

Miniature video camera - 20% discount

16 extra  
pages free

# ELECTRONICS WORLD

Austria Asch. 65.00  
Denmark DKr. 66.00  
Germany DM 15.00  
Greece Dra. 1000.00  
Holland Dfl. 14.50  
Italy L. 8500.00  
Malta Lm. 1.45  
IR £3.30  
Singapore S\$12.60  
Spain Pts. 800  
USA \$5.50

A REED BUSINESS PUBLICATION  
SOR DISTRIBUTION

INCORPORATING WIRELESS WORLD

July/August 1996 £2.25

## High-fidelity preamplifier

**Multi-Pentium  
motherboards**

**Power factor  
correction**

**Talking  
thermometer**

**Lab amplifier**

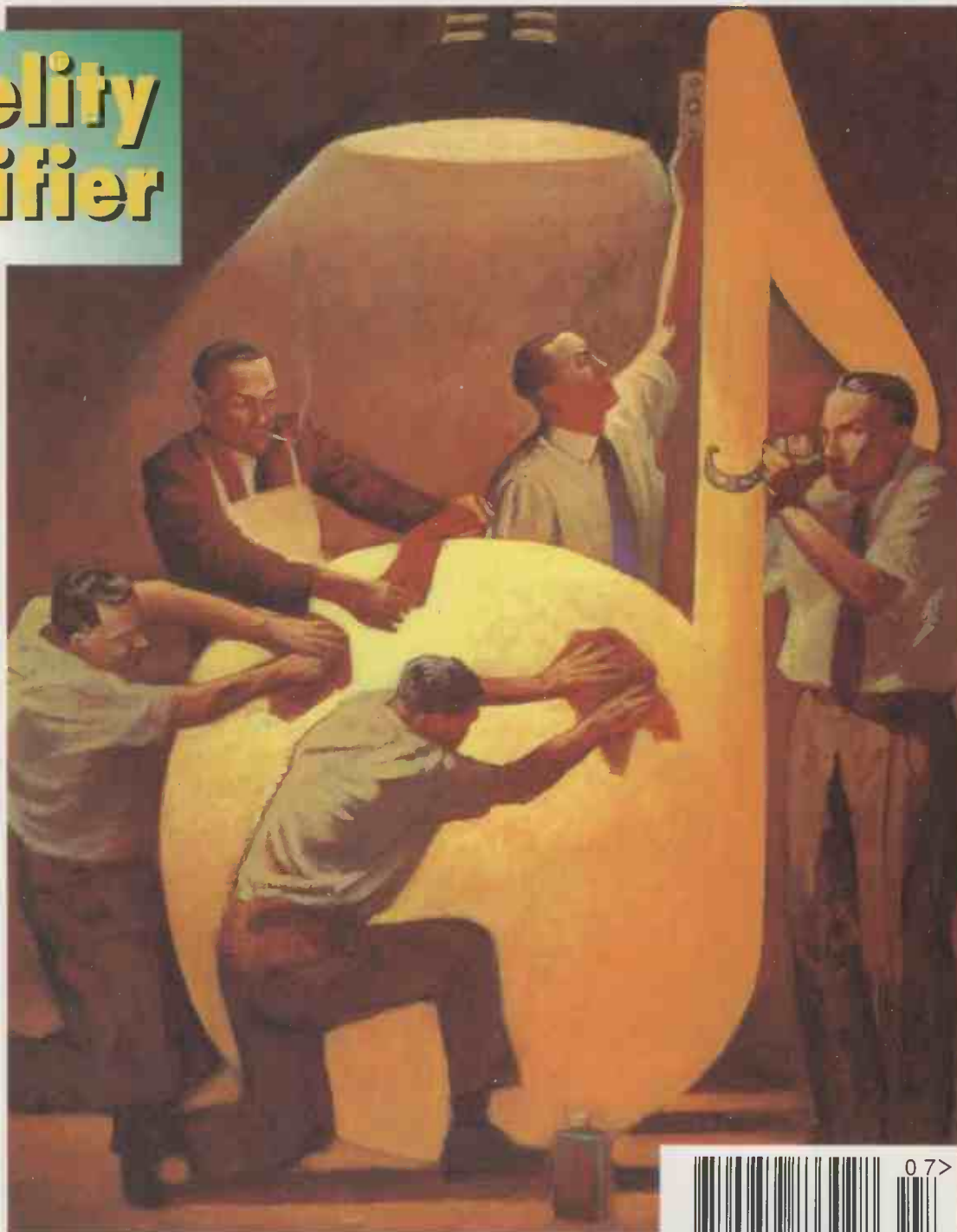
**Visualising  
circuits**

**Capacitance  
meter covers pF**

**Relay for audio**

**Speaker cables**

**Review - Pico's  
new fast a-to-d**



**50MHz virtual instrument - special offer**



9 770959 833028

Small

Awkward

# PROBLEMS?

BIG

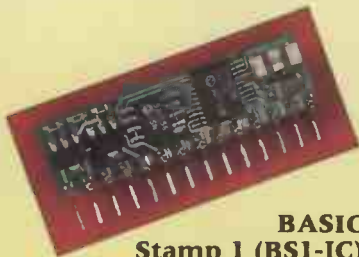
No Time

# SOLUTION!

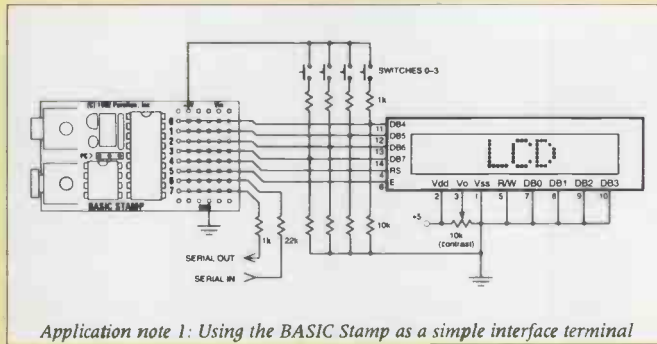
PIC based TOOLS to help you realise your project:  
from single applications to full scale production

## BASIC STAMPS®

PIC based BASIC Stamps are perfect for one-off and low volume applications. Their easy to learn but powerful BASIC syntax (with familiar instructions such as GOTO, FOR ... NEXT, and IF ...THEN as well as instructions for serial I/O, pulse measurement, button debounce, DTMF, X-10 etc) will get your application up and running in hours. Once programmed, the Stamp runs independantly of your PC and programs are stored in non-volatile EEPROM so they can be changed at will. Detailed manuals cover many commonly needed routines and the Stamp is well supported by a growing list of custom application kits to cut development time even further. Available in two formats:

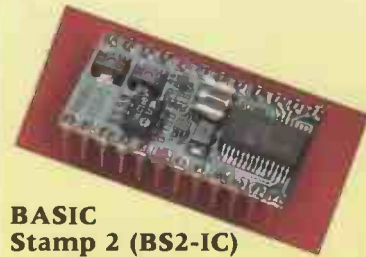


**BASIC Stamp 1 (BS1-IC)**  
8 I/O Lines  
up to 80 program lines  
Comms to 2400 baud  
35x10mm size  
£29 single price



Application note 1: Using the BASIC Stamp as a simple interface terminal

Typical Application



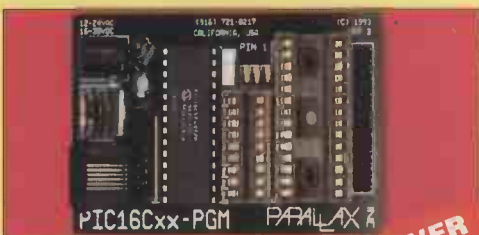
**BASIC Stamp 2 (BS2-IC)**  
16 I/O Lines  
up to 500 program lines  
Comms to 50 kbaud  
24pin DIP package  
£49 single price

**BASIC Stamp Development Kits** including PC software, manuals, 24+ application notes, downloader cables, Stamp (BS1-IC or BS2-IC) and corresponding Project Board - £99 / £119

## PIC16Cxx DEVELOPMENT TOOLS

For medium to large volumes and high speed requirements, the popular range of PICs is hard to beat. We offer an extensive range of programmers, emulators and associated hardware to support the following PICs: 52 54 55 56 57 58 620 621 622 61 62 63 64 65 71 72 73 74 84

### PIC16Cxx Programmer

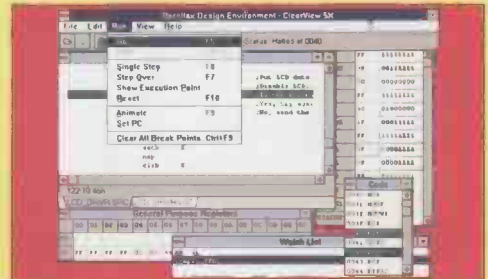


OVER 5000 SOLD

- Also stocked
- \* ZIF sockets
  - \* SOIC/SSOP/PLCC adapters
  - \* Prototyping boards
  - \* Compilers/Simulator

### In Circuit Emulators

- \* True hardware emulation of program memory, registers and I/O
- \* Unlimited breakpoints.
- \* Single stepping
- \* Software-programmable oscillator
- \* Windows Environment
- \* Runs from 32Khz to 10Mhz ('xx) and 20Mhz ('5x)
- \* Source level debugging for PASM(X), MPASM and MPC
- \* Optional trace facility



**Milford Instruments**  
Milford House, 120 High Street,  
SOUTH MILFORD LS25 5AQ  
01977 683665 Fax 01977 681465

Please call or fax to receive our catalogue and price list. All prices exclude VAT and £3 shipping.  
BASIC Stamp & the Parallax logo are registered trademarks of Parallax, Inc.

**PARALLAX**   
3805 Atherton Road, #102  
Rocklin, CA 95765 USA  
916-624-8333, Fax 916-624-8303  
<http://www.parallaxinc.com>

# Contents

Cover - Hashim Akib



## 540 PRECISION PREAMPLIFIER '96

Doug Self describes a no-compromise audio preamplifier using high-performance op-amps - part I.

## 548 CROSSOVER NETWORKS MADE SIMPLE

Bill Teleki's short C program makes determining components for Butterworth loudspeaker crossovers quick and easy.

## 552 C METER RESOLVES TO 0.1pF

Emil Vladkov's meter spans 0.1pF-1.999 $\mu$ F - with autoranging - and is trimmable to give up to 0.1% accuracy.

## 558 IN THE PICTURE

Vector diagrams, Bode plots and poles and zeros all have different *fortes*, as Ian Hickman explains.

## 562 NEW RELAY FOR POWER AUDIO

A new relay design is said to offer high power audio switching without compromising signal integrity.

## 566 VIRTUALLY FAST

Paul Mapp looks at a new fast a-to-d converter that turns your pc into a spectrum analyser, dso and meter.

## 570 MEASURING SPEAKER CABLE DIFFERENCES

Ben Duncan explains his technique for measuring loudspeaker cable differences.

## 572 THERMAL ISSUES

Ray Morris argues that thermal engineering is a better proposition than thermal management.

## 580 IF GOES DIGITAL

Andy Thurston describes the benefits of using digital techniques in IF stages.

## 586 IMPROVING POWER FACTOR

Power factor correcting ICs are fine for new designs but what about existing supplies? Irving Gottlieb describes a passive alternative.

## 592 HANDS-ON INTERNET

Cyril Bateman discusses the benefits and limitations of new applications on the World Wide Web.

## 596 LISTENING FOR CLUES

The ultimate squawk box - combining an precise audio amplifier with an af millivoltmeter - designed by Ian Hickman.

