ms, i.e.

$$DFT\_window\_length = N \times \frac{1}{f_{Nyquist}}$$
$$= 2048 \times \frac{1}{20480}$$
$$= 100\text{ms}$$

where N is again the number of samples.

The DFTs require a lot of multiplications. They are typically one of the slower operations on most computers. All N samples must be multiplied by sine and cosine values, which takes $2N$ multiplications. This must be repeated for all $N/2$ frequencies, for N^2 total multiplications – or nearly 16.2 million multiplications for this particular requirement!

Because of the computation-hogging multiplications, an alternative to the DFT was sought. In around 1965, a couple of men named Cooley and Tukey at Bell laboratories noticed that there were many redundancies in the DFT that could be eliminated, and still give identical results. Their method is known as the fast Fourier transform, or FFT. It is used universally in place of other DFT algorithms. This subject is an article in itself so for this article we will take the bottom line, which is that the FFT reduces the real multiplications from $4N^2$ real multiplications for the DFT by the correlation method down to $4N(\log_2 N)$ for the FFT. **Figure 3** compares the speed of DFT by correlation and the FFT algorithm.

The improvement in computation speed over the DFT increases rapidly with increasing N. A 4096-point FFT was found to be around a thousand times faster than the DFT version when measured on a 100MHz Pentium system.

In addition, the FFT is also more precise, as the smaller number of calculations means fewer round-off errors, **Fig. 4**. The FFT is also memory efficient in that it re-uses interim data locations as the calculations progress. The FFT just makes the whole DSP world practicable by vastly reducing computation time to acceptable levels.

The fundamental spectral components of E_u and E_s, amplitude and phase are then extracted from the FFT results and used in the same way as described before for the impedance calculations.

Such a DSP approach is very processor intensive. Even with a modern Pentium processor, it is only suitable for the basic accuracy region of a LCR instrument, working up to around 10kHz.

According to S. W. Smith in the book mentioned earlier, an FFT bench-mark tests on a 100MHz Pentium took 70ms to process a 1024 point FFT. By proportion, a 2048 point FFT would take;

$$\frac{4N_2}{4N_1} \times \frac{\log_2 N_2}{\log_2 N_1} = 22 \times 70\text{ms} = 154\text{ms}$$

The FFT calculation is carried out twice for E_s and E_u. Using a 100MHz Pentium, total time is 308ms plus a 100ms window length for full accuracy. Assuming that both E_s and E_u are being monitored simultaneously using dual A-to-D converters, this results in 408ms for a repetitive measurement. It can be assumed that the impedance and display algorithms are only a small proportion of this measurement time. As a result, a low-

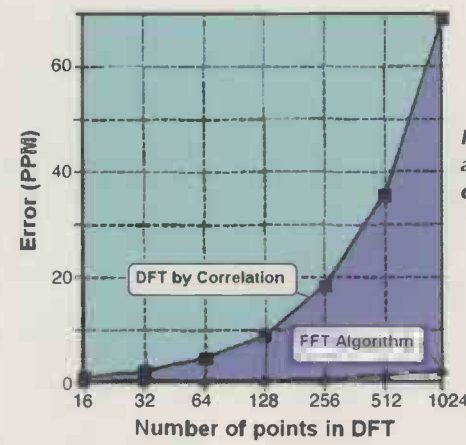


Fig. 4. FFT accuracy comparison.

cost Pentium could achieve two readings a second using dual A-to-D converters and separate E_s/E_u ranging

With a single A-to-D converter, measurement time reduces to about 1.5 to 1.8 readings a second as E_s and E_u need to be sampled sequentially and there are additional setting delays.

Commercially, you may want the processor to do everything to avoid the additional cost of a DSP chip. the FFT calculations being carried out in machine code. On an up market instrument, use of a DSP chip with its ultra-fast instruction sequences, such as shift and add, and multiply and add, would greatly increase the throughput of the FFT calculations.

A-to-D converter review

A DSP bridge would need a state of the art A-to-D converter with better than the 22-bit resolution used before. In-phase and quadrature data are now being derived from 2048 time samples, which results in increased round-off error. This means looking at the latest high resolution A-to-D converters.

The current 'state of the art' in IC form are 24 bit A-to-D converters with over 190kHz conversion rate. They can operate well above the required 20.48kHz sample rate. See **Table 1** for a comparison of current 24-bit IC A-to-D converters.

Table 1. Review of high resolution A-to-D converters with sample rates over 20ksample/s.

Manufacturer	Type	Resolution (bits)	Sample rate (ksampls/s)	Sinal/noise (weighted)	Analogue I/Ps	S/(D+ N) (dB)	DNL (max)	INL (max)
AKM	AK5394A	24 bit	192	123dB	Two channel	110 dB	Not spec	Not spec
	AK5393	24 bit	96	117dB	Two channel	105 dB	Not spec	Not spec
	AK5392	24 bit	48	116dB	Two channel	105 dB	Not spec	Not spec
	AK5383	24 bit	96	110dB	Two channel	103 dB	Not spec	Not spec
	AK5381	24 bit	96	106dB	Two channel	96 dB	Not spec	Not spec
	AK5380	24 bit	96	105dB	Two channel	94 dB	Not spec	Not spec
Crystal	CS96/97	24 bit	96	120dB	Two channel	105 dB	Not spec	Not spec
	CS5394	24 bit	96	117dB	Two channel	103 dB	Not spec	Not spec
	CS5361	24 bit	192	114dB	Two channel	103 dB	Not spec	Not spec
	CS5360	24 bit	48	105dB	Two channel	95 dB	Not spec	Not spec
	CS5351	24 bit	192	105dB	Two channel	103 dB	Not spec	Not spec
	CS5333	24 bit	96	98dB	Two channel	88 dB	Not spec	Not spec
Texas	ADS1252	24 bit	41	No spec.	Single channel	Not spec	4, ±1LSB	8, ±1LSB
	ADS1250	20 bit	25	No spec.	Single channel	Not spec	1, ±1LSB	16, ±1LSB
Analog Devices			<20ksamp/s					
Linear Technology			<20ksamp/s					

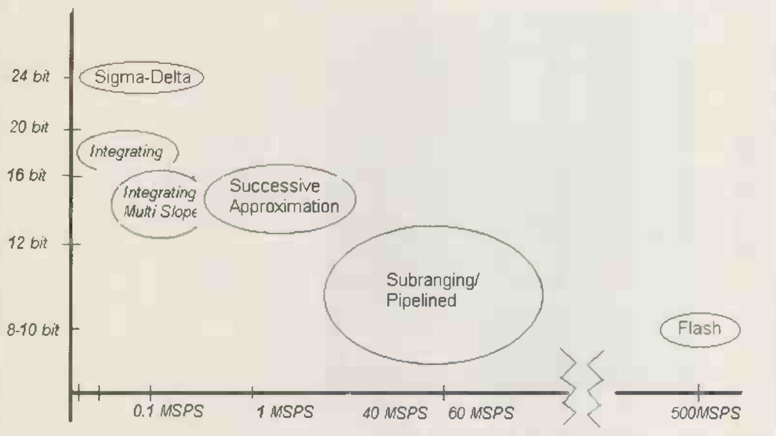


Fig. 5. Map of A-to-D conversion resolution against conversion rate for the main technologies in use today.

Published dynamic performance for these ICs are at these higher sample rates. By operating then at only 20.48kHz, it may still be possible to achieve near 24-bit effective resolution. The availability of such chips shows what could be possible with a custom-designed A-to-D converter using separate ICs for the analogue and digital functions and more sophisticated digital filtering for best noise performance.

Everything then hinges on the achievable performance of this functional block. Therefore, a review of present day A-to-D conversion techniques is appropriate.

Figure 5 shows a survey of present day A-to-D converter technologies, resolutions and conversion rates. Generally, as you might expect, resolution trades off for speed. There are five main technologies used;

Integrating dual slope. As discussed earlier, this is an accurate technique with up to around 20-bit resolution. But it is also a slow method. Integrate periods are normally designed to be locked to the supply frequency for high supply-noise rejection. Accuracy is ultimately limited by capacitor dielectric absorption and the integrator amplifier, as discussed in my second article last month.

Multi-slope integrating converters. This is a derivative of the dual-slope A-to-D converter, developed by HP Instruments for the company's HP3458A multimeter. High conversion rate was achieved by changing the integration and de-integration periods into short slopes of decreasing rate and increasing integrator gain and resolution. This resulted in high resolution combined with high sample rates. Like the successive-approximation technique, the resolution here is limited by the accuracy of resistor matching. Using this method, HP achieved 16 bits resolution at 100kHz conversion rate in the 1980s.

Charge-balancing. Discussed in depth in my previous article, the charge balancing technique is also known as quantised feedback. It is inherently linear (monotonic) due to the use of a single switch. Integration is slow though so the method is unsuitable for DSP.

Successive approximation. Resolution of the successive-approximation converter is limited by the accuracy of the resistor network and matching of the analogue switches. This is a reasonably fast technology. Resolution of available ICs is around 16 bits at 100kHz conversion rates. This technique has insufficient resolution for LCR instrumentation.

Flash converters. Also known as parallel converters, these types have the fastest available sample rate – in the region of 500Msamples/s – but they have limited resolution due to tolerances in the potentiometer chain and the voltage offsets of each comparator. Resolution ranges from 6 to 10 bits. Flash converters are mainly used for digitising video and IF signals. At resolutions up to 10 bits and conversion rates above a few hundred megasamples per second, flash converters dominate.

Pipe-line/sub-ranging converters. This is a new approach that uses flash converters and programmable gain amplifiers, or PGAs. Partial digitisation is carried out by the flash converter. Code is converted back to analogue form and subtracted from the input signal. The difference signal is amplified with a PGA and flash converted. The process is repeated until the desired resolution is achieved.

This technique is very much under development with the aim of achieving high resolution at high speed for digitising video and higher radio frequencies. This method suffers from latency due to the multi-stage operation.

Delta and sigma-delta modulator converters. At present, for A-to-D conversion resolution beyond 20 bits, the sigma-delta modulator types have it almost to themselves. Like the charge balance type, they can be inherently monotonic if a one bit D-to-A converter is used in the modulator. Monotonic 24-bit converters with 192kHz sample rate for professional stereo audio applications are now available in IC form. For this reason, I will further investigate the possibilities of using this type of converter. Monotonic 24-bit converters with 192kHz sample rate are now available in IC form, **Table 1**. They are useful for professional stereo audio applications.

CONVERSION CODE

RANGE OF ANALOG INPUT VALUES	DIGITAL OUTPUT CODE
4.5 • 5.5	0 ... 101
3.5 • 4.5	0 ... 100
2.5 • 3.5	0 ... 011
1.5 • 2.5	0 ... 010
0.5 • 1.5	0 ... 001
0 • 0.5	0 ... 000

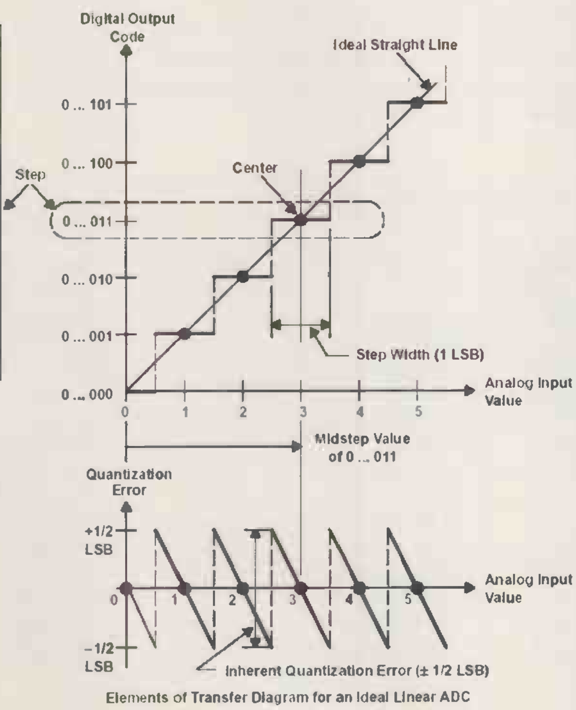


Fig. 6. Perfect A-to-D conversion staircase function.

Sigma-delta modulator development

The sigma-delta converter brings together several techniques that have only become practicable in the last 20 years. The perfect A-to-D converter will have a stair-step transfer function with 2^{bit} evenly quantised steps, passing through zero, **Fig. 6**.

This function can be viewed as a linear summer with quantisation noise adding to the analogue input to form the converted output. In the frequency plane, all the quantisation noise power is folded and evenly spread into the frequency band from DC to the half sample rate or Nyquist frequency.

For any given input level, the total noise power remains constant. If we now increase the sample frequency, the noise-power spectral density falls in proportion to the increased over sample rate as the same noise energy is spread over a wider band.

Input signal power is unchanged, therefore as noise power is proportional to $\sqrt{4KTBw}$, the signal to noise ratio SNR increases in proportion to the square root of the over sample rate, **Fig. 7**.

By suitable digital filtering, quantisation noise is removed and the sampling frequency is reduced down to a sensible conversion rate – just high enough to avoid aliasing with increased word length. In the case outlined here, this would be between 20 to 25kHz. This is referred to as sub-sampling or decimation, **Figs 8 & 9**.

The delta modulator – an also ran

To make any A-to-D converter inherently monotonic, there should be only one switched function in the analogue circuit. It would be extremely difficult to manufacture precision ratio trimming of sufficient accuracy for two or more analogue-switched circuits (as used in lower resolution successive approximation and integrating type converters) to anywhere near the required accuracy. Remember that 24-bit resolution implies a quantisation step of 0.06 PPM.

If the analogue signal could be tracked with time to within one LSB, you could use one switch to form a one bit D-to-A converter for the error correction. This is achieved by the delta modulator, **Fig. 10a**).

The fundamental principle behind the modulator is to use a single-bit A-to-D converter embedded in an analogue negative feedback loop with very high open-loop gain. With a high-frequency clock, the modulator loop is forced to over sample and processes the analogue input at a rate much higher than the bandwidth of interest. Typical over-sample rates range from 32 to over 500 times the conversion rate.

The modulator is actually a simple, switching regulator which tracks the input signal level with time and generates an over sampled serial PWM stream. **Figures 10a) & 10b)** show the basic operation.

Analogue input is compared with the average feedback level from the one-bit D-to-A converter that can only switch between the two references $+V_{ref}$, $-V_{ref}$. The corresponding high/low output from the comparator and latch drives the D-to-A converter, which in turn applies defined positive or negative V_{ref} current pulses to the summing junction of the modulator input.

The phasing is arranged to form a high gain negative feedback closed loop, which forces the average feedback level from the one-bit D-to-A converter to match the input signal level. At the comparator output, the analogue signal will have been converted to a serial pulse-width modulated (PWM) one bit stream clocked at the over sampling frequency. However, the delta modulator, which has been widely used in voice communications codecs – has some severe limitations.

Consider a 16-bit digital-audio application for example.

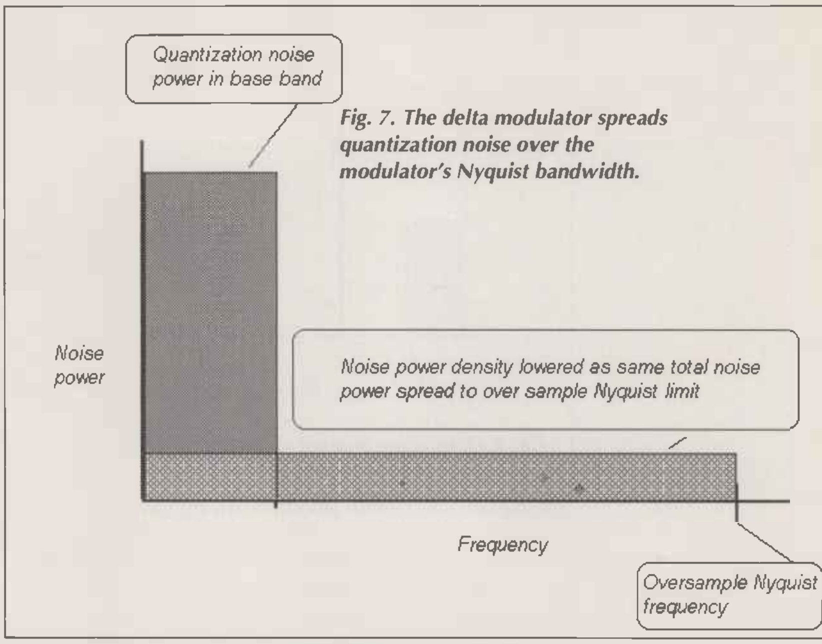
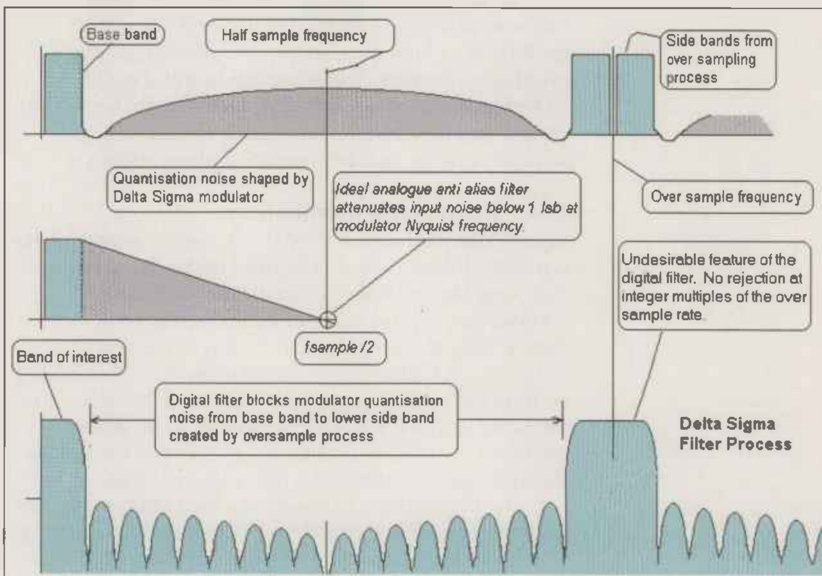


Fig. 7. The delta modulator spreads quantization noise over the modulator's Nyquist bandwidth.



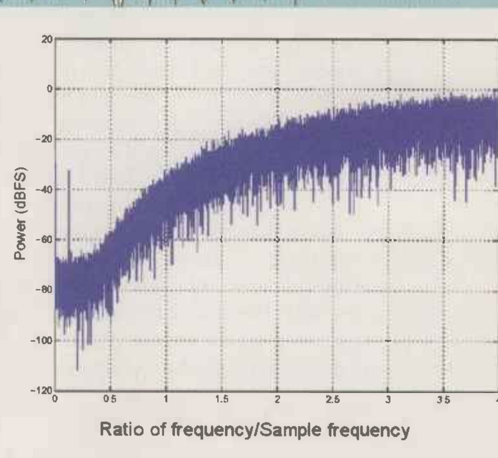


Fig. 8. Digital filtering in frequency plane, a), and sigma-delta mod output noise, b).

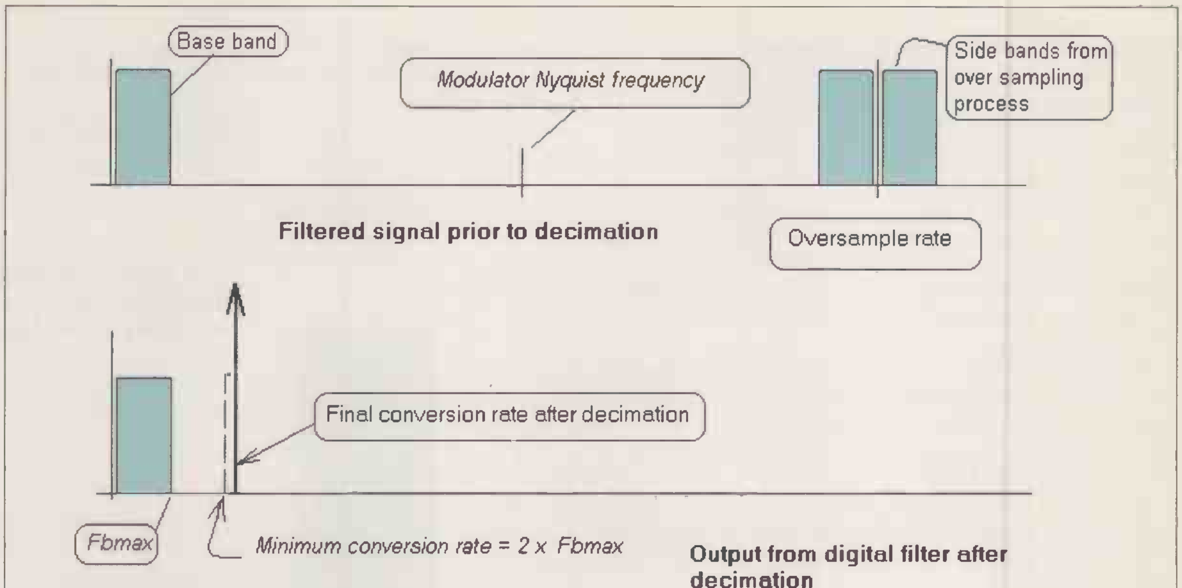


Fig. 9. Decimation process in frequency plane.