## 600 THERMOMETER ANSWERS BACK

A digital voice recorder chip can replace a panel meter and in this instance Heikki Kalliola makes a speaking thermometer.

## 619 FASTER FILTERS

Kamil Kraus looks at how high-speed filters benefit from a high-performance current-mode op-amp.

## 620 DESIGNING CRT DEFLECTION

David Sharples discusses the mechanisms by which tv and monitor deflection transistors fail.

## 624 MULTIPROCESSOR MOTHERBOARDS

Latest high-performance PC motherboards use multiple processors, but how do the processors talk to each other?

## Regulars

### 531 COMMENT

Memory for the masses.

### 533 NEWS

Interactive satellite tv service announced.

### 537 RESEARCH NOTES

New ball lightning findings.

### 575 NEW PRODUCTS

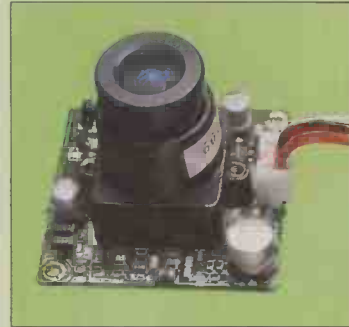
Pick of the month - classified.

### 588/603 LETTERS

Help wanted questions and answers.

### 608 CIRCUIT IDEAS

Pulse-integrating tachometer, complete 30W bridge amp.



Measuring only 32 by 32 by 23mm, this camera outputs composite video and costs just £75 - fully inclusive - but only to readers of *Electronics World*: page 607.



Ball lightning has long puzzled scientists. Jonathan Campbell presents some new evidence on page 539.

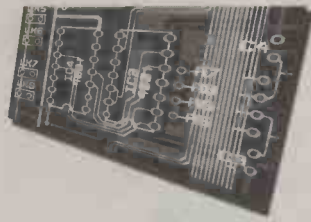
## EW reader discount

Got a PC? If so, you could have a 50MHz sampling DSO, 25MHz spectrum analyser, a digital voltmeter and frequency meter for just £469 by taking advantage of our special reader discount on page 569.

## NOTICE TO SUBSCRIBERS

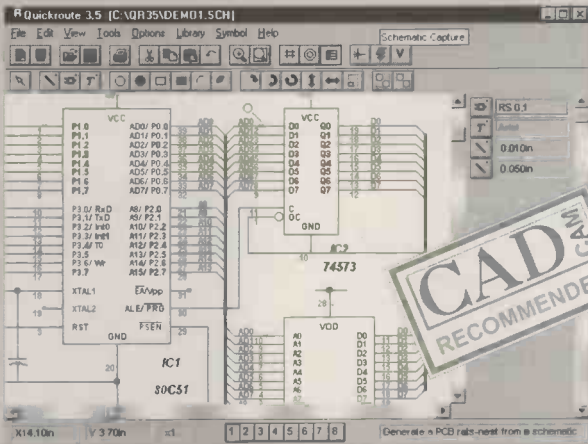
This special combined July/August issue of *Electronics World* will not affect your subscription. You will still receive twelve copies of *Electronics World* for your yearly subscription - including this special combined issue.

**SEPTEMBER ISSUE  
ON SALE 1 AUGUST**



"..it certainly gets my vote!"

Computer Shopper Nov 1995



"..a very capable package which will be of interest to many electronic designers, especially because of its low price."

CADCAM, March 1996

For just £249\* Quickroute 3.5 PRO provides a complete schematic & PCB design system for Windows 3.1, '95 and NT. The system includes multi-sheet schematic capture with power rail and bus support, auto-routing on 1 to 8 layers, netlist, CAD-CAM and WMF file export as well as design rule and connectivity checking.

More advanced functionality is provided by Quickroute 3.5 PRO+ which for just £399\* offers all the features of PRO as well as copper fill, enhanced auto-routing, netlist import, Gerber import/viewing, DXF file export, and links to a wide range of simulation packages. PRO+ also includes engineering change/enhanced connectivity checking which will update your PCB from a schematic, adding or removing nets and components automatically.

Call now and we will send you our free demonstration pack.

\*Prices are PRO £249 and PRO+ £399. Post & packing is £5 (UK), £8 (Europe), and £12 (worldwide). Please add V.A.T to the total amount. Lower cost versions are also available.

Tel/Fax 0161 449 7101  
www.quickroute.co.uk



Email: info@quicksys.demon.co.uk  
Quickroute Systems Ltd., 14 Ley Lane, Marple Bridge,  
Stockport, SK6 5DD, U.K.

Prices and specifications are subject to change without notice.  
All trademarks are acknowledged & respected.

CIRCLE NO. 106 ON REPLY CARD

## RADIO DATA MODULES, SYSTEMS & ACCESSORIES

UK, E.E.C, Scandinavia, Eastern Europe, North & South America, Middle East, South Africa, New Zealand, Far East or Australia. Wherever you are, we have a module on the right frequency for you!

### New I: TXR-XXX-DTR100



Only 55 x 23 x 15mm

- \* UK, North American, Australian \*
- \* MPT, I-ETS, ISM & FCC Approvals \*
- \* Up to 64 selectable channels \*
- \* 433, 458, 462/468 & 472MHz Versions \*
- \* Range up to 5Km + Internal Antenna \*
- \* Compact Size ideal for Hand Helds \*

Special Starter Kit: 2 x -DTR100 + Manual + P&P Now Only £299.95

### New 3V, 20,000bps Transmitters to Simplify Interfacing

- \* Drives directly from a PIC micro output Port III \*
- \* Same R.F power but twice as fast as the Std - A version \*
- \* Matching 20,000bps 5V Receiver (SILRX-XXX-F only £22.50) \*
- \* Available UK Approved MPT1340 418MHz \*
- \* Export I-ETS-300-220, 433.92MHz \*



TXM-418-F Transmitter

\* Special Starter Kit: TXM-F + SILRX-F + data, inc (UK) P&P + Vat £29.95 \*

### South African Data Modules & Security Products on 403MHz

- \* 1mW ERP in to 50 Ohms, P.A's Available ! \*
- \* Evaluation Kits and 100uA RX Decoder Available \*
- \* TXM-403's £14.75, SILRX-403-A £22.50 RXM-403-A £29.50 \*
- \* PEN-403-A £28.00, 1CH-403-A £29.95, 1CH-403-LP £32.50 \*



1CH-403-LP



PEN-403-A

Starter Kit: TXM-A + SILRX-A + RXM-A + 1CH-403 + 1CH-403-LP + PEN-403-A + EVAL KIT + 2 x Antenna + Data Sheets: Only £149.95.

### VHF Modules & Systems for UK, Australia and Beyond !

- \* UK, 173MHz to MPT1344 & MPT1328 Licence Exempt \*
- \* Telemetry Systems: Digital, 12-bit Analogue & Pulse \*
- \* Miniature Low Cost 1 & 10mW Transmitters \*
- \* Exclusive 173.500MHz Modules and Telemetry for Australia \*
- \* Meter reading modules and transmitters to MPT1601 \*



We have over 100 products of various frequencies & powers in stock. Please contact our sales office for a free catalogue. 8 o/p 12-bit Receiver

Corporate Web Site <http://www.radio-tech.co.uk>  
Radio - Tech Limited, Overbridge House, Weald Hall Lane  
Thornwood Common, Epping, Essex CM16 6NB.  
Sales +44 (0) 181 368 8277 Fax +44 (0) 181 361 3434  
Int'l +44 (0) 1992 57 6107 Fax +44 (0) 1992 56 1994

CIRCLE NO. 107 ON REPLY CARD



C. Bateman Engineering

### EMC/RFI Filter Simulator uses 'Real-Time' Components.

Dedicated EMC Filter Simulation Software for 'Windows'® offers simplest possible 'Net-List' generation and correction for Capacitor-Inductor 'Frequency Dependant' parameters.

All Filter Schematics are Pre-drawn, including Capacitor or Inductor parasitic elements, together with 'Startup' 'Default' values. Simply 'overtyp' the 'Defaults' with required values and click on 'Simulate' Button for instant, realistic, results.

Automatically displays on screen: - 'Return - Loss', 'Group - Delay', and 'Insertion - Loss', - no user configuration needed.

This new and unique Simulator uses 'Real-Time' modelling of components by calculating the 'Frequency Dependant' change of value and loss factor for Capacitors and Inductors.

### Unique features of the 'EMC Filter' software:-

- Automatic 'Net-List' Generation - No Learning curve.
- Filter Schematics pre-drawn - with Parasitics and 'Defaults' \*
- Overtyp 'Defaults' with values desired for simulation.
- Choice of 'Capacitor' and 'Inductor' materials defines losses.
- Select 'Worst Case' or desired 'Source-Load' impedance.
- Automatic 'Return-Loss' plot - Filter/source interaction.
- Automatic 'Group-Delay' plot - Filter/signal interaction.
- Automatic 'Insertion-Loss' plot - the attenuation of EMC.

Price:- £100 inc. for the full package with manuals (Software and Filter), as used for Electronics World May '96 pp 384-388. A 'Demo' disk is also available for £7 inc.- refund on purchase.

C. Bateman. Design Consultant. Tel. 01493-750114.  
'Nimrod', New Road, ACLE, Norfolk . NR13 3BD.  
cyrilb@ibm.net 76251,2535@Compuserve

CIRCLE NO. 108 ON REPLY CARD

#### EDITOR

Martin Eccles  
0181 652 3128

#### EDITORIAL ASSISTANT

Mark Hefley  
0181 652 8638

#### CONSULTANTS

Jonathan Campbell  
Philip Darrington  
Frank Ogden

#### DESIGN

Alan Kerr

#### EDITORIAL

#### ADMINISTRATION

Jackie Lowe  
0181-652 3614

#### E-MAIL ORDERS

jackie.lowe@rbp.co.uk

#### ADVERTISEMENT MANAGER

Richard Napier  
0181-652 3620

#### DISPLAY SALES EXECUTIVE

Malcolm Wells  
0181-652 3620

#### ADVERTISING PRODUCTION

0181-652 3620

#### PUBLISHER

Mick Elliott

#### EDITORIAL FAX

0181-652 8956

#### CLASSIFIED FAX

0181-652 8956

#### SUBSCRIPTION HOTLINE

01622 721666  
Quote ref INJ

#### SUBSCRIPTION QUERIES

01444 445566  
FAX 01444 445447

ISSN 0959-8332

#### NEWSAGENT ENQUIRIES

Contact MarketForce  
(UK) Ltd.  
Telephone:  
0171-261 5555  
Fax: 0171-261 6106

 REED BUSINESS  
PUBLISHING  
GROUP

## Memory for the masses

**T**here should be a number of benefits resulting from the collapse of the price of d-ram, which has fallen to a quarter of its 1995 price.

Nowadays, d-ram is so ubiquitous that its price affects the retail price of many electronic products – though the one it affects most is the personal computer.

The pc has been a revelation – the most important industrial product of the second half of the century. But how much further does it have to go?

We're looking at 30 per cent household penetration levels in the West and it could be that all those who want access to a pc, already have it.

But how about the other 70 per cent who don't want access to a pc? Can anything be done for them? This looks like a silly question, but the truth is that many people who are at first indifferent to new products – like cars, tvs or mobile phones – often come round to buying them when they become cheap enough and easy enough to use.

At the moment the pc is still the province of the educated middle-class. If it is to have a market outside the educated middle-class it probably has to change its current evolutionary course.

Instead of blindly pursuing faster processing, it may have to start looking at what people want to do with it. Furthermore, if the pc is to become as universal as the telly, it has to be made as easy to use and as cheap as the telly.

But, at the moment, the future of the pc is driven by the supercharged techies of Silicon Valley. To them the absolutely overriding issue is more performance.

To techies, the pc is still a vehicle for fulfilling the same urge that drove the pc's pioneers – to impress their peers – rather than to make something saleable to the masses.

In the early days of the motorcar, the pioneers similarly vied with each other for more and more power. Enzo Ferrari once famously dismissed W.O. Bentley's cars as 'lorries'. But then came Henry Ford. He had a different priority. Ford's vision was to make cars affordable – cheap enough for Joe Soap to buy.

That was the original promise of the microprocessor which, in the words of its inventor Ted Hoff, "democratised the computer."

The microprocessor was invented 25 years ago this November. Ever since then, the evolving



*Isn't it time someone did for the pc what Ford did for the automobile?*

price/performance ratio of the computer should have been linked to the chip learning curve, i.e. doubling in performance or halving in price every eighteen months.

For a while it did. By now the power of a 1980s pc can easily be incorporated on a single chip. That should mean that the High Street shops are stuffed with affordable computers. But they are not. Instead pcs tend to cost from £800 to £1500. That's because the chip and computer industry prefer the option of doubling in power every two years rather than halving in price. That way they keep computer prices and chip prices high and margins fat.

And they don't get any easier to use. The average Joe Soap despairs of the unfriendliness and non-intuitiveness of pc software and finds it a nightmare trying to add on a modem or even connect up a printer. If the electronics industry wants pcs to reach the other 70 per cent of the West's potential pc market, then pcs will have to be made as easy to use as calculators.

Two things might persuade people to make computers for Joe Soaps. First a number of microprocessors are getting to be powerful enough to emulate the ubiquitous 486, and Pentiums without losing significant performance, and secondly, the cost of d-ram is now low and sinking. So there is a good opportunity to supply that 70 per cent of the potential Western market for cheap, easy-to-use pcs which the computer industry is currently unwilling to supply. ■

*David Manners*

Electronics World is published monthly. By post, current issue £2.35, back issues (if available) £2.50. Orders, payments and general correspondence to L333, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Tlx: 892984 REED BP G. Cheques should be made payable to Reed Business Publishing Group Newstrade: Distributed by Marketforce (UK) Ltd, 247 Tottenham Court Road London W1P 0AU 0171 261-5108. Subscriptions: Quadrant Subscription Services, Oakfield House Perymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 01444 445566. Please notify change of address. Subscription rates 1 year £30 UK 2 years £48.00 3 years £70.00. Surface mail 1 year £35.00 2 years £56.00 3 years £80.00 Air mail Europe/Eu 1 year

£43.00 2 years £68.00 ROW 1 year £52.00 2 years £83.00  
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. 2nd class postage paid at Rahway NJ Postmaster. Send address changes to above. Printed by BPCC Magazines (Carlisle) Ltd, Newtown Trading Estate Carlisle. Cumbria, CA2 7NR Typeset by Wace Publication Imaging 2-4 Powerscott Road, Sidcup, Kent DA1 4SDT, Reed Business Publishing Ltd 1995 ISSN 0959 8332

# NOW, THE BATTLE IS OVER



## ULTIBOARD

**BUNDLED WITH**  **SPECCTRA**  
SHAPE BASED AUTOROUTER

ULTIboard's interactive strength has always been the major selection criterion of professional Printed Circuit Board designers. Now that every ULTIboard Designer system will be supplied with a SPECCTRA SP4 Autorouter, ULTIboard designers now get the best of both worlds.

All ULTIboard Designer Users with valid update subscription get a MAINTENANCE UPGRADE with the SPECCTRA SP4 (4 signal layers + power/ground layers) Shape based Autorouter. This shows that ULTIimate Technology is *the* PCB-Design Tool vendor that *really* cares for their customers!

**THE ULTIMATE  
SPECIAL OFFER**

**ULTIboard Entry Designer\* £ 1295 (excl. VAT) will now  
be supplied with SPECCTRA Shape Based Autorouter  
\*free Upgrade with EMC-EXPERT mid 1996 (list price at release £ 1875)**

CIRCLE NO. 109 ON REPLY CARD

**ULTIMATE**  
TECHNOLOGY

Corporate Headquarters:  
Energiestraat 36 • 1411 AT Naarden  
The Netherlands

tel.: (+31) 35 - 6944444  
fax: (+31) 35 - 6943345

UK/Ireland Sales-Office:  
2 Bacchus House • Calleva Park  
Aldermaston Berkshire • RG7 4QW

tel.: 01734 - 812030  
fax: 01734 - 815323

## 200MHz Pentium running late

Intel is announcing its 200MHz Pentium this week while privately telling PC vendors that volume production using the processor will only be possible later this summer.

This contrasts markedly with previous Intel processor launches which have always shipped in volume once announced. Intel is telling its customers that yields of the 200MHz Pentium are still very low.

Sources close to Intel say that the 200MHz Pentium introduction was rushed to prevent Cyrix from getting too much attention with its 200MHz 6X86 P200+ processor (*EW*, June 5, p3).

Despite the shortage of the Intel device, major PC companies will this week announce 200MHz Pentium-based systems. These include Compaq Computer, Dell Computer, Hewlett-Packard and IBM.



Intel's new 200MHz Pentium processor was announced this week but won't start volume production until later this summer.

## Battery capacity could double

Chemists at the University of St Andrews have produced rechargeable lithium ion cell using a manganese compound which is far cheaper than the cobalt compound used at present. Developments with the material could double existing storage capacity.

Peter Bruce, Professor of Chemistry at St Andrews said: "Manganese, as a raw material, is 100 times cheaper than cobalt and much less toxic." But a useful manganese compound, with the correct structure, has been difficult to make. The positive electrode in most lithium ion cells is  $\text{LiCoO}_2$ , a cobalt based material.

Bruce said: "A Japanese manufacturer is just about to bring out a cell based on  $\text{LiMn}_2\text{O}_4$ . This is an alternative to the cobalt compound, It cannot store as many lithium ions, which means it holds less power."

Bruce's team has produced  $\text{LiMn}_2\text{O}_4$ , in a form suitable for battery use. "The structure we have is a lithium-oxygen-manganese-oxygen sandwich which stores ions effectively."

The capacity of the St Andrews' cell is currently 260Wh/l, good commercial cobalt cells currently achieve 280Wh/l, but cycle life is still low.

## New infra red camera

The Jet Propulsion Laboratory and Amber in Goleta, California are collaborating to develop a cooled long wavelength infra red (LWIR) camera. The aim is to design an infra red imaging system based on using a quantum well infra red photodetector (QWIP) and Amber's 256x256 readout multiplexer.

Infra red (IR) detectors made from materials already tested in lasers promise superior IR cameras and night-vision devices. These QWIP devices are made from alternate layers of semiconductor materials arranged atom by atom into layers just a few atoms thick, such as Gallium Arsenide (GaAs) and Indium Gallium Arsenic Phosphide (InGaAsP).

Quantum wells are already widely used in lasers to generate light from

electricity but in night-vision devices and infra red cameras this process is reversed. With conventional quantum well devices electrons can only exist in one of two energy bands, either the low energy "valence" band or the high-energy "conduction" band. In a conventional detector a photon striking the detector surface liberates an electron into the conduction band which may generate an electrical signal if a voltage is applied across the detector head. The most recent QWIP's are so sensitive that incident photons may be detected which only have enough energy to shift electrons within the bands.

An infra red QWIP array camera mounted on a plane, ground based vehicle or low earth orbit satellite should be capable of high resolution infra red images.

## Cable modem market to double

The cable modem market is forecast to almost double this year as frustrated Internet users turn to the speedier devices. The US market research firm Dataquest forecasts 92 per cent growth in cable modem unit shipments this year to reach 25,000 units. In 1997 this is set to grow to 80,000 units.

Cable modems, however, will soon begin competing with ISDN and XDSL communications

technologies which have the advantage of running on existing telephone lines. "The most compelling reason to use a cable modem is speed, but speed alone won't be enough to win the battle," said Dataquest industry analyst Lisa Pelgrim.

Although ISDN and XDSL will be available to greater numbers of people, Dataquest points to the advantages of cable modems: they can easily transmit data types like video and two-way audio, they offer lower cost per transmitted bit, and also support constant connectivity down the line.

# Wireless interactive services – via satellite

Satellite operator Astra is planning to introduce interactive services, using a transparent radio channel and, ultimately, an uplink from domestic satellite systems.

The system, the Astra Multimedia Service Platform, will use two transponders on Astra 1H, at its dig orbital position, due for launch in the third quarter of 1998. Frequencies will be in the Ka band, using 18.80-19.30 GHz for the downlink and 29.50GHz for the uplink. This will allow Astra to offer both broadcast and on-line services on a point-to-multipoint and point-to-point basis. Initially, these will be offered to businesses, providing hybrid multimedia transmissions in real time or store-and-forward. Eventually, the service would be extended to direct-to-home satellite customers.

The announcement, made in Luxembourg last month at a press conference outlining Astra's plans for the digital era, show that the satellite operator is determined not to lose ground to the cable companies, which have recently been making much of their 'unique' ability to serve the needs of interactive communications via asymmetrical return paths, easily incorporated in high-capacity fibre-optic cable.

Until now, Astra and its direct-to-home broadcaster customers, such as

Sky, have been restricted to the prospect of a fairly crude version of interactivity relying on a telephone link between the user and the service centre at the broadcaster's uplink. Users are restricted by the low bandwidth of telephone lines and the geographic limitations of cable penetration.

Few technical details are as yet available from SES. Questions raised at the conference – but not answered – involved the design and power of domestic satellite systems which also operate as transmitters, whether users would need radio licences, and how the transponders would cope with thousands of signals from different users. On this last point, the best guess was some form of cellular multiplexing, as with mobile phones. It is perhaps significant that the newly-appointed technical director, Aldis Grinbergs, who was with Astra until 1988, returns after five years with Motorola, working on its Iridium satellite-based mobile communications project.

● Astra has also announced a second orbital slot, at 28.2° E, for digital broadcasting. The first satellite in this position, Astra 2A, is scheduled for launch next summer, and BSkyB has already booked 14 transponders – representing half its capacity. Astra is

in "advanced negotiations with major public and private broadcasters' on the remaining transponders, according to director general Romain Bausch. These involve "an important amount of services primarily targeting the the UK market." Two satellites are so far planned, the second due up in late 1998, giving a total capacity of 56 transponders, or around 400 digitally-compressed channels.

Transponder output will be 100W, and signals will be receivable on 50cm dishes in the British Isles.