To convert a maximum amplitude 16-bit word, the one-bit modulator has to perform 2^{16} toggles per conversion period. This means a sample rate of 44kHz would require an unacceptably high sample rate of $44.1\times10^3\times2^{16}$=2.9GHz!

If the over-sample rate is reduced to a practicable hardware level, the quantised noise level becomes intolerable. A high over-sample rate is also essential to avoid slope overload within the modulator, **Fig. 11**.

Over sampling also has the advantage of not needing a sample-and-hold circuit, eliminating the associated acquisition, jitter and droop errors of these circuits.

Enter sigma-delta modulation

Sigma-delta modulation (SDM) – or more correctly, delta-sigma modulation – was developed in the sixties to overcome the limitations of the delta modulator.

SDMs quantise the delta, or difference between the current sample, and the sigma, or sum of the previous difference. An integrator is placed at the quantiser input to perform the summing and averaging. An SDM quantifies the signal directly; not its derivative, as in the delta modulator. Now, the maximum signal amplitude, not the signal frequency, determines the quantiser range.

Again, to achieve high resolution, high sample rates are required. In addition, to reducing the noise power density with over sampling, the sigma-delta modulator also acts like a high-pass filter to the quantisation noise and a low-pass filter to the input signal. This characteristic concentrates the quantisation noise energy higher up in frequency and out of the base bandwidth, **Fig. 8**.

The noise revolves around the Nyquist or half sample frequency. This is called 'noise shaping'. It improves the signal-to-noise ratio by 9dB for a first order modulator (one integrator) for each doubling in over sample rate.

Noise shaping can be improved by increasing the order or number of integrators in the modulator loop. Unfortunately, this also increases the complexity and degrades the modulator stability. IC manufacturers generally do not use more than fourth-order filtering in their modulators. An exception is a patented seventh-order, tri-level delta-sigma modulator produced by Crystal Semiconductor in 1997. It is used in the company's 24-bit 96kHz Audio A-to-D converters.

The modulator output feeds a combination of digital filters which;

- Blocks quantisation-shaped noise centred on the Nyquist or half-sample frequency.
- Outputs a digitised moving average of the analogue input at the over all analogue-to-digital conversion rate.
- Provides sharp cut-off of the converter bandwidth.
- Decimates, or sub samples, the modulator sample rate to a practicable conversion rate of just over twice the signal bandwidth.
- Provide high-pass filtering at around 1Hz to block any DC component.

The stop-band response of this filter must be sufficient to bring the concentrated quantisation RMS noise below one least-significant bit, or LSB. The filter is normally an n-tap finite impulse response, or FIR, type that outputs a weighted moving average of N modulator outputs.

After the digital stop-band filtering, the modulator sample rate is finally, converted down in frequency (decimation in time) to the required analogue-to-digital conversion rate by accepting only every Dth sample, where D is the chosen decimation factor, Figs 7, 8 & 9.

Now leaving any proofs aside, the theoretical signal-to-noise ratio of the RMS of a full-scale sine signal to the RMS level of the quantised noise for a perfect A-to-D converter of N bits resolution is $SNR=6.02N+1.76\text{dB}$.

As a result, a perfect 24-bit A-to-D requires a noise floor, that's –144dB below full output. However, the resolution of real converters falls off with frequency due to thermal, quantisation and distortion noise products all increasing with frequency. This leads to the performance criteria known as the 'effective resolution' or 'effective number of bits'. Here, *effective resolution*=($SINAD$–1.76 dB)/6.02 and $SINAD$ is the ratio of the RMS full-scale signal to the RMS of all the noise terms excluding the DC term, which is also removed in the digital filtering. This takes account of not only thermal and quantisation noise but also differential and integral non-linearity's which in turn, create intermodulation products.

The above equation assumes that the noise is measured over the entire Nyquist bandwidth – i.e. DC to half the sample rate. If the signal bandwidth, f_{bw}, is less than the

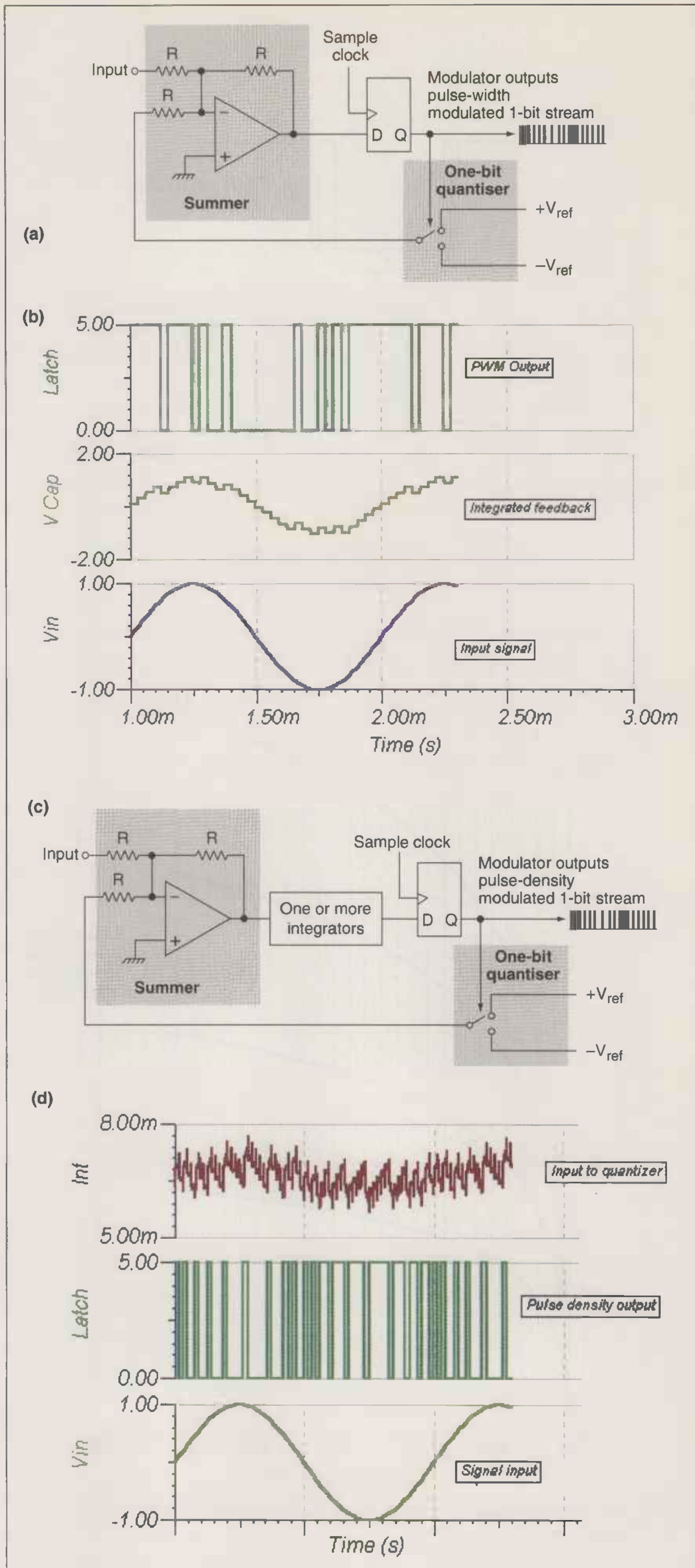


Fig. 10. The sigma delta modulator, or SDM, was developed from the delta modulator, a), by the simple addition of an integrator in the forward path, c). The delta modulator outputs a pulse-width modulated (PWM) serial stream whereas the SDM outputs a pulse density modulated stream, d).

Nyquist frequency then the signal-to-noise ratio within the signal bandwidth BW is increased because the amount of quantisation noise power within the signal bandwidth is proportionally smaller.

The following addition to the above equation models this effect;

$$SNR = 6.02Nbits + 1.76\text{dB} + 10\log\frac{f_{sample}}{2f_{bw}}$$

This equation reflects the conditions produced by over sampling, where the sampling frequency is much higher than the Shannon requirement. The following is a more general equation for delta-sigma modulator noise versus the over-sample ratio including the order or number of integrators in the modulator;

$$6.02Nbits + 1.7\text{dB} + (M + 0.5)\left\{10\log\frac{f_{sample}}{2f_{bw}}\right\}$$

Figure 12 is a plot of this equation for modulator filter orders from first to fourth. You can see that there is an expected diminishing return in over sample rate performance beyond say 128×, but there is a directly proportional gain in SNR with filter order. From this, you can see how a fourth-order filter and over sampling at 128× would give approximately optimum SNR. More on this later.

Apart from very-low-frequency versions, sigma-delta analogue-to-digital converters suffer from slow settling delay – typically taking five to fifteen conversions to fully settle. This is due to the moving average action of the digital filter. Converter output is a function not only of the most recent analogue input, but also of previous inputs.

In a multiplexing application, all information of old input needs to be flushed out of the digital filter before the converter output word represents the new input. This has to be allowed for by extending the FFT data block length accordingly but only reading 2048 samples into memory.

There will be a transient in switching from E_u to E_s, which will vary with range setting. By starting the converter at the switch transition and monitoring the samples until steady state is reached the system-switching transient and all old filter data will be removed.

With a DSP-based bridge, a dual A-to-D converter would be used to save measurement time and continuously monitor the E_u and E_s signals. **Figure 13** shows the heart of a DSP bridge. This would minimise the problem to an auto-ranging measurement, which can be much less accurate as these are ball park measurements in order to select the optimum E_u or E_s range.

Timing and windowing

In a DSP based LCR instrument, the ROM based synthesised sine-wave generator, the sigma-delta modulator, digital filter and E_u/E_s switching would be clocked from a common system crystal oscillator. As a result, the converter will be inherently referenced to the stimulus with a fixed system offset timing or phase relationship. This offset can be removed by using a common reset signal or via software.