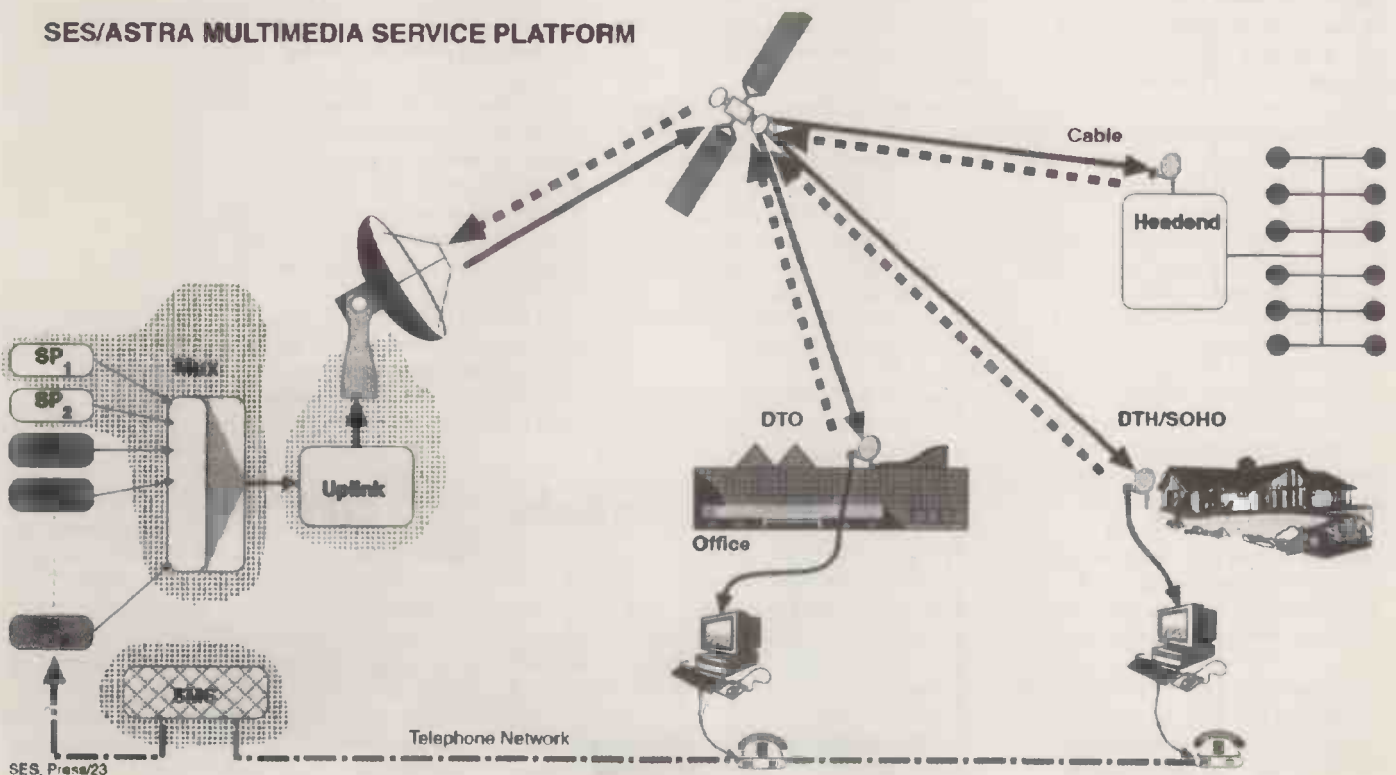
Existing 60 or 80cm dishes, pointed at 19.2° E, should be able to receive signals from the new satellites, provided they are equipped with appropriate Inbs. However, neither Astra nor its broadcasters is recommending this approach. Few existing Sky subscribers, for instance, have the requisite Inb fitted.

A probable scenario will be for Sky to replicate existing analogue services as part of the new digital package – they would all fit onto three of its 14 transponders – enabling subscribers to flaunt the new, smaller dish.

Sky also has some digital capacity booked on Astra 1E and 1F. This results from long-standing bookings and is to be used for continental broadcasting, said an Astra spokesman.

*Astra plans to make satellite transmission a two-way affair, with businesses and home users having a narrow-band return path over which they can engage in all the interactive opportunities already planned for cable.*

## SES/ASTRA MULTIMEDIA SERVICE PLATFORM





## UK centre of Europe for set-tops

The UK is set to become the European centre for volume manufacturing of digital set-top boxes as consumer electronics makers line up with announcements.

Last week, Sony started shipping digital set-top boxes from its Pencoed Technology Centre in Wales. The boxes are designed and manufactured in Wales and are Digital Video Broadcast (DVB) compliant. The first generation boxes will be delivered to Canal Plus for its 24 hour service in France.

Matsushita and the US receiver developer ComStream announced recently their production of digital set-top boxes in Cardiff, Wales, this year. In the start-up phase, scheduled to begin in July, Matsushita will produce around 500,000 units. From August much higher volumes will then be produced.

Pioneer is also close to a decision with regards to volume manufacturing digital set-tops in the

UK, due to start at the end of this year.

"The first generation of set-top boxes will be done in Japan and then we'll switch the production to Europe. The UK is a serious candidate," said one Pioneer spokesman.

These announcements follow the joint declaration from Digi Media Vision and Mitsubishi earlier this year for the development and manufacture of such systems in Scotland. In addition, Pace, the indigenous set-top box volume manufacturer manufactures in excess of 800,000 units per year.

Matsushita and ComStream will supply set-top boxes for satellite, cable, MMDS (Microwave Multipoint Distribution System) and digital terrestrial television broadcast. The boxes will be designed by ComStream, but manufactured by Matsushita under the Panasonic brand name. Svetlana Josifovska  
*Electronics Weekly*

## DMX wins satellite award

DMX was voted runner-up in the 'Most innovative satellite product/application' sector at the 1996 European Cable & Satellite Awards. DMX, the revolutionary new digital audio subscription service, was launched in the UK on March 20 of this year.

As the UK's first digital audio subscription

service, DMX is available on satellite and cable, offering continuous music 24 hours a day with no interruptions from DJs or advertising. There is something for everyone with 62 channels available on the service, each one dedicated to a particular genre of music – from rock to reggae, from jazz to dance and from opera to mariachi.

## Ceramic laser

Japanese workers have developed what is claimed to be the first neodymium-doped yttrium-aluminium-garnet (Nd:YAG) laser based on ceramic materials.

Nd:YAG lasers are used for micro fabrication and, through fibre-optic light pipes, for medical work.

Normally the lasers are made from monocrystalline material. The size, and thus the power, of these is limited by the size of the single crystals that can be grown. Growing large crystals can take over

a month and defects often develop during the growth time.

The bulk material for the ceramic laser, developed by Krosaki Corporation and Prof K. Yoshida at Osaka Institute of Technology, can be made by sintering in a few hours.

Another advantage of ceramics is that up to 10 percent of Nd can be incorporated. This contrasts with only one percent of Nd included in monocrystals. The group found that 2.4 percent gives the maximum power output, twice that of the monocrystalline material.

## Talking your way through the web

In future, computer nerds will surf the Web by talking to their terminals. So claim researchers at the Massachusetts Institute of Technology (MIT).

The spoken language systems group at MIT, led by Dr Victor Zue, is working on its third generation of voice recognition and understanding systems called Galaxy. Six researchers have spent over two years programming the software based system.

Zue says: "It is not just a case of linking the recognition and understanding bits together. In speech it can be difficult to tell where one word ends and another begins. An example is 'euthanasia' and 'youth in asia'." Zue claims to have solved many of the problems of speech taken out of context.

In an Internet system, the local user will have a client program that ferries the digitised speech, such as "What are the flight times from London to New York?", to a central server. The server attempts to recognise and understand the speech, forms the correct response and delivers the answer back across the Net to the client, either through a text transfer or a voice synthesis system.

Zue thinks a working system for tailored applications using specific knowledge bases could be in use within five years.

Apple Computer's PlainTalk system already provides plug-ins for Netscape Navigator that allows control of the navigator via speech. Users can speak hypertext links, bookmarks and commands such as 'Go Back' and 'Reload'.

### IN BRIEF

#### GPS for taxis

Next time you are left waiting for a taxi to show up remember that the technology exists to make your cab arrive faster.

A cab firm in Singapore has fitted a global positioning system (GPS) receiver to its taxis. As a result the position of each taxi is calculated to within 100m and then broadcast back to the control centre, enabling operators to match calls to cabs more efficiently.

GPS receivers were supplied by Motorola and the radio data comms system was developed by Cambridge company Spectronics Micro Systems.

#### New microwave notch filter is tunable

Researchers at Kings College and Surrey University have demonstrated a simple, electrically-tunable monolithic notch filter for microwaves. The proof-of-concept single-stage device offers better than 50dB rejection with independently adjustable Q and a tuning range of 2-3.5GHz. Modifications could extend the tuning range to 10:1.

#### Global GSM network

Iridium, the prospective satellite phone operator owned by Motorola and a number of international telephone operators, has placed an order with Siemens for GSM switching systems to be used in the ground segment of its global network. Iridium's network, which is scheduled to begin service by 1998, aims to be compatible with existing terrestrial GSM networks while offering intercontinental coverage using its own satellite base stations.

#### Tethered satellite report released

NASA and the Italian Space Agency (ASI) have recently released the report of the investigative board appointed to determine factors which resulted in the February 25 tether break and loss of the Tethered Satellite during the STS-75 Space Shuttle mission.

Findings of the board identified primary causes which accounted for the tether break during deployment of the Tethered Satellite.

"The tether failed as a result of arcing and burning of the tether, leading to a tensile failure after a significant portion of the tether had burned away," the report concludes.

(Turn to page 538 for more details)

**TRANSISTORS**

Table listing various transistor models (e.g., IN 4001, 2N 1711, BC 108, etc.) and their prices in pounds.

**INTEGRATED CIRCUITS**

Table listing various integrated circuit models (e.g., HCF4000BEY, M74HC10B1, etc.) and their prices in pounds.

**SPECIAL INTEREST**

Table listing various electronic components and assemblies (e.g., Rittal Steel Cabinet Enclosures, Mains Filters, etc.) and their prices in pounds.

**B. BAMBER ELECTRONICS**  
5 STATION ROAD, LITTLEPORT, ELY,  
CAMBS CB6 1QE

**TEL: 01353 860185**  
**FAX: 01353 863245**

**MAIL ORDER ONLY**

**TERMS: CASH WITH ORDER. DELIVERY CHARGES ARE FREE WHEN YOUR ORDER TOTALS £30 OR MORE. IF LESS PLEASE ADD £3.35 + V.A.T.**

**VISA AND ACCESS WELCOME**

**V.A.T. @ 17.5% MUST BE ADDED TO THE TOTAL OF ALL ORDERS**

**CIRCLE NO. 110 ON REPLY CARD**

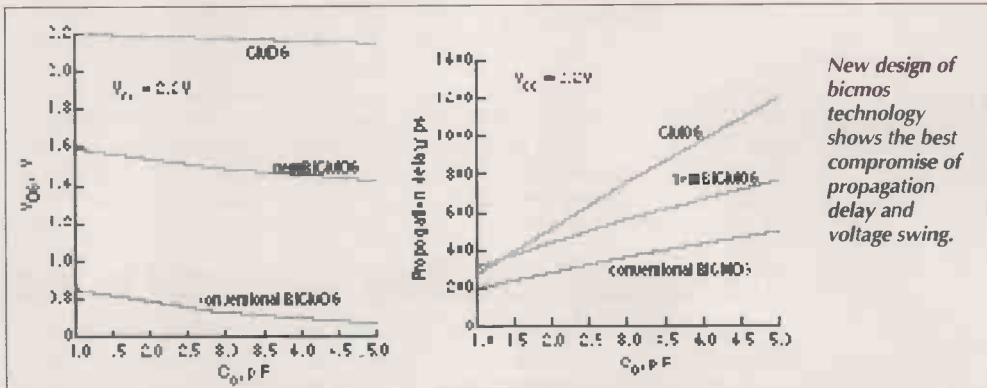
# RESEARCH NOTES

Jonathan Campbell

## Lateral thinking turbo-charges submicron bicmos

Conventional bicmos technology – ideal for low voltage low-power applications – has a limitation when it comes to trying to achieve the ever higher packing densities required for vlsi. The speed of the bicmos gate shows a rapid deterioration as it is scaled down to 0.5-0.25 $\mu$ m levels. But by adding on a lateral bjt to the standard bicmos design, to create additional charging and discharging paths, two circuit electronics engineers at Nanyang Technological University, Singapore, have created a circuit that gives speeds and voltage swings much greater than has been obtained by bicmos at the submicron level ('Novel low-voltage bicmos digital circuits employing a lateral p-n-p bjt in a p-mos structure', S S Rofail and Y K Seng, IEE Proc – Circuits Devices Syst, Vol 143, No 2, pp. 83-90).

The principle of the new design is that the additional lateral p-n-p bjt traps charge during the pull up cycle, and



New design of bicmos technology shows the best compromise of propagation delay and voltage swing.

uses it to speed up the pull down cycle.

Tests on 0.25 $\mu$ m technologies are reported to show a good comparison with other circuits in terms of speed, output voltage swing and power dissipation.

According to the workers, large voltage swings at high speeds are easily achievable under 2.2V operation.

Nand gate implementation of the new design also seems to demonstrate

the best compromise of performance characteristics compared with conventional sub-micron bicmos and cmos technologies.

More information from S S Rofail, Microelectronics Centre of the School of Electrical & Electronic Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 2263.

## Giant leap in magnetic sensor design?

A cheap, simple sensing system based on the principles of giant magnetoimpedance has been developed by a team of researchers in Spain. The device does not use optical technology so should be suitable for dusty industrial atmospheres, yet it is much less

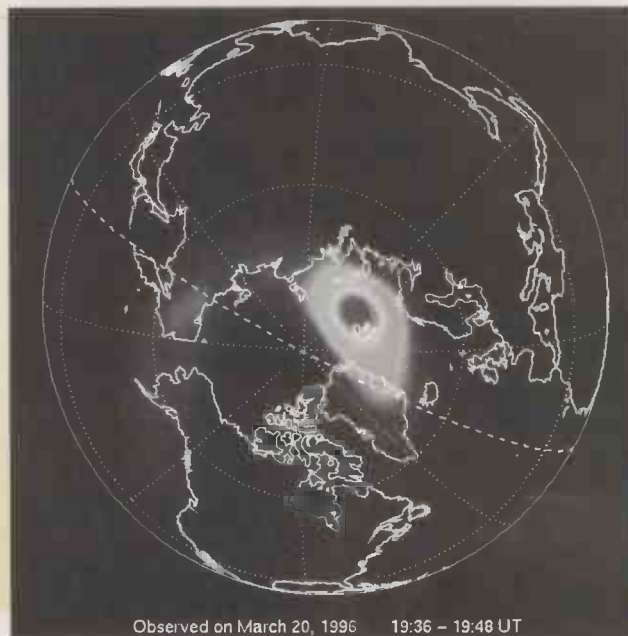
complex than other magnetic-field sensing techniques.

Giant magnetoimpedance (gmi) describes the effect where ferromagnetic materials subjected to an ac current exhibit a strong decrease in their impedance in the presence of a dc magnetic field. R Valenzuela and

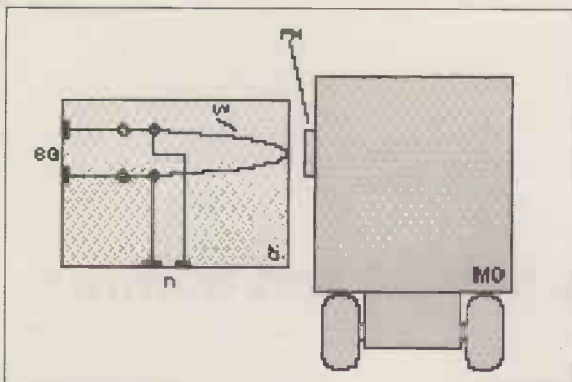
colleagues have used gmi as the basis for a magnetic-field sensor, adapted to monitor the passage of moving pieces or vehicles in industrial processes. The gmi mechanism in wires is actually quite complicated but is now well understood and accepted. Impedance in the Spanish

**X-ray spec-tacular:** The first global x-ray image ever obtained of the Earth's aurora shows a hot spot of x-rays emanating from the atmosphere near midnight at the onset of a small magnetic disturbance and a wide band of weak x-ray emissions extending through the night and morning hours to noon. It was taken on March 20, 1996 by the Polar Ionospheric X-ray Imaging Experiment (Pixie) aboard the Nasa Polar spacecraft.

The image is presented in false colour with the colour corresponding to the measured x-ray intensity from blue (weakest) through red (strongest). The x-ray energy range covered by this image is from about 2000eV to over 10,000eV, and the x-rays were emitted when energetic electrons from the Earth's magnetosphere struck the upper atmosphere. Intensity of the x-rays is directly related to the intensity of the precipitated electron flux. Asymmetry in the emissions between the local time regions corresponding to early morning (over Siberia and Alaska) and late afternoon (over northern Canada and Greenland) is the result of the natural motion of energetic electrons in the Earth's magnetic field. The field causes electrons to drift to the east from their source region, probably far from Earth and near the equator on the night side at the longitude near where the X-ray intensity is highest. As they drift around the Earth, some of the electrons are lost into the atmosphere, producing the wide blue band of x-ray emissions. When the electrons reach the day side near noon, they can be swept out of the magnetosphere by the effects of large-scale electric fields. Goddard Space Flight Center, Greenbelt, MD.



Observed on March 20, 1996 19:36 – 19:48 UT



Using giant magnetoresistance to detect a moving object.

wire sensor ('A position sensor based on magnetoimpedance', R Valenzuela et al, *J Appl Phys*, Vol 79, No 8, pp. 6549-6551) changes steeply as it comes close to a permanent magnet.

In experiments, 90mm of

amorphous CoFeBSi wire of low, negative magnetoresistance were used, bent and placed inside a small acrylic cylinder 40mm long. In this way, two sections of the middle part of the wire could be exposed to small, localised magnetic fields.

The wire was then submitted to an ac current of 10mA (rms) at a frequency of 100kHz and a small permanent magnet bought near to it to simulate the movement of an object. Throughout, the voltage response was monitored as a function of the distance between the wire and the magnet. In tests,  $V$  decreased from 770mV for large distances to 605mV for physical contact. For a working detection distance of 20mm the voltage was 680mV. So a drop from

770mV to 680 could be taken as positive indication of detection.

In a real application the ac signal could be easily rectified to a dc signal and fed to a data acquisition system allowing a process to be monitored and controlled.

The advantage of the device is that the well-defined threshold in the voltage response makes for much simpler electronics than trying to deal with sensitive detection of the magnitude of the dc field, leading to a rugged device that could be relatively cheap to produce.

Contact M Vazquez at Instituto de Magnetismo Aplicado, UCM, and Instituto de Ciencia de Materiales, CSIC, PO Box 155, 28230 Las Rozas, Madrid, Spain vazquez@pinar1.csic.es

## Tethered satellite was not a loss

Embarrassing breaking free of the satellite linked by a tether to spaceship *Columbia* earlier this year may not have been the ignominious failure it once looked. In fact scientists are excitedly claiming that information gathered during the few hours that the satellite was being unreeled, means that models accepted by scientists for more than 30 years are incorrect and must be rewritten.

The aim of the experiment was to unreel a satellite on the end of a 20km tether to investigate – amongst other things – new sources of spacecraft power.

Unfortunately, just short of the full distance, its tether broke. However, the science instruments on the satellite and Shuttle, which had been operating during the five hours of deployment

operations, sent a flood of readings that were received and recorded by scientists on the ground.

Now, analysis by a joint US-Italian team investigating the information gathered during the mission has been completed, and according to Nobie Stone, the mission scientist at the Marshall Space Flight Center, Huntsville, "Even the quick-look made to date reveals that this data harvest is rich in content."

Perhaps the most significant finding is that tether currents proved to be up to three times greater than existing theoretical models predicted prior to the mission. Reversing the direction of current flow puts the system into an electric-motor mode, so that the harnessed energy could furnish thrust for reboosting a space station, satellite

or Shuttle in a decaying orbit.

Traditionally, the primary source of power for long-term space platforms has been solar arrays. But these cells can only produce power when exposed to sunlight during the two-thirds of each 90-minute orbit when a space station, for instance, is not on Earth's dark side. But a tether system might provide a constant source of energy.

Other important revelations from the mission include observations of the satellite's thrusters interacting with the ionosphere. When the thrusters were fired, the neutral gas emitted became ionised increasing current flow, while the satellite's potential dropped several hundred volts.

More information from Nobie Stone, Marshall Space Flight Center, Huntsville, AL, USA.

## Talking of alternatives to the breathalyser...

We accept that slurred speech is often a tell-tale sign that someone's been drinking. Now, a Georgia Institute of Technology researcher is working with colleagues from Indiana University to digitally quantify this tell-tale sign, in the hope of developing a simple, non-invasive way to test a person's sobriety.

According to Kathleen Cummings, a lecturer in Georgia Tech's School of Electrical and Computer Engineering, speaking is basically an effect of fine motor control. Preliminary results show that intoxicated speech is marked by jumpy changes in pitch and energy

production and unsteady opening and closing of the vocal cords.

Cummings discovered distinct differences between normal speech and that produced under emotional stress, with an accuracy rate of over 90%.

For her current research the idea is to do the same thing with sober versus intoxicated speech. So a sample of somebody's speech from an accident or at a particular time, can be analysed against a normal, sober speech sample to say if that person is intoxicated.

The analysis would be done by computer, based on a mathematical formula that would yield a percentage probability as to whether the speaker was intoxicated. Although much work is left to be done, Cummings said translating her research into a practical public safety device could be relatively easy. Police officers could record someone's speech at an accident or traffic stop, then analyse it later against a sample taken at a different time. However there are still technical and operational problems to be overcome not least of which are recording quality and legal issues, such as a person's refusal to give two samples for comparison.

More information from Kathleen Cummings, School of Electrical and Computer Engineering, Georgia Tech, Atlanta, Georgia 30332-0828, USA.

Breathalysers may be obsolescent. Speech is being computer analysed at Georgia Institute to detect intoxication – simply and non-invasively – and preliminary results are encouraging.

# Ball lightning comes down to earth

The phenomenon of ball lightning has long puzzled scientists. Reports of floating luminescent globes mysteriously zig zagging above the ground then disappearing with a bang go back centuries – without explanation. Now a scientist at the CSIRO research institute in Australia has developed a theory that not only explains what ball lightning is, but also suggests why it moves as it does.

J J Lowke, in the Division of Applied Physics, took as his starting point the fact that reports of ball lightning usually follows a local lightning strike. The luminous ball, which can be up to 25cm in diameter, is seen to glow with the intensity of a 20W lamp and travel about 1m above the ground at a speed of around 3m/s. It can float for up to 10s – inside houses and even aircraft – after which time it extinguishes, sometimes silently, and sometimes with a bang.

Ball lightning has also been seen to pass through glass panes without affecting them, though some observers have reported wood singes and the smell of ozone and nitrogen oxides.

Previous theories have ranged from an optical illusion, to a standing wave of electromagnetic radiation, to anti-matter, to the latest that the ball is the manifestation of complex chemical phenomena involving water vapour.