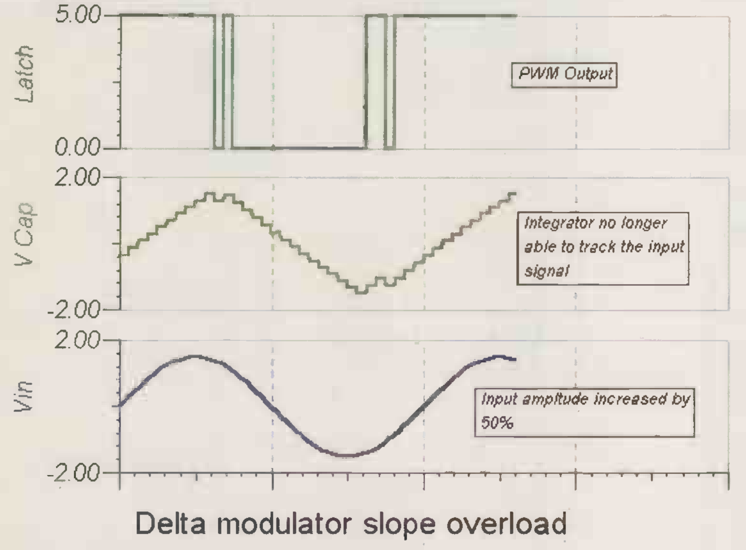


Fig. 11. Waveform of delta modulator overlaod.

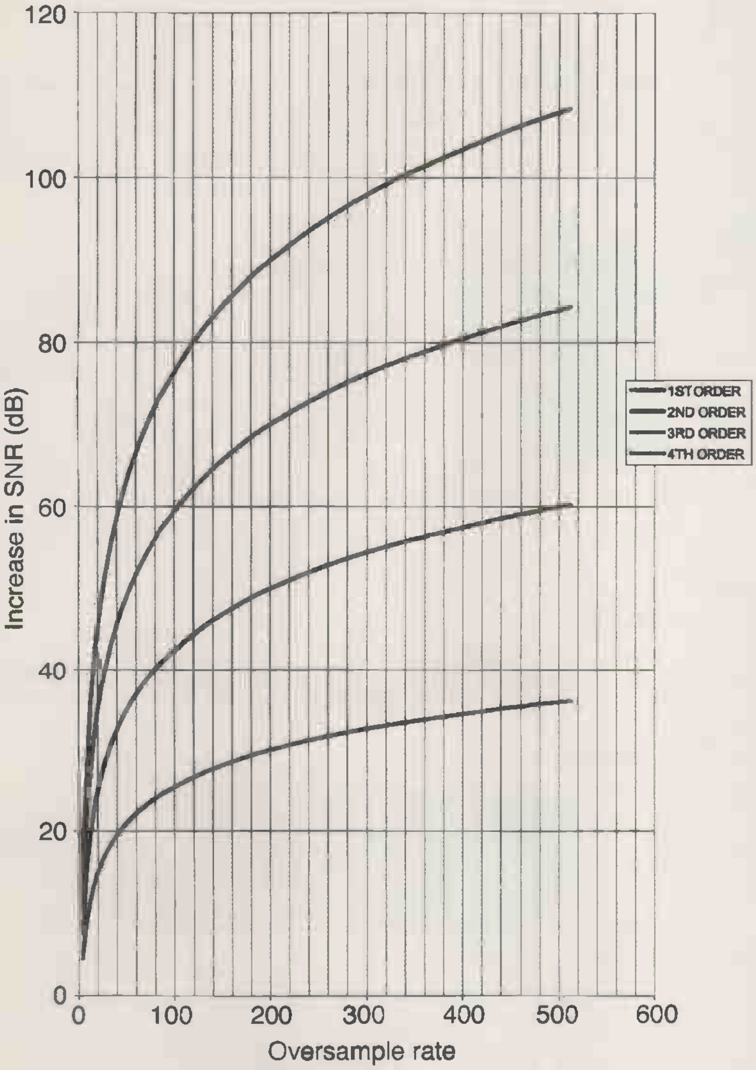


Fig. 12. Plot of signal-to-noise ratio improvement versus sample rate and modulator order.

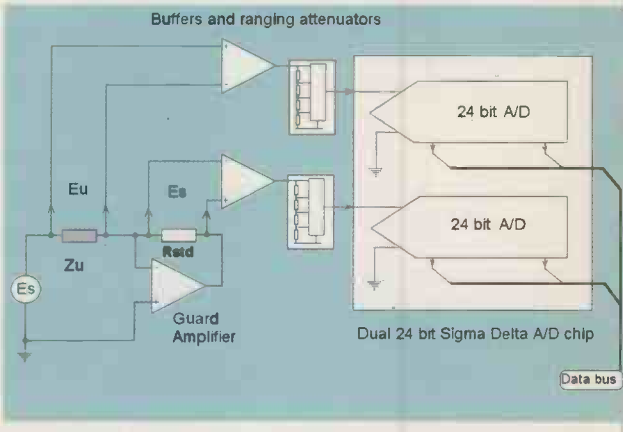


Fig. 13. Elements of a simplified LCR bridge based on DSP.

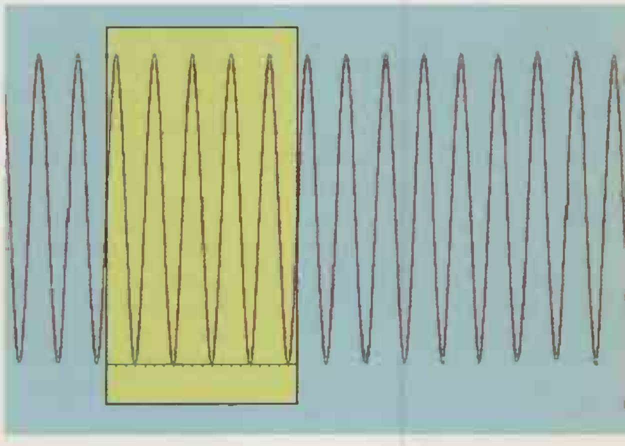


Fig. 14. By sampling from zero crossings and whole multiple periods of the measured signal, perfect windowing is obtained by the FFT. This avoids spectral leakage or blurring of the FFT output spectrum.

Common clocking allows the use of the latest two-channel stereo sigma delta A-to-D converters. A snap-shot sample in time of the E_u and E_s signals would be taken over a whole number of cycles that add up to the 100ms sample period as before. Now though, the samples are synchronised with the stimulus signal zero crossings to ensure a clean sample with no signal discontinuities.

At this stage, the sample looks like an infinite stream to the FFT maths. Sampling odd multiples of cycles would create non-symmetrical distortion in the time domain, which causes ringing in the frequency plane (Gibbs effect).

Mathematics for the FFT assumes a continuous signal with time, but it will not see any difference between the sample taken from zero crossing to a multiple whole period zero crossing and an infinite stream of E_u or E_S.

This is perfect 'windowing' of the signal, **Fig. 14**, and gives no distortion in the frequency plane. The FFT will then output a clean spectrum with no spectral leakage at each spectral line or bin, or indeed any errors other than those due to converter accuracy and noise. ■

LETTERS to the editor

Letters to "Electronics World" Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam Road, Surrey SM3 8BZ e-mail j.lowe@highburybiz.com using subject heading 'Letters'.

John Lindsley Hood

As a rank amateur, who has only a few college and training school certificates, who has been reading *EW* for 18 years, may I say a few words on behalf of John Lindsley Hood.

It has been noted that he hasn't written any articles in *EW* for a while – do you blame him!! After years of getting slagged off for his use of Mosfets, and lately for his use of star earthing.....

To me JLH is a giant in audio design, and, unlike others, he is too much of a gentleman to have ongoing arguments, and again, unlike others, doesn't try to ram his ideas down peoples throats. Let me put my case! – In the sixties I built valve amps and other value gear, in the early seventies, I bought a commercial solid state amp. Due to personal circumstances, I had to get rid of my speakers and listen on head phones, so I went for the best (at the time) - Stax Lamba Electrostatics - right away the 'phones showed up the amp as being lo-fi. I wasn't attracted to any designs until, in the early eighties, JLH came out with his 80 watt Mosfet amp. I am totally immune to adverts, but John's words took hold of me and convinced me I had to build his amp if I wanted to listen to music - his words were nearly religious. Unlike others, I built it and he was right. I have no access to 'in house mags' etc. and as the 'man on the street' John was innovative:

1) Variable resistor at the power amp input for seeing CD direct input
2) 150Kohm input impedance. In one stroke, shutting the mouths of 'golden ears' as to loss of 'high frequency' due to low impedance.
3) His research of capacitor 'sounds'.
4) High sensitivity - 150mV for full output.
5) Although star earthing was around earlier, John expanded on it in his solid state amps – i.e. isolated inputs to star earth etc.
6) His use of Mosfets not only at the output but also in the VAS stage and power supply.

I have also built his latest pre-amp published in *EW* - minus the low frequency cut off, using high quality Burr-Brown chips, and also his THD meter published, also, in *EW* - and yes, it goes down to -100dB.

On his star earthing – let me put the case! After 20 years I decided to update his amp, entirely in keeping with John's own views in his books and *EW*. I added a cascode stage and a driver stage. It showed the quality of his design that it worked first time (the comp/capacitor is as per D. Self) - it is 40pF - helped by the gate capacitance of the Mosfet in the VAS. I fitted two Japanese bipolars of high gain, high voltage, very low noise at the input. 10mF polypropelene capacitor at the signal input - 30mF, also poly at the negative feedback. Not needing 80 watts, I removed 2 Mosfets from each channel and reduced the voltage rails to plus or minus 28V. I increased standing current to about one and a half amps (fan fitted until I can afford a large chunk of aluminium). It now runs in class A over and above that required by the interface unit of the Staxs. The residual is typical class A - a sine wave with slight crumping at the top. THD is down by 12dB - not a lot, but good enough for me. I also removed the output passive components, as leaving in the series wirewound resistor caused great loss of HF series impedance (Scroggie/Radio Laboratory Handbook P308) – it looks into the transformer interface.

All this caused big problems at the output, namely 12mV of noise, -15mV power supply distortion and sets of HF oscillations at 80KHz and 14MHz, the last at 20mV.

Firstly I fitted six 10,000mF Phillips capacitors at the power supply output, but this only brought down the power supply distortion by 2mV. Secondly, I gritted my

Shot in the foot

The arrival this morning of an invitation to renew my subscription to your magazine has prompted me to write to say that I will do so – for one year only to see if the complaints of J. Jardine, M. Cook, J. Johnson etc. are acted upon.

After 58 years (I am 74) of purchasing *Wireless World* et al, I contemplated stopping buying the magazine that has changed (for the worse) over the years so that now the main area of interest is limited to 'Circuit Ideas'.

It appears that you have joined the ranks of those who are intent on shooting themselves in the foot. You have lost readership and advertising revenues through your policy of almost ignoring the proletariat i.e. the amateurs who, in the past, were your main purchasers. Hi-tec is OK for some, but take a look at the price now of shares in that sector – there is a lesson somewhere in that.

The October issue illustrates the appalling decline in spelling and English in general referred to by T.R. Mortimer. Mind you 'Free Grid' of blessed memory was given to castigating those guilty of these sins whilst writing in 'unbiased' about the hoi polloi. Hoi being the definitive article in ancient Greek. Perhaps I should have replied 'Hoi su technon' (and you, boy). No, I am not a classic scholar, but merely a person of wide ranging interests especially in science, music and languages.