But Lowke's explanation ('A theory of ball lightning as an electric discharge', *J Phys D: Appl Phys*, vol 29 (1996), pp. 1237-1244) begins by noting that when lightning strikes a point on the earth's surface, an amount of charge, usually negative, is transferred via the lightning arc from the cloud to the ground. Positive charge is then transferred from the ground to cloud. Previous calculations of space charge effects have assumed



Picture Science Photo Library

that the Earth is a perfect conductor for the dispersing charge. But Lowke points out that earlier experiments carried out by other researchers show that lightning can produce filamentary arcing along the surface of the ground to distances of 20m and over. The sequence of events, according to Lowke, begins with the development of strong negative electric charges in the base of a thunder cloud, for example due to the interaction of wind and freezing supercooled rain drops. Next, there is the rapid transfer of charge through the highly conducting arc of a lightning strike – positive charge going to the cloud and negative charge to the Earth, to distances of many metres. Finally, there is the very much slower further dispersion of negative charge along fingers of relatively high electrical conductivity on the earth, in which the field at the heart of the advancing charge in the earth will be less than 1MV/cm. This produces an electric field above the earth which is the source of the power and motion for the ball lightning.

Lowke's contention is that in the air above this charge there will be occasions when the field will be greater than 5kV/cm and so able to sustain ball lightning. Normally the field for electric breakdown in air is

about 30kV/cm. But once a conducting plasma has been formed it can be sustained at the much lower figure.

Crucially, Lowke refers to two eyewitnesses who, observing ball lightning at night, told him they saw a faint luminosity between the main ball and the ground. This would tend to support the ground-based mechanism.

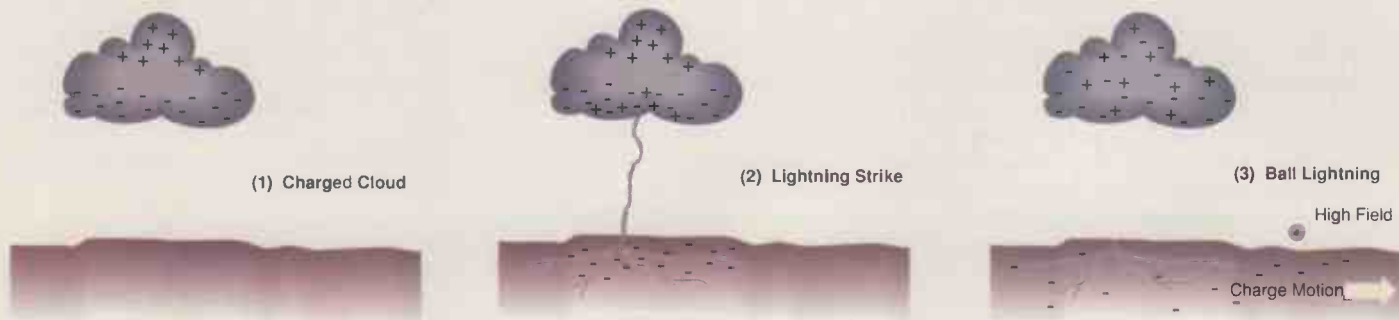
On this model, the ball lightning itself would be an electric discharge which is continuously varying on a microsecond time scale.

Calculation shows that space charge distortions by positive and negative ions can produce a local maximum in the electric field about 1m above the Earth's surface and sustain a time-varying discharge with the properties similar to ball lightning.

The theory gives a credible and relatively simple explanation for the life-time and energy source of ball lightning. In addition it explains some of the other odd characteristics of ball lightning – particularly why it hovers rather than rises and why it moves erratically and seems unaffected by wind.

*More information from J J Lowke at CSIRO Division of Applied Physics, Sydney, NSW 2070, Australia.*

*Electric charge redistribution after a lightning strike could explain the origin of ball lightning.*



# Precision

## preamplifier '96

### Part I



**Douglas Self** has thoroughly analysed the requirements for a no-compromise audio preamplifier making the most of today's high-performance op-amps. This first article covers the preamp's overall configuration and focuses on disc replay.

**A** new preamp design is timely. There is more variation in audio equipment than ever before, so to a greater extent preamps are required to be all things to all persons. High source resistance outputs and low-impedance inputs must be catered for, as well as ill-considered and exotic cabling with excessive shunt capacitance. The last preamp design I placed before the public was in 1983<sup>1</sup>, extend-

ed in facilities by the moving-coil head amp stage published in 1987<sup>2</sup>.

In the last ten years, small-signal analogue electronics has undergone few changes. Most circuitry is still made from TL072s, with resort to 5532s when noise and drive capability are important. In this period many new op-amps have appeared, but few have had any impact on audio design; this is largely a chicken/egg problem, for until they are used in large numbers the price will not come down low enough for them to be used in large numbers. Significant advantage over the old faithfuls is required.

This new design uses the architecture established in reference 1, which has not been improved upon so far. The already low noise levels have been further reduced. The tone controls were fixed-frequency, and proved inflexible compared with the switched-turnover versions in my previous designs<sup>3,4</sup>, so these frequencies are now fully variable, and a non-interrupting tone-cancel facility provided.

This preamplifier is designed to my usual philosophy of making it work as well as possible, by the considered choice of circuit configurations etc, rather than the alternative approach of specifying exotic components and hoping for the best.

**The evolution of preamplifiers**  
Minimal requirements are source selection and level control, as in Fig. 1a; an RIAA disc

#### Adding tape facilities and tone control

There are two basic architectures for tape record/replay handling. The simpler, in Fig. 1d, adds a tape output and a tape monitor switch for off-tape monitoring on triple-head machines.

The more complex version in Fig. 1e allows any input to be listened to while any input is being recorded, though how many people actually do this is rather doubtful. This method demands very high standards of crosstalk inside the preamp. There is usually no tape return input or tape monitor switch as there is now no guarantee that the main path signal comes from the same original source as the tape output.

The final step is to add tone controls. They need a low-impedance drive for predictable equalisation curves, and a vital point is that most types – including the Baxandall – phase-invert. Since the maintenance of absolute polarity is required, this inversion can conveniently be undone by the active gain control, which also uses shunt feedback and phase-inverts. The tone-control can be placed before or after the volume control, but if afterwards it generates noise that cannot be turned down. Putting it before the volume control reduces headroom if boost is in use, but since maximum boost is only +10dB, the preamp inputs will not overload before 3V<sub>rms</sub> is applied; domestic equipment can rarely generate such levels. Figure 1f shows the final architecture.

preamp stage is one input option. This sort of 'passive preamplifier' (a nice oxymoron) is only practical if the main music source is a low-impedance high-level output like cd.

The only parameter to decide is the resistance of the volume pot; it cannot be too high because the output impedance, which reaches a maximum of one quarter the track resistance at -6dB, will cause high-frequency roll-off with the cable capacitance. On the other hand, if the pot resistance is too low, the source equipment will be unduly loaded. If the source is valve equipment, which does not respond well to even moderate loading, the problem starts to look insoluble.

Adding a unity-gain buffer stage after the selector switch, Fig. 1b, means the volume control can be reduced to 10kΩ, without loading the sources. This still gives a maximal output impedance of 2.5kΩ, which allows you only 5.4 metres of 300pF/m cable before the response is 1.0dB down at 20kHz. For 0.1dB down at 20kHz, only 1.6 metres is permissible.

The input RC filters found on so many power-amps as a gesture against transient intermodulation distortion add extra shunt capacitance ranging from 100pF to 1000pF, and can cause additional unwanted hf rolloff.

Unfortunately only a cd source can fully drive a power amplifier. Output levels for tuners, phono amps and domestic tape machines are of the order of 150mV rms, while power amplifiers rarely have sensitivities lower than 500mV. Both output impedance and level problems are solved by adding a second amplifier stage as Fig. 1c, this time with gain. The output level can be increased and the output impedance kept down to 100Ω or lower.

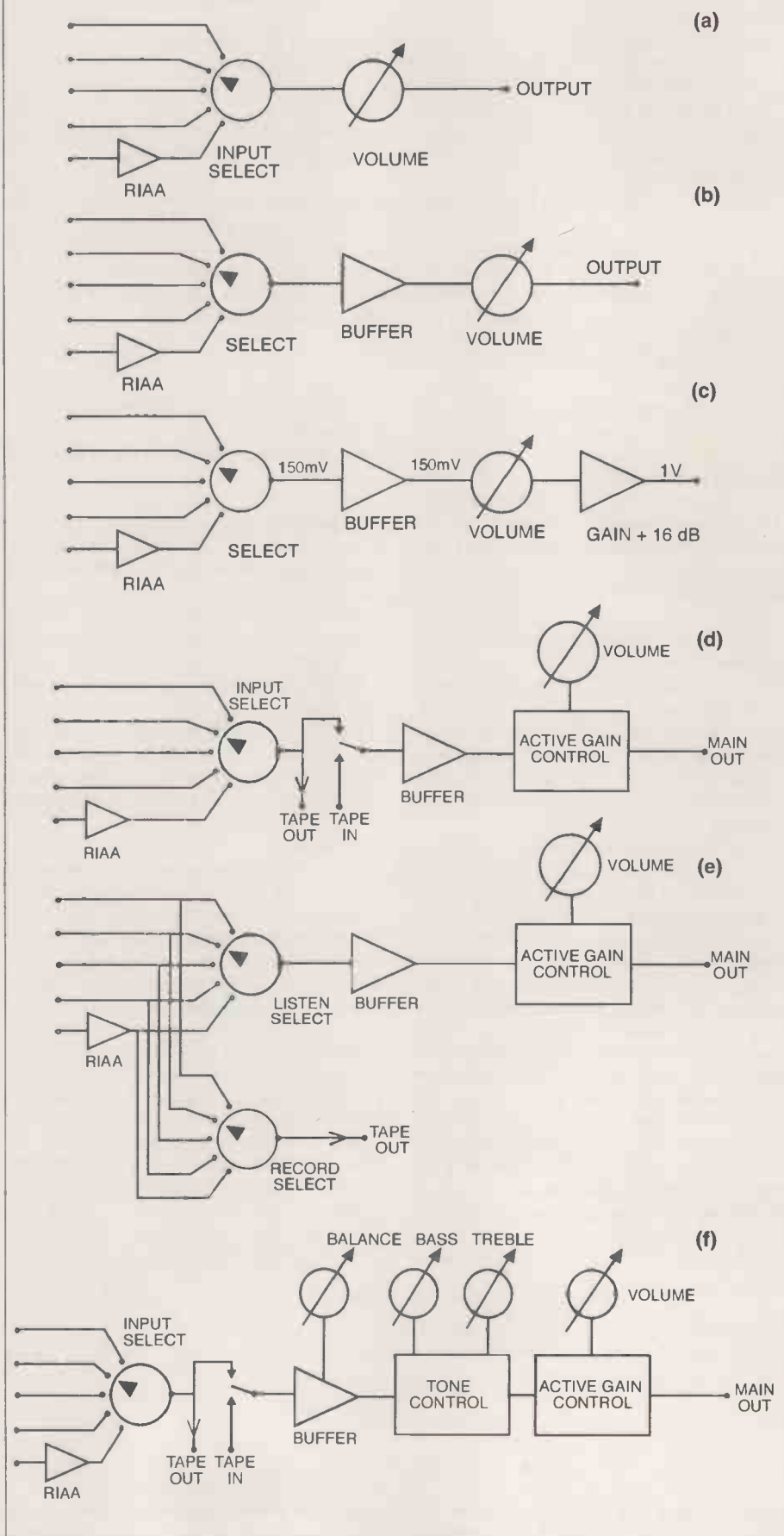
This amplifier stage introduces its own difficulties. Nominal output level must be at least 1V rms (for 150mV in) to drive most power amps, so a gain of 16.5dB is needed. If you increase the full-gain output level to 2Vrms, to be sure of driving exotica to its limits, this becomes 22.5dB, amplifying the input noise of the gain stage at all volume settings. Noise performance thus deteriorates markedly at low volume levels - the ones most of us use most of the time.