The high price quoted for the power amplifier printed circuit boards which featured fairly recently must be due, in part, to the lower readership figures and subsequent lower demand for them. The additional cost of components and a suitable preamplifier makes it a very expensive item. We also need a list of high-grade parts as has been made obvious in the 'Capacitor Sound' articles.

Also, a search through all the 1976 issues has not produced any evidence of a ripple regulator using a 7805 referred to in 'Letters' Oct 2002. Perhaps Jim Brassant meant 1967. In any case, years ago, I saw a one transistor device in 'Circuit Ideas' to reduce hum level in a power unit to a few microvolts. It washed but was sniffily dismissed by Elektor as 'a shunt regulator' when I wrote to them about it. Not been able to trace the idea again, but will try. Meanwhile, don't forget we (or is it us?) amateurs.

Yours sincerely
A C Bloomfield
Gloucester, UK

teeth and fitted D. Self circuits on power supply rejection. I have to be honest and say that it works. Nothing I did could get rid of the other problems. I am against fitting small value capacitors as I think this reduces the openness of an amp. And thirdly, as a last resort I removed the 10 ohm resistor between high and low earth returns. The amp went into burn out. Switching off, I reconnected to a Variac, bringing the amp up to just a small oscillation at the output. I ran an earth return to the input capacitors and to the star earth - no difference. Leaving it there, I removed the feedback and input component earth returns and then only, I returned via the two volume controls (no balance needed) to the star earth and switched on. I couldn't believe my eyes – slowly turning up to full voltage, all I could see on my Tektronix 465B *(option 5, I hope – ED)* scope was 500 microvolts of noise. I fed in a 1KHz sine wave for an output of 5 watts and then left it for two hours. On returning, the noise was approx 1mV and nothing behind it.

Capacitor is 40pF (helped by Mosfet Gate Capacitance of the VAS Mosfet), input filter capacitor was reduced to 30pF. At full volume and no signal, there is not the slightest noise or hum.

I now have a JLH designed power amp for the 21st century - totally open and detailed, totally smooth, fast and excellent imaging - qualities in today's market which would cost you £1000 plus. It excels in vocals, all the emotion in the music coming through. It is not an amp for that soul destroying heavy thumping house music - it would be wasted there – oh, and frequency response is flat from 10Hz to 20kHz.

A few thoughts – if a 50 watt power amp with no distortion and then say any fault re production my be sought elsewhere - are they right or wrong? The real answer is not no distortion, but the circuit design and components used. And JLH wins out.

To slag off hi-fi buffs is total hypocrisy - talk about biting the hand that feeds you. John put his 80 watt amp into the market place, leaving him open to fault finding. Go on, tell us the make and model that is in the shops just now.

I think we're talking flying pigs and blue moons here. Designing an amp with nil distortion doesn't mean it will sound good. I have three class A commercial amps that are sold as smooth - yes they are, but at the expense of detail. They are not 'open', so do not convey the feeling in the singers voice.

This is where John is head and shoulders above the rest.

I do not apologise for the criticism of others – I thought by this time that somebody would have risen in defence of John. When he goes to that big amplifier in the sky, I don't want to read crocodile tears from his detractors.

D Lucas
Anstruther
HE Fife, Scotland

DSPs

Thank-you for printing my letter 'CPU Design' in the November issue of the magazine. Further to my comments in that letter, I have been putting more thought into the design and I realise that the 'differentiated multi-processor ' concept is ideal for running a packet based bus structure. This does bring: it into today's age! The idea is that the input-output processors communicate with the high-level language core using packet transmission, in addition to their boosting straightforward hardware input-output bandwidth.

Like yourself, (I read with- interest your introductory editorial), I am interested by digital signal processors. I first developed a digital signal processing design in 1977, using a minicomputer-on-a-chip processor which offered a firmware multiply. It was an experiment in speech recognition, still a developing field. Since then, I have experimented with a variety of manufacturers' starter kits for their DSP designs, and investigated the literature. Texas Instruments produces the widest variety of designs, however I like the Analog Devices DSPs because they are more sophisticated. For example AD offer an 'algebraic' assembler for their ADSP 16-bit fixed point processor family, which is the highest level of assembly language programming tool available. AD also produce a good range of-technical support literature.

The main problem with DSPs is their increased sophistication compared to older microprocessor concepts, and the consequent large learning curve. The higher clock rates of a DSP necessitate high-speed digital design technique, such as a multi-layer printed circuit board, and the -assembly languages are much harder to get one's head round than those of the PIC! Even programming them in 'C', the high-level programming language, doesn't-make them an easy option.

Keep up the good work!

Allan Campbell
Newcastle upon Tyne
UK

The archive and other things

I should like to add to the recent lively debate on the direction that *Electronics World* is taking.

I have been pleased with the article on capacitors; this is the sort of basic information that is invaluable, and follows a long line of similar articles that have appeared over the years on a variety of components. Such things are no longer taught in the universities.

There used to be a 'readers ads' column, but this may have gone out of use through apathy or the various websites that are now available. Could I suggest a 'swopshop' for back copies of the magazine?

There may be a place for a 'going back' article, of circuits and ideas from 50 or 75 years ago, this has been popular in other magazines; as a vintage enthusiast I may volunteer to write this as I have a magazines going back to the 30's. It is often surprising how many circuits and techniques are continually re-invented and how well some of them perform in today's environment.

To come up to date I think a series on the basics of one of the modern micros such as the PIC, showing how to achieve simple operation and without pages of incomprehensible code would be welcome, this could be similar to the article on the BBC and Z80 that were published many years ago.

There has been a discussion on the use of symbols in circuit drawings and their variation between contributors. Most schematic capture packages allow importation of library symbols. Would it be possible to have an EW set of basic symbols that authors could download and use in their articles? This would give continuity to articles without the expense of re-draughting.

Ed Dinning
Burnopfield
Newcastle upon tyne
UK

I'll certainly give the EW standard symbol set some thought, especially as it would make our job a bit easier. ED

Glory days

Judging by the letters in the October issue, it seems quite clear that *EW* has a devoted band of long term, i.e. older, readers. That is not a problem provided new readers can be attracted at least as fast as we fall off our perches. It would be a problem if they turn out to be just a lot of old dogs that refuse to learn any new tricks.

By my reckoning the glory days of EW (in one or other of its previous incarnations) were the nineteen seventies. That was the time a few general-purpose transistors, a few op amps or a bunch of logic gates could do all sorts of things we had only dreamed of in the valve era. Circuit Ideas recaptures that feeling, perhaps that is why it is so popular.

Today the nearest equivalent of the general purpose transistors or op amps is probably the PIC and similar microcontrollers. In the seventies, several weather satellite reception articles were published. Signals were decoded and maps displayed by all sorts of weird and wonderful devices including a windscreen wiper motor and a very large slowly charging capacitor used to provide a Y timebase for an oscilloscope display which was photographed in a darkened room. Today it would all be done in software on a general purpose computer. Surely EW should reflect that change. Or should we forget the FFT and drag out some nice chunky inductors and capacitors because they are real electronics?

I'm a field biologist who has dabbled in electronics for forty years. I read EW because it is the professionals' magazine. By which I mean that by and large it delivers exactly what it promises on the cover, the breaks in multipart articles are sensible rather than just hiding a lot of padding to make sure the reader buys next month's copy and there's little hype. I hope it stays that way.

Dr Les May
Rochdale, Lancs, UK

More diversification

I want to respond and express my frustration on some of the e-mailers from the letters pages.

How dare those chosen few, aka disciples of the electronics industry express their hatred of computer, software and technology topics. Don't they know at all about atomics manipulation?

As an undergraduate studying electronics, at college we are encouraged to be diverse beyond the field of the specialised electronics degree. For that, we mix and choose additional modules to study as part of the course and be prepared for changing industries. In the first year of the course, we were introduced to BBC Basic programming, (Some laughed and disrespected the old technology), but soon some came to realise the importance of interfacing and algorithms.

As a mature student, who has come to love electronics by experimenting with hi-fi magazines, I personally would like to see more diversified electronics related subjects, especially industrial ones. More of circuit ideas from the experts and outsiders to fire one's imagination.

Oh! yes more of the supply components for sale is great and budget electronic topics for oneself to be proud of.

Thminh Truong
UK

Some praise

I have subscribed to *Wireless World* and later *Electronics World* continuously since I was 16 in 1947. Is this a record? My newsagent at the time told me that Wireless World would be too technical for me!

I think the present format and contents of EW are about right. Personally, I would like to have more articles on 'how things work' such as satellite receivers, Digital TV, CD players, DVD, radio controllers, MSF Rugby clock, GPS, Caesium beam, frequency standard, numerical control and readout for machine tools, also of interest would be the application of electronics to scientific instruments such as telescope drives, electron microscopes, spectrometers, ph meters, and gas analysis instruments. Constructive articles are always most welcome.

Oh dear! Quite a list, but I hope you can do something along these lines.

Anyhow, keep up the good work – I hope Electronics World will last forever.

Ron MacRae
Dorchester, Dorset, UK

We'll have a go! - ED

PCBs again

I must take issue with a point raised by Cyril Bateman regarding providing PCB layouts in a commonly readable format.

PDF is simply THE ONLY sensible way to do it. The format produces very compact files, readable on pretty much any operating system in common use, and as it's vector (not bitmap) based and will print at whatever resolution the user's printer is capable of.

As regards generating PDFs, Adobe provide a PDF printer driver, so any PCB software that can produce a useable printout can produce a useable PDF file just as easily, so I don't understand the comment about the "number of file conversions" he thinks is necessary.

Adobe's PDF driver is part of the Acrobat package, although I believe there are some lower cost or freeware methods of achieving the same result - a web search for 'PDF Printer Driver' will find many other solutions. Incidentally, if anyone has version 1 of Linear Technology's 'Linearview' component databook CD, this has a version of Acrobat Exchange which includes a PDF printer driver that works in Windows 3.1, 95 and 98.

Mike Harrison
Loughton, Essex
UK

More PCBs II

It is with great interest that I follow the writings of Cyril Bateman in your excellent and enjoyable magazine.

In the letters section of the November issue, the issue of capturing schematics (and PCB boards) in a common (Windows) file format was brought up. I might have a positive contribution on this topic.