One answer is to split the gain before and after the volume control, so that there is less gain amplifying the internal noise. This inevitably reduces headroom before the volume control. Another solution is double gain controls - an input-gain control to set the internal level appropriately, then an output volume control that requires no gain after it.

Input gain controls can be separate for each channel, doubling as a balance facility<sup>3</sup>. However this makes operation rather awkward. No matter how attenuation and fixed amplification are arranged, there are going to be trade-offs on noise and headroom.

All compromise is avoided by an active gain stage, ie an amplifier stage whose gain is variable from near-zero to the required maximum. You get lower noise at gain settings below maximum, and the ability to generate a quasi-logarithmic law from a linear pot. This gives

Fig. 1. The course of preamp evolution, as impedance and level matching problems are dealt with.



Requirements for the RIAA network

- The RIAA network must use series feedback, as shunt feedback is 14 dB noisier.
- Correct gain at 1kHz. Sounds elementary, but you try calculating it.
- Accuracy. The 1983 model was designed for  $\pm 0.2\text{dB}$  accuracy 20–20kHz, which was the limit of the test gear I had access to at the time. This is tightened to  $\pm 0.05\text{dB}$  without using rare parts.
- It must use obtainable components. Resistors will be E24 series and capacitors E12 at best, so intermediate values must be made by series or parallel combinations.
- $R_o$  (Fig. 2), must be as low as possible as its Johnson noise is effectively in series with the input signal. This is most important in moving-coil mode.
- The feedback network impedance to be driven must not be low enough to increase distortion or limit output swing – especially at high frequencies.
- The resistive path through the feedback arm should ideally have the same dc resistance as input bias resistor  $R_{18}$  (Fig. 8), to minimise offsets at A1 output. The circuitry here meets all these requirements.

excellent channel balance as it depends only on mechanical alignment.

Design philosophy

There is great freedom of design in small-signal circuitry, compared with the intractable problems of power amplification. Hence there is little excuse for a preamp that is not virtually transparent, with very low noise, crosstalk and thd.

Once all the performance imperatives are addressed, the extra degrees of freedom can be used to, say, make components the same value for ease of procurement. Opamp circuitry is used here, apart from the hybrid moving-coil stage. The great advantage is that all the tricky details of distortion-free amplification are confined within the small black carapace of a 5532.

One route to low noise is low-impedance design. By minimising circuit resistances the contribution of Johnson noise is reduced, and hopefully conditions set for best semiconductor noise performance. This notion is not exactly new – as some manufacturers would have you believe – but has been used explicitly in audio circuitry for at least fifteen years.

In the equalisation and AGS stages, gains of much less than one are sometimes required. In these cases, avoiding the evils of attenuation-then-amplification (increased noise) and amplification-then-attenuation (reduced headroom) requires the use of a shunt feedback configuration. In the classic unity-gain stage, the shunt amplifier works at a noise gain of  $\times 2$ , as opposed to unity, so using shunt feed-

back introduces a noise compromise at a very fundamental level.

Absolute phase is preserved for all input and outputs.

The preamp gain structure

Compared with ref. 1, the moving-magnet disc amplifier gain has been increased from +26 to +29dB (all levels are at 1kHz) to bring the line-out level up to 150mV nominal. This is done to match equipment levels that appear to have reached some sort of consensus on this value. The input buffer has a gain of +1.0dB with balance central.

The maximum gain of the AGS is therefore reduced from +26 to +22dB, to retain the same maximum output of 2V. This affects only the upper part of the gain characteristic.

Disc input

While vinyl as a music-delivery medium is almost as obsolete as wax cylinders, there remain many sizable album collections that it is impractical to either replace with cds or transfer to digital tape. Disc inputs must therefore remain part of the designer's repertoire for the foreseeable future.

The disc stage here accepts a moving-coil cartridge input of 0.1 or 0.5mV, or a moving-magnet input of 5mV. It also includes a third-order subsonic filter and the capability to drive low impedances. The moving-coil stage simply provides flat gain, of either 10 or 50 times, while the moving-magnet stage performs the full RIAA equalisation for both modes.

Moving-coil input criteria

This stage was described in detail in ref. 2. The prime requirement is a good noise figure from a very low source impedance – here  $3.3\Omega$  to comply with, for example, the Ortofon MC10 cartridge. The circuit features

- triple low- $r_b$  input transistors
- two separate dc feedback loops
- combined feedback-network and output-attenuator.

The very low value of  $R_6$  means that a series capacitor to reduce the gain to unity at dc is impracticable; there is no dc feedback through  $R_7, R_{10}$  around the global loop. Local dc negative feedback via  $R_2, R_3$  sets input transistor conditions, and dc servo  $IC_2$  applies whatever is needed to  $IC_1$  non-inverting input to bring  $IC_1$  output to 0V.

The two gains provided are  $10\times$  and  $50\times$ , so inputs of 0.5mV and 0.1mV will give 5mVrms out. The equivalent input noise of the moving-coil stage alone is  $-141\text{dBu}$ , with no RIAA. Johnson noise from a  $3.3\Omega$  resistor is  $-147\text{dBu}$ , so the noise figure is a rather good 6dB. Resistor  $R_6$  is also  $3.3\Omega$ . This component generates the same amount of noise as the source impedance, which only degrades the noise figure by 1.4dB, rather than 3dB, as transistor noise is significant.

If discrete transistors seem like too much trouble, remember a 5532 stage here would be at least 15dB noisier.

The moving-magnet input stage

The first half of Morgan Jones's excellent preamp article<sup>5</sup> appeared just after this preamp design was finalised. While I thoroughly endorse most of his conclusions on RIAA equalisation, we part company on two points. Firstly, I am sure that 'all-in-one-go' RIAA equalisation as in Fig. 2a is definitely the best method for IC op-amp designs at least. In my design the resultant loss of high-frequency headroom is only 0.5dB at 20kHz, which I think I can live with.

Secondly, I do not accept that the difficulties of driving feedback networks with low-impedance at hf are insoluble. I quite agree that 'very few preamps of any age' meet a +28dB ref 5mV overload margin, but some exceptions are ref. 1 with +36dB, ref. 3 with +39dB, and ref. 4 with a tour-de-force +47dB. My design here gives +36dB across most of the audio band, falling to +33dB at 20kHz

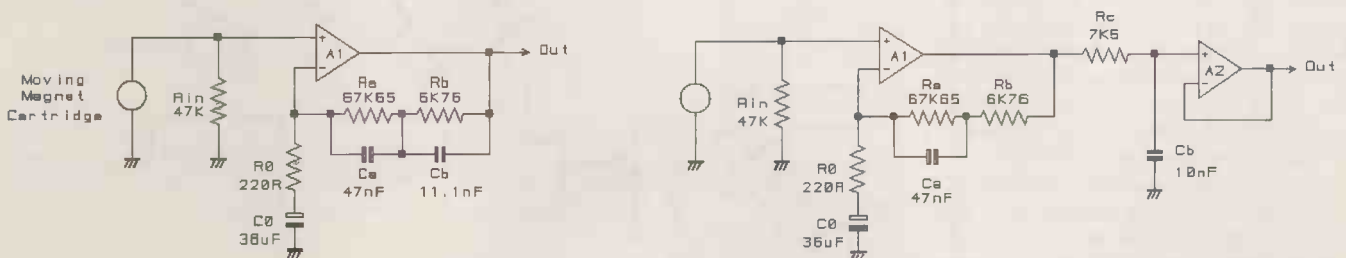


Fig. 2. The basic RIAA configurations. Fig. 2a is the standard 'all-in-one-go' series feedback configuration; the values shown do not give accurate RIAA equalisation. Fig. 2b is the most common type of passive RIAA, with a headroom penalty of 14dB at 10kHz.



(due to hf pole-correction) and +31dB at 10Hz (due to the IEC rolloff being done in the second stage).

Many contemporary disc inputs use an architecture that separates the high and low RIAA sections. Typically there is a low-frequency RIAA stage followed by a passive hf cut beginning at 2kHz, Fig. 2b. The values shown give a correct RIAA curve.

Amplification followed by attenuation always implies a headroom bottleneck, and passive hf cut is no exception. Signals direct from disc have their highest amplitudes at high frequencies so this passive configuration gives poor hf headroom. Overload occurs at A1 output before passive hf cut can reduce the level.

Figure 3 shows how the level at A1 output (Trace B) is higher at hf than the output signal (Trace A). Trace C shows the difference, ie the headroom loss; from 1dB at 1kHz this rises to 14dB at 10kHz and continues to increase in the ultrasonic region. The passive circuit was driven from an inverse RIAA network. Using this, a totally accurate disc stage would give a straight line just below the +30dB mark.

A related problem is that A1 in the passive version must handle a signal with much more hf content than A1 in Fig. 2a. This worsens any difficulties with slew-limiting and hf distortion: The passive version uses two amplifier stages rather than one, and more precision components.

Another difficulty is that A1 is more likely to run out of open-loop gain at hf. This is because the response plateaus above 1kHz, rather than being steadily reduced by increasing negative feedback. Passive RIAA is not an attractive option.

Alternatively there may be a flat input stage followed by a passive hf cut and then another stage to give the lf boost, which has even more headroom problems and uses yet more bits. The 'all-in-one-go' series feedback configuration in Fig. 2a avoids unnecessary headroom restrictions and has the minimum number of stages.

### In search of accurate RIAA

I have a deep suspicion that such popularity as passive RIAA has is due to the design being much easier. The time-constants are separate and non-interactive; only the simplest of calculations are required.

In contrast the series-feedback system in Fig. 2a has serious interactions between its time-constants and design by calculation is complex. The values shown in Fig. 2a are what you get if you ignore the interactions and simply implement the time-constants as  $R_a \times C_a$  equals 3180 $\mu$ s,  $R_b \times C_a$  equals 318 $\mu$ s, and  $R_b \times C_b$  equals 75 $\mu$ s. The resulting errors are  $\pm 0.5$ dB ref 1kHz.

Empirical approaches (cut-and-try) are effective if great accuracy is not required, but attempting to reach even  $\pm 0.2$ dB by this route becomes very tedious and frustrating. Hence the Lipshitz equations<sup>6</sup> have been converted to a spreadsheet, and used to synthesise the

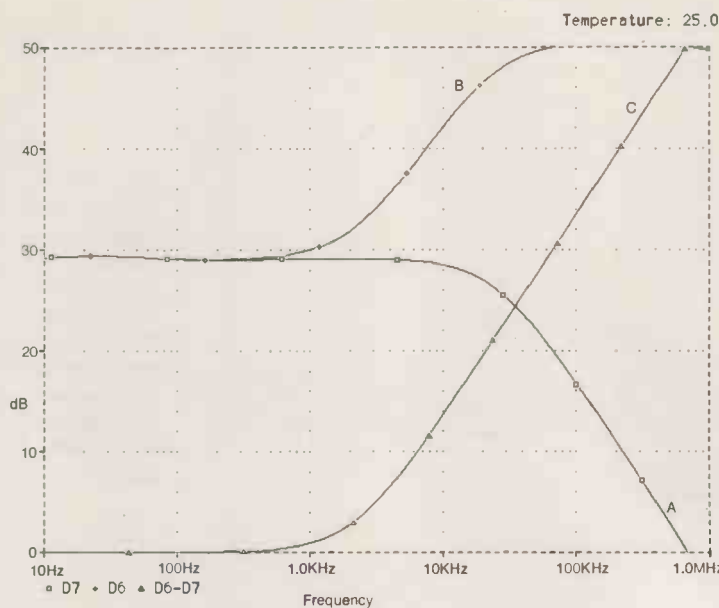


Fig. 3. Headroom loss with passive RIAA equalisation. The signal at A1 (Trace B) is greater than A2 (Trace A) so overload occurs there. The headroom loss is plotted as Trace C.