I myself use an ancient MSDOS (student) version of OrCAD (V4.02). I run this software in a DOS box under Windows. If I want to capture a schematic printout, I run the PRN2FILE utility program prior to starting OrCAD. This program redirects the printer output of a MSDOS program to a file. If I use one of the DESKJET drivers of OrCAD, I can use the HPJ2PCX utility program to translate this printer file to a PCX graphics file. This PCX file can be opened by any graphics program and converted to a (compact) GIF file. The results are good enough for on screen viewable schematics, which print well too. The GIF file sizes are (very) small, making them ideal for publishing these schematics on the internet. For publishing such schematics in a magazine such as yours, the results are probably too 'low-res', with jagged diagonal lines and circles. None the less, this may very well be a good starting point for exploring other possibilities.

I did manage to find a Windows based (shareware) program capable of capturing printer data (Virtual Port Monitor by Alphatronics), but I was unable to convert those files using HPJ2PCX with success. Even though this may be of interest to Cyril and other readers.

All the above mentioned programs can be downloaded from my site (www.XtendRepair.nl/downloads.htm). Even though this is a Dutch site, I've made the Downloads page bilingual (English and Dutch) for this occasion.

Xavier van Unen MSC EE
www.XtendRepair.nl
Netherlands

Spring to life

N. L. Smith of Stoke-on-Trent is absolutely correct. As shown in the diagram (Electronics World, July 2002, page 30), the two springs are in series. So each supports the full weight W, and consequently each stretches by, say, D. Consequently, the weight W hangs 2D lower than it would if weightless.

With string X cut, the two springs are in parallel, and each only supports a weight W/2. Thus each is stretched only by $\Delta/2$, and the weight hangs $\Delta/2$ lower than it would if weightless. Thus, on cutting string X, the weight rises by $3\Delta/2$.

Hot Electron

Biased opinion

In *Electronics World* Oct. 2002 the £50 winner circuit idea "Mobile phone triggered combination lock" does not work as advertised. GSM mobile phones do not usually generate the required DTMF audio signals as they are not needed. Instead most mobile phones generate only an indication sound when a button is pushed, there may be only three different tones available in this way. DTMF tones are needed by analogue telephones when they transmit the selected numbers over analogue lines without the help of a modem. GSM mobile phones are fully digital and therefore have no use for DTMF signalling. Thus mobile phones are not practical in this application.

Pentti Haikonen
Nokia Research Center

Pentti, I think you probably never use anything but Nokia equipment. Both my old Ericsson and my new Motorola mobiles have a menu option that allows DTMF tones to be heard as you hit the keypad. DTMF signalling is also very useful when accessing the awful automated 'call centres' that we all hate when dealing with our bank, for example. ED ■

WEB DIRECTIONS

Put your web address in front of 18,000 electronic fanatics. Electronics World acknowledge your company's needs to promote your web site, which is why we are dedicating 2 pages in every issue to WEB ADDRESSES.

Linage only will cost £150 + vat for a full year.

Linage with colour screen shot will cost £350 + vat for a full year, this will include the above plus 3cm shot of your web site which we can produce if required.

To take up this offer or for more information telephone

Reuben Gurunlian

Tel 0208 722 6028

E-mail

r.gurunlian@highburybiz.com

ANASOFT LTD

http://www.anasoft.co.uk

SuperSpice, the affordable, mixed-mode windows circuit simulator. Wrote by an analogue design engineer for those Teletubbies who like keeping things simple.

BEDFORD OPTO TECHNOLOGY LTD

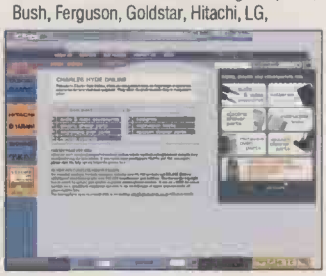
http://www.bot.co.uk

Optoelectronic products UK design development manufacture standard and custom, LED bargraphs, circuit board indicators, stand offs, transmissive/reflective switches, baseefa optocouplers tubular and surfacemount, pannel mount LED assemblies.

CHARLES HYDE & SON Ltd

http://www.charleshyde.co.uk

Search for both original and copy spare parts in our extensive database covering Akai, Alba, Bush, Ferguson, Goldstar, Hitachi, LG,



Marantz, Matsui, Nokia, Saisho, Sanyo, Sony, Sharp, Thomson, Panasonic, Philips, Samsung, Tascam, Teac, Toshiba, Yamaha and many more. In addition huge ranges of Lasers, Lopts, Remote controls and Semiconductors may be accessed.

CHYGWYN

http://www.chygwyn.com

ChyGwyn Limited offers electronic design and embedded software development for remote monitoring, embedded appliances, set-top boxes and similar devices. We are experts in customisation of Linux and write device drivers for custom hardware.

CONFORD ELECTRONICS

http://www.confordelec.co.uk/index.shtml

Lightweight portable battery/mains audio units offering the highest technical performance. Microphone, Phantom Power and Headphone Amplifiers. Balanced/unbalanced signal lines with extensive RFI protection.

CROWNHILL ASSOCIATES LTD

http://www.crownhill.co.uk

Crownhill supply low cost development tools for use with Micro-Controllers and Smart Cards. Products include Smart Card development tools, Smart cards, Micro Development tools and Bespoke Design Services.

CRICKLEWOOD ELECTRONICS

http://www.cricklewoodelectronics.co.uk

Cricklewood Electronics stock one of the widest ranges of components, especially semiconductors including ICs, transistors, capacitors, all at competitive prices.

DB TECHNOLOGY

http://www.dbtechnology.co.uk/

EMC Testing and Consultancy.
Anechoic chamber and open area test site.

- Compliance Tests
- Rapid, accurate pre-compliance tests.
- Fixes included. FCC Listed.
- Flexible, hourly booking available.

DESIGNER SYSTEMS CO.

http://www.designersystems.co.uk

Electronic product design company with over a decade of experience promoting it's own product range and designing and manufacturing innovative products for client companies/individuals.

EAGLE PCB DESIGN SOFTWARE

http://www.puresoft.co.uk

- Professional PCB design made easy!

- Fully functional freeware download.
- Schematics, Layout & Autorouting.
- Free tech support

EasySync

http://www.easysync.co.uk

EasySync supplies a wide range of USB-RS232 and USB-RS422/485 converters. It also specialises in USB test and measurement devices.

EQUINOX TECHNOLOGIES UK LTD

http://www.equinox-tech.com

Equinox Technologies UK Ltd., specialise in development tools for the embedded microcontroller market.

FELLER UK

http://www.feller-at.com

Feller (UK) Ltd. manufacture Fully approved cordsets (Moulded mains plugs and connectors) and Power Supply Cables for all Industrial Countries to National and International Standards

FUTURE TECHNOLOGY DEVICES INTL. LTD.

http://www.ftdichip.com

FTDI designs and sells USB-UART and USB-FIFO Interface i.c.'s. Complete with PC drivers these devices simplify the task of designing or upgrading USB peripherals

GREENWELD

http://www.greenweld.co.uk

Audio ● Batteries & Chargers ● Books ● Communications ● Computer ● Cable ● Capacitors● Car Equipment ● Craft Goods ● Disco Equipment ● Enclosures ● Electrical ● Fuses ● Graphic supplies ● Hardware ●Instrumentation ● Kits ● Lighting Mechanical ● Optical ● Photographic ●Power supplies ● Transformers Resistors ● Semiconductors ● Software ● Soldering Irons ● Surplus goods ● Switches ● Relays ● Telephone Accessories ● Tools ● Plus much more.

Whether your interest is in electronics, model engineering, audio, computer, robots or home and leisure products (to name just a few) we have a wide range of new and surplus stock available.

J W HARDY COMMUNICATIONS

http://www.jwhardy.co.uk

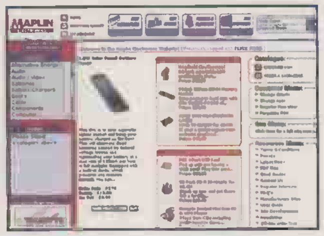
R.F. Network Specialist.
Shop online - for R.F.network components. We supply a full range of TV, radio reception equipment to receive analogue/digital signals from both terrestrial and satellite sources. We provide a free planning service for your R.F. networks, MATV and SMATV etc

LOW POWER RADIO SOLUTIONS

http://www.lprs.co.uk

LPRS produces radio modules with embedded "easy-Radio" software protocols for short range radio applications. We also represent Circuit Design narrow band modules in the UK.

To reserve your web site space phone Reuben Gurunlian
Tel: 020 8722 6028
Fax: 020 8722 6096



MAPLIN ELECTRONICS

http://www.maplin.co.uk
A fully secure and interactive internet ordering system from Maplin Electronics, the specialist electronic retail and mail order company to business and retail consumers alike. 15,000 products available on line.

MATRIX MULTIMEDIA LTD

www.matrixmultimedia.co.uk

Matrix Multimedia publishes a number of highly interactive CD ROMs for learning electronics including: Complete electronics course, Analogue filter design, and PICmicro(R) microcontroller programming (C and assembly).

NORCALL Ltd

http://www.norcall.co.uk

e-mail Norcall@aol.com

Suppliers programmers and repairers of new and refurbished two-way radio equipment. Retuning and recrystalling service available. All types of batteries chargers and aerials supplied.

PHAEDRUS LTD

www.phaedrusltd.co.uk

Manufacturer and supplier of low cost general purpose and serial I/O digital modules and accessories. PC based software for data logging and control applications.

QUASAR ELECTRONICS

www.quasarelectronics.com

Over 250 electronic kits, projects and ready built units for hobby, educational & industrial applications.
TEL: 01279 467799, FAX: 07092 203496 or EMAIL:
ewsales@quasarelectronics.com

RADIO-TECH LIMITED

http://www.radio-tech.co.uk

Radio modules, modems, telemetry, audio transmitters, pagers, antenna, remote controls and much more. All UK designed and manufactured.

RADIOMETRIX

http://www.radiometrix.co.uk

Radiometrix specialises in the design and manufacture of VHF & UHF, RF data modules. We offer a broad range of PCB mounted miniature transmit, receive and transceiver modules for OEM use. They comply with European harmonised standards EN300 220-3 and EN301 489-3 and are CE certified by an independent Notified Body.

RALFE ELECTRONICS

professional test & measurement

www.ralfe-electronics.co.uk

SOFTCOPY

http://www.softcopy.co.uk

As a PC data base or hard copy, SoftCopy can supply a complete index of Electronics World articles over the past ten years. Photo copies of articles from back issues are also available.

TELNET

http://www.telnet.uk.com

Top quality second-user Test and Measurement Equipment
eMail sales@telnet.uk.com

TELEVES

http://www.televes.com

Tel: 44(0) 1633 875821
email hbotas@televes.com
Televes website was launched as an easier way to keep in contact with our World-wide Network of Subsidiaries and Clients. This site is constantly updated with useful information/news plus you can download info on our range: TV Aerials & accessories, Domestic and Distribution amplifiers, Systems Equipment for DTT and Analogue TV, Meters and much more.