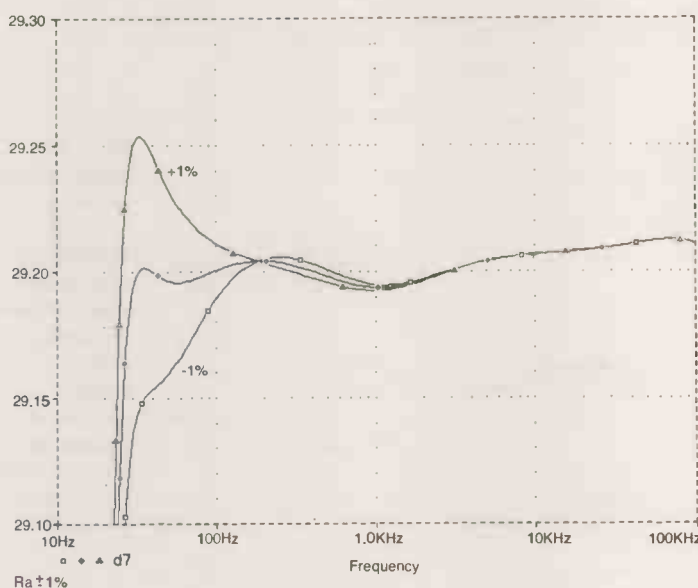


Fig. 4. The effect on RIAA accuracy of a  $\pm 1\%$  variation in  $R_a$ . Worst-case is 0.05dB, only significant below 100Hz.

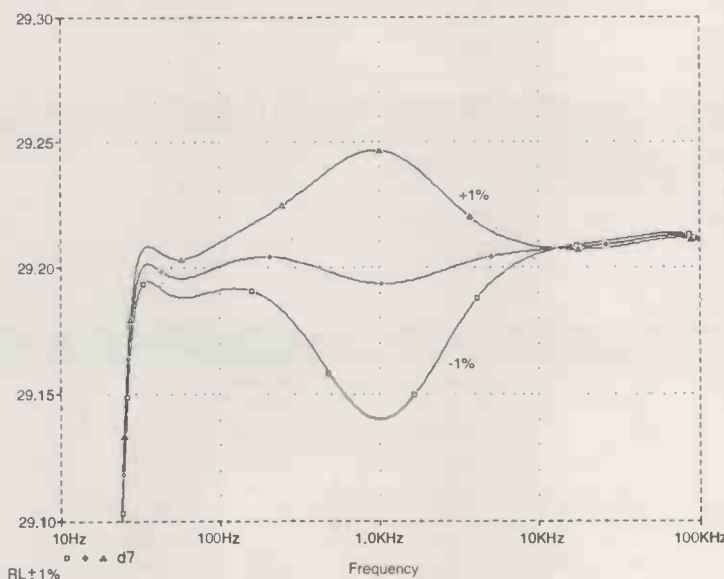


Fig. 5. The effect on RIAA accuracy of a  $\pm 1\%$  variation in  $R_b$ . Worst-case 0.05dB around 1kHz.

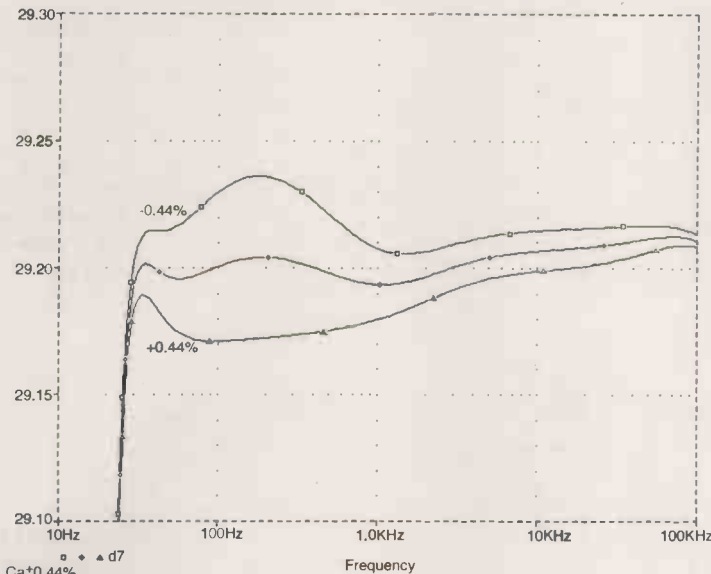


Fig. 6. The effect on RIAA accuracy of a  $\pm 0.44\%$  variation in  $C_a$ . Effect is less than  $\pm 0.05$  dB at low frequencies, with a small effect on the upper audio band.

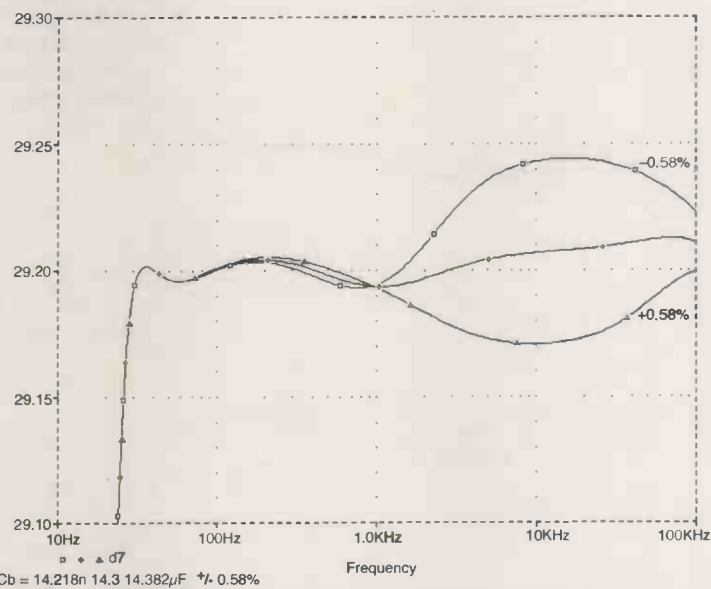


Fig. 7. The effect on RIAA accuracy of a  $\pm 0.58\%$  variation in  $C_b$ . Effect is less than  $\pm 0.05$  dB on top four octaves. Smaller variation is permissible in the capacitors for the same RIAA error.

design in Fig. 8.

A great deal of rubbish has been talked about RIAA equalisation and transient response, in perverse attempts to render the shunt RIAA configuration acceptable despite its crippling 14dB noise disadvantage. The heart of the matter is that the RIAA replay characteristic apparently requires the hf gain to fall at a steady 6dB/octave forever. A series-feedback disc stage with relatively low gain cannot make its gain fall below one, and so the 6dB/octave fall tends to level out at unity early enough to cause errors in the audio band. Adding a high-frequency correction pole – ie low-pass time constant – just after the input stage makes the simulated and measured frequency response identical to a shunt-feedback version, and retains the noise advantage.

At this level of accuracy, the finite gain open-loop gain of even a 5534 at hf begins to be important, and the frequency of the hf pole is trimmed to allow for this.

What RIAA accuracy is possible without spending a fortune on precision parts? The best tolerance readily available for resistors and capacitors is  $\pm 1\%$ , so at first it appears that anything better than  $\pm 0.1$  dB accuracy is impossible. Not so. The component-sensitivity plots in Figs 4, 5 show the effect of 1% deviations in the value of  $R_a, R_b$ ; the response errors never exceed 0.05dB, as there are always at least two components contributing to the RIAA response.

Sensitivity of the RIAA capacitors is shown in Figs 6, 7 and you can see that tighter tolerances are needed for  $C_a$  and  $C_b$ , than for  $R_a$  and  $R_b$  to produce the same 0.05dB accuracy. The capacitors have more effect on the response than the resistors.

Finding affordable close-tolerance capacitors is not easy; the best solution seems to be, as in 1983, axial polystyrene, available at 1% tolerance. These only go up to 10nF, so some parallelling is required, and indeed turns out to be highly desirable. The resistors are all 1%, which is no longer expensive or exotic, though anything more accurate certainly would be.

For  $C_a$ , the five 10nF capacitors in parallel reduce the tolerance of the combination to 0.44%. This statistical trick works because the variance of equal summed components is the sum of the individual variances. Thus for five 10nF capacitors, the standard deviation (square root of variance) increases only by the square root of five, while total capacitance has increased five times. This produces an otherwise unobtainable 0.44% close-tolerance 50nF capacitor.

Similarly,  $C_b$  is mainly composed of three 4n7 components and its tolerance is improved by root-three, to 0.58%.

**Noise considerations**

The noise performance of any input stage is ultimately limited by Johnson noise from the

Table 1. Measured noise results, showing the 5532's superiority.

Z <sub>source</sub>	TL072	5532	5532 benefit	5532 EIN
1k	-88.0	-97.2dBu	+9.8dB	-126.7dBu
Shure M75ED	-87.2	-92.3dBu	+5.1dB	-121.8 dBu

(Preamp gain +29.55dB at 1kHz. Bandwidth 400-22kHz, rms sensing)

Table 2. Calculated minimum noise results.

Case	e <sub>n</sub> nV/√Hz	i <sub>n</sub> pA/√Hz	R <sub>in</sub>	R <sub>0</sub>	Output dBu	S/N ref 5mV dB	EIN dBu
1 Noiseless amp	0	0	1000M	OR	-104.0	-89.7dB	-133.5 A
5 Noiseless amp	0	0	47k	OR	-97.1	-82.8dB	-126.5 C
7 Noiseless amp	0	0	47k	220R	-96.7	-82.4dB	-126.2
11 2SB737, i <sub>c</sub> =70µA	1.7	0.4	47k	220R	-95.3	-81.0dB	-124.8
16 5532	5	0.7	47k	220R	-92.5	-78.2dB	-122.0
18 TL072	18	0.01	47k	220R	-86.9	-72.6dB	-116.5

input source resistance. The best possible equivalent input noise data for resistive sources, for example microphones with a 200Ω source resistance, i.e. -129.6dBu, is well-known, but the same figures for moving-magnet inputs are not.

It is particularly difficult to calculate equivalent input noise for moving magnet stages as a highly inductive source is combined with the complications of RIAA equalisation<sup>7</sup>. The amount by which a real amplifier falls short of the theoretical minimum equivalent input noise is the noise figure, NF. I often wonder why noise figures are used so little in audio; perhaps they are a bit too revealing.

The noise performance of disc input stages depends on the input source impedance, the cartridge inductance having the greatest influence. It is vital to realise that no value of resistive input loading will give realistic noise measurements.

A 1kΩ load models the resistive part of the cartridge impedance. But it ignores the fact that the 'noiseless' inductive reactance makes the impedance seen at the preamp input rise very strongly with frequency, so that at higher frequencies most of the input noise actually comes from the 47kΩ loading resistance. I am grateful to Marcel van de Gevel<sup>8</sup> for drawing my attention to this point.

Hence, for the lowest noise you must design for a higher impedance than you might think, and it is fortunate that the RIAA provides a treble roll-off, or the noise problem would be even worse than it is. This is not why it was introduced. The real reason for pre-emphasis/de-emphasis was to discriminate against record surface noise. Table 1 shows the two most common audio