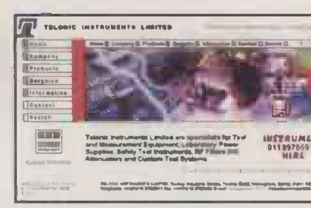
TEST EQUIPMENT SOLUTIONS

http://www.TestEquipmentHQ.com

Test Equipment for rental or second user sale at the industry's lowest prices. All types of equipment from all leading manufacturers including general purpose, communications and industrial test. Items fully refurbished with 1 year warranty. Rental rebate given on purchases.

TELONIC

http://www.telonic.com



Telonic specialists in laboratory AC & DC Power Supplies, Electronic AC & DC Loads, Electrical Safety Testing and complete test systems. Plus RF Filters, Attenuators, Diesel Engine Smoke Measurement, Quartz Crystal Microbalances.
Tel +44 (0) 118 9786911

TOTAL ROBOTS

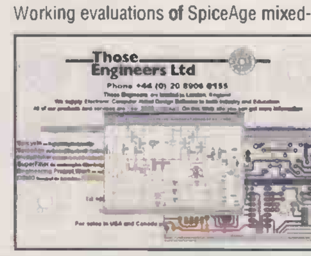
http://www.totalrobots.co.uk

Robot Kits and Control Technology products, including OOPic the first Object-Oriented Programmable Integrated Circuit. Secure on-line ordering and fast delivery.

THOSE ENGINEERS LTD

http://www.spiceage.com

Working evaluations of SpiceAge mixed-



mode simulator, Spicycle PCB design tools and Superfilter demo (synthesises passive, active, digital filters). Tech support, sales links and price list.

ULTRA-CREA OY

http://www.ultra-crea.fi

Our business idea is to provide our customers complete service, i.e. design from the customer specification to the delivery of finished and tested products. Our offerings are as follows:

- RF transmission line filters from 100MHz to 3GHz
- Special antennas to frequencies as above
- Transmitter and Receiver modules
- RF-subunits such as amplifiers, oscillators, directional couplers etc.

VULTRAX PCB DESIGN SOFTWARE

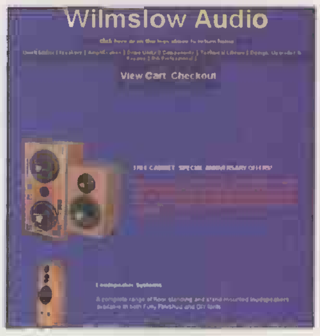
http://www.vultrax.co.uk

Vultrax electronic schematic and pcb design system for Windows 95/98, ME, NT, 2000, XP and Linux. Limited capacity FREE version downloads available, all upgradeable to various customised level.

WILMSLOW AUDIO

http://www.wilmslow-audio.co.uk

"Uk's largest supplier of high quality loudspeaker kits and drive units. Comprehensive range of components and accessories, including damping products, connectors and grilles materials. Demonstration facilities available.



Put your web address in front of 18,000 electronic fanatics. Electronics World acknowledge your company's needs to promote your web site, which is why we are dedicating 2 pages in every issue to WEB ADDRESSES.

Linage only will cost £150 + vat for a full year.

Linage with colour screen shot will cost £350 + vat for a full year, this will include the above plus 3cm shot of your web site which we can produce if required.

To take up this offer or for more information telephone

Reuben Gurunlian

Tel 0208 722 6028

E-mail

r.gurunlian@highburybiz.com

Ten year index: new update

www.softcopy.co.uk

Photo copies of *Electronics World* articles from back issues are available at a flat rate of £3.50 per article, £1 per circuit idea, excluding postage.

Hard copy *Electronics World* index

Indexes on paper for volumes 100,101, and 102 are available at £2 each, excluding postage.

Hard copies and floppy-disk databases both available

Whether as a PC data base or as hard copy, SoftCopy can supply a complete index of *Electronics World* articles going back over the past nine years.

The computerised index of *Electronics World* magazine covers the nine years from 1988 to 1996, volumes 94 to 102 inclusive and is available now. It contains almost 2000 references to articles. circuit ideas and applications - including a synopsis for each.

The *EW* index data base is easy to use and very fast. It runs on any IBM or compatible PC with 512K ram and a hard disk.

The disk-based index price is still only £20 inclusive. Please specify whether you need 5.25in, 3.5in DD or 3.5in HD format.
Existing users can obtain an upgrade for £15 by quoting their serial number with their order.

Ordering details

The *EW* index data base price of £20 includes UK postage and VAT. Add an extra £1 for overseas EC orders or £5 for non-EC overseas orders
Postal charges on hard copy indexes and on photocopies are 50p UK, £1 for the rest of the EC or £2 worldwide.
For enquires about photocopies etc please send an sae to SoftCopy Ltd. **Send your orders to SoftCopy Ltd, 1 Vineries Close, Cheltenham GL53 0NU.**
Cheques payable to SoftCopy Ltd, please allow 28 days for delivery.

As an advertiser you can be certain that your sales message is going to be read by decision-making electronics professionals with the power to purchase your products.

The pre-paid rate for semi-display setting is £17 per single column centimetre (maximum 4cm). Box number £22 extra. All prices plus 17½% VAT. All cheques, postal orders etc to be made payable to Highbury Business Communications Ltd. Advertisements together with remittance should be sent to Electronics World Classified, Highbury Business Communications Ltd, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8DZ.
Tel: 020 8722 6028. **Fax: 020 8770 2016.**

Service Link

ARTICLES WANTED

FOR SALE

SERVICES

WANTED

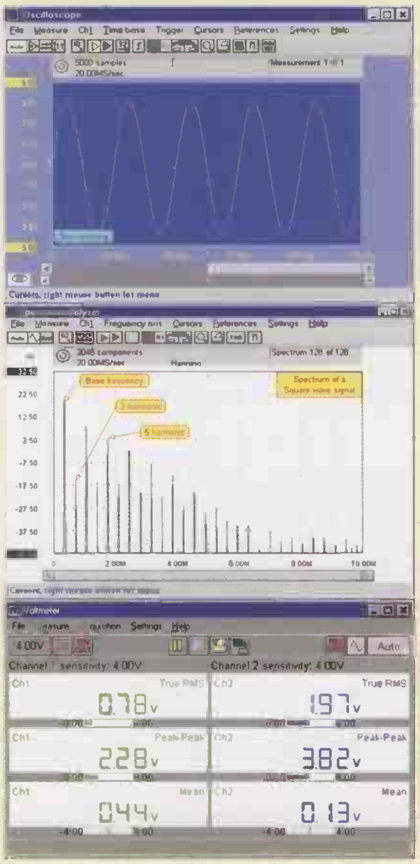
SERVICES

Service Link

OSCILLOSCOPE | FFT ANALYSER | VOLTMETER | RECORDER

The Handyscope 3 is a powerful and versatile two channel measuring instrument with an integrated function generator.

- USB 2.0 connection (USB 1.1 compatible)
- sample speed up to 100 MHz per channel
- 8 to 16 bit resolution (6 μVolt resolution)
- 50 MHz bandwidth
- input sensitivity from 200 mVolt up to 80 Volt
- large memory up to 131060 samples per channel
- four integrated measuring devices
- spectrum analyser with a dynamic range of 95 dB
- fast transient recorder up to 10 kHz
- several trigger features
- auto start/stop triggering
- auto disk function up to 1000 files
- auto setup for amplitude axis and time base
- auto trigger level and hysteresis setting
- cursor measurements with 21 read-outs
- very extensive function generator (AWG) 0-2 MHz , 0-12 Volt



HANDYSCOPE HS3

WWW.TIEPIE.NL

C3

for more information, demo software, software, source code and DLL's visit our internet page: http://www.tiepie.nl

TiePie engineering (NL)
Koperslagersstraat 37
8601 WL SNEEK
The Netherlands
Tel: +31 515 415 416
Fax: +31 515 418 819

TiePie engineering (UK)
28, Stephenson Road, St. Ives
Cambridgeshire, PE17 3WJ, UK
Tel: 01480-460028
Fax: 01480-460340

TEST EQUIPMENT SOLUTIONS

Quality Second User Test Equipment
With 12 Months Warranty

The Industry's Most Competitive Test Equipment Rental Rates

	Sale (GBP)	Rent (GBP)
AMPLIFIERS		
Amplifier Research 10W1000B 1GHz 10W RF Amplifier	2950	95
Amplifier Research 1W1000 1GHz 1W RF Amplifier	950	41
DATACOMMS		
Fluke DSP4000 Cat 5e/6 LAN Cable Tester	2950	88
HP J3446C LAN Fast Ethernet Internet Advisor	6950	255
Microtest PENTA SCANNER+ Cat 5 Cable Tester & Injector	1300	68
ELECTRICAL NOISE		
HP 346B 18GHz APC3.5 Noise Source	1150	45
HP 8970B/020 2GHz Noise Meter	7950	235
ELECTRICAL POWER		
BMI 100G POWERVISA 1 Phase Mains Disturbance Analyzer	1950	75
BMI A-116 1-600A Current Clamp For BMI 4800/100G	650	19
Kikusui TOS8850 Insulation Tester	1250	43
Megger RM215/ L/2 Breakdown Leakage Tester	1250	37
EMC		
Chase HFR2000 30MHz Measuring Receiver	750	34
Chase LFR1000 9KHz-150KHz Interference Meas Receiver	850	34
Chase MN2050 30MHz LISN	395	20
R&S EB100 20MHz-1GHz EMC Test Receiver	1950	75
R&S EPZ100 Panoramic Display For EB100	695	28
Schaffner NSG200E EMC Mainframe	795	34
Various Schaffner NSGxxx Plug Ins (From)	795	34
FREQUENCY COUNTERS		
EIP 578 26GHz Microwave Source Locking Counter	1850	75
HP 53131A/030 3GHz Universal Frequency Counter	1350	40
HP 53181A 225MHz 10 Digit RF Counter	895	31
HP 5385A 1GHz Frequency Counter	595	26
Marconi CPM46 46GHz Counter Power Meter	4950	210
Racal 1992/04C 1.3GHz Counter Timer	1150	34
Racal 1998 1.3GHz Frequency Counter	695	26
FUNCTION GENERATORS		
HP 33120A 15MHz Function/Arbitary Waveform Generator	950	28
HP 3325B 21MHz Function Generator	3500	105
HP 8116A 50MHz Function Generator	2650	96
HP 8904A/001/002/003 600KHz Function Generator	2950	116
Philips PM5191 2MHz Function Generator	1250	39
Philips PM5193 50MHz Function Generator	1750	62
Tek AWG2021 125MHz 250MS/s Arbitary Waveform Gen	5750	208
LOGIC ANALYSERS		
HP 16500C Logic Analyser Mainframe	2350	85
HP 16510A 100MHz Timing 25MHz State 80 Ch Card	975	43
HP 1660C 500MHz Timing 100MHz State 136 Ch Log Ana	4500	198
HP 1661A 500MHz Timing 100MHz State 102 Ch Logic Ana	2950	169
HP 1663C/015 500MHz Timing 100MHz State 34 Ch Ana	1850	75
MULTIMETERS		
Keithley 2400 Digital Sourcemeter	2500	75
Schlumberger 7150+ 6.5 Digit Precision Multimeter	395	25
Thandar 1604 4.75 Digit Digital Multimeter	395	32
NETWORK ANALYSERS		
Anritsu S251B/05 2.5GHz Dual Port Scalar Network Analyser	6950	208
Anritsu S331B 3.3GHz Scalar Network Analyser	5500	218
Anritsu S332B/05 3.3GHz Scalar Network And Spectrum Ana	7950	295
HP 35677A 200MHz 50 Ohm S Parameter Test Set	1895	56
HP 3577A 5Hz-200MHz Network Analyser	4750	142
HP 4195A 500MHz Network/Spectrum Analyser	9500	285
HP 85047A 6GHz 50 Ohm S Parameter Test Set	5500	195
HP 8510C 50GHz Microwave Network Analyser	22500	809
HP 8515A 26.5GHz S Parameter Test Set	21500	885

	Sale (GBP)	Rent (GBP)
HP 8714C 300KHz-3GHz Vector Network Analyser	8950	323
HP 8720C 20GHz Vector Network Analyser c/w S Param	26500	954
HP 8752A/003 3GHz Vector Network Analyser c/w TR	5950	179
HP 8753C/006 6GHz Vector Network Analyser	13500	486
OSCILLOSCOPES		
Various Active Scope Probes (from)	275	12
HP 54501A 4 Channel 100MHz 20MS/s Digitising Scope	1250	37
HP 54542A 4 Channel 500MHz 2GS/s Digitising Scope	3950	143
HP 54601B 4 Channel 100MHz 20MS/s Digitising Scope	1950	71
HP 54615B 2 Channel 500MHz 1GS/s Digitising Scope	3250	117
HP 54825A 4 Channel 500MHz 2GS/s Digitising Scope	10500	378
HP 54845A 4 Channel 1.5GHz 8GS/s Digitising Scope	13950	503
Kikusui COM7201 4 Channel 200MHz Digitising Oscilloscope	2350	70

Checkout our new 2003 Product Guide!! Call Us Now for Your Copy

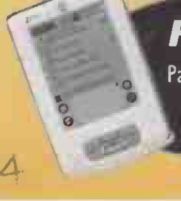
	Sale (GBP)	Rent (GBP)
Lecroy LT344 4 Channel 500MHz 500MS/s Digitising Scope	5750	207
Tek A6302/AM503/TM501 Current Clamp System	700	25
Tek TAS455 2 Channel 60MHz Analog Scope	395	17
Tek TAS465 2 Channel 100MHz Analog Scope	495	21
Tek TDS3054/3FFT/3TRG 4Ch 500MHz 5GS/s Dig Phos Scope	6500	195
Tek TDS320/14 2 Channel 100MHz 500MS/s Digitising Scope	1450	69
Tek TDS350 / 014 2 Ch 200MHz 1GS/S Digitising Scope	2150	78
Tek TDS420A 4 Channel 200MHz 100MS/s Digitising Scope	2950	125
Tek TDS460 4 Channel 350MHz 100MS/S Digitising Scope	3250	143
Tek TDS520A 2 Channel 500MHz 500MS/s Digitising Scope	3250	117
Tek TDS540A 4 Channel 500MHz 2GS/s Digitising Scope	4500	162
Tek TDS640A 4 Channel 500MHz 2GS/s Digitising Scope	4500	201
Tek THS720 2Ch 100MHz 500MS/s Handheld Scope c/w DMM	1350	55
POWER METERS		
HP 436A RF Power Meter	650	28
HP 437B/002 RF Power Meter	1350	62
Various HP 848x Sensors (from)	450	25
HP E4412A 10MHz-18GHz 100mW Power Sensor	695	25
HP E4418A/002 Single Channel Power Meter	1695	52
HP E4419A Dual Channel RF Power Meter	2500	75
Marconi 6960/GPIB RF Power Meter	695	25
POWER SUPPLIES		
Various DC PSU's up to 100V / 150A (from)	150	12
Kikusui PCR1000L 1KVA Voltage/Frequecy Convertor c/w IEEE	4250	127
Kikusui PLZ150W 150W Electronic Load	595	25
RF SWEEP GENERATORS		
HP 8340B 26.5GHz Synthesized Sweep Generator	19500	702
HP 8350B Programmable Sweep Oscillator Mainframe	1950	85
Various HP 835xx Sweep Plug Ins (from)	3950	143
HP 83620A/ 001 10MHz To 20GHz Synthesized Sweeper	18500	667
HP 83630B 10MHz To 26.5GHz Synthesized Sweeper	24500	995
SIGNAL & SPECTRUM ANALYSERS		
Advantest R3361A 9KHz-2.6GHz Spectrum Analyser With TG	5950	185
Advantest R4131D 3.5GHz Spectrum Analyser	4250	189
Advantest R9211A 100KHz Dual Channel FFT Analyser	2950	99
Anritsu MS2602A/01/04 100Hz-8.5GHz Spectrum Analyser	8950	298
Anritsu MS2711A/05 3GHz Portable Spec Ana c/w Pwr Meas	4950	148

	Sale (GBP)	Rent (GBP)
Anritsu MS610B 2GHz Spectrum Analyser	2650	89
Anritsu MS710C 23GHz Spectrum Analyser	7500	235
HP 339A 110KHz Distortion Analyser	1250	37
HP 3561A 100KHz Dynamic Signal Analyser	2950	115
HP 3562A 100KHz Dual Channel Dynamic Signal Analyser	3950	118
HP 35660A 102.5KHz Dual Channel Dynamic Signal Analyser	3250	97
HP 70000 2.9GHz Spectrum Analyser System	4950	185
HP 85024A 3GHz Active Probe	1450	43
HP 8560A/002/H03 2.9GHz Spectrum Analyser	6950	210
HP 8561E 6.5GHz Spectrum Analyser	12500	389
HP 8562A 22GHz Spectrum Analyser	13500	399
HP 8566B 22GHz Spectrum Analyser	13500	499
HP 8590B/021 1.8GHz Spectrum Analyser	3500	141
HP 8591E/041 1.8GHz Spectrum Analyser	4500	148
HP 8592B 22GHz Spectrum Analyser	7500	235
HP 8593E 22GHz Spectrum Analyser	14500	522
HP 8594E/041/101/105 2.9GHz Spectrum Analyser	6500	255
HP 8901B/001 1.3GHz Modulation Analyser	1250	39
HP 8903B/10/51 20Hz To 100KHz Audio Analyser	2450	75
SIGNAL GENERATORS		
Anritsu MG3633A / 002 10KHz-2.7GHz Signal Generator	5500	182
HP 8642A/001 1GHz High Performance Synthesised Sig Gen	1650	59
HP 8648C 9KHz-3.2GHz Synthesised Signal Generator	4500	190
HP 8657A/001 1GHz Synthesised Signal Generator	1750	52
HP 8657B/001 2GHz Synthesised Signal Generator	3500	85
HP 8672A 2-18GHz Synthesised Signal Generator	4950	148
Marconi 2022 Synthesized 1GHz Signal Generator	695	28
R&S SMY02 9KHz-2GHz Synthesised Signal Generator	3150	115
TELECOMS		
HP 37717C/UKJ PDH Transmission Analyser	2450	88
HP 37722A 2MBPS Digital Telecom Analyser	4950	199
HP 37724A Portable SDH/PDH Analyser	4950	199
HP 3788A/001 2MBPS Error Performance Analyser	1350	40
Marconi 2840A 2MB Handheld Transmission Analyser	1250	45
Phoenix 5500A Telecomms Analyzer + Interfaces	2500	75
Trend AURORA DUET Basic Rate ISDN Tester	995	29
TTC Fireberd 6000A Communication Analyser	4500	135
Various Fireberd Comms Interfaces (from)	495	21
W&G PFA-35 2MB/s Digital Transmission Analyser	3850	115
TV & VIDEO		
Minolta CA-100 CRT Colour Analyser	2650	96
Philips PM5418TDS +Y/C TV Pattern Generator Y/C + RGB	2150	73
Philips PM5518GTX/RGB TV Pattern Generator	1750	58
Philips PM5518TN & Y/C TV Pattern Generator	1750	58
Tek 1751 PAL Vectorscope	2500	97
WIRELESS		
Anritsu ME4510B Digital Microwave System Analyser	12500	285
HP 83220A/022 DCS/PCS1800 (1710-1900) Test Set	1950	60
HP 8920A/B 1 GHz Radio Comms Test Set - Various (from)	4950	148
HP 8922M/001/003/101 1GHz GSM MS Test Set	5950	178
Marconi 2955B 1GHz Radio Comms Test Set	3500	126
Marconi 2965/012 1GHz Radio Communications Test Set	5950	178
R&S CMD55/B3/4/6/9/19/43/61/U18/20 Rad Comms Test Set	6750	202
R&S CMS52/B1/B5/B9/B15/B28 1GHz Radio Comms Test Set	5750	172
R&S CMT56/B1/4/6/9/11/13/U1/9 1GHz Rad Comms Test Set	1950	58
Racal 6103/1/2/14/4T GSM/DCS Dig Mobile Radio Test Set	6500	195
Wavetek 4201S Triband Radio Test Set	3950	119
Wavetek 4202S Triband Radio Test Set with AM Sig Gen	4750	143

If you don't see what you want, please CALL!

See our extensive online catalogue at www.TestEquipmentHQ.com

Flexible commercial solutions available on all products



FREE Palm Zire shipped with every order over £5K

Prices shown are for guidance in £UK and are exclusive of VAT. Rental prices are per week for a rental period of 4 weeks. Free carriage to UK mainland addresses for Sales. This is just a selection of the equipment we have available - If you don't see what you want, please call. All items supplied fully tested and refurbished. All manuals and accessories required for normal operation included. Certificate of Conformance supplied as standard; Certificate of Calibration available at additional cost. Test Equipment Solutions Terms apply. E&OE.

01753 596000
Fax: 01753 59 6001
www.TestEquipmentHQ.com
email: info@TestEquipmentHQ.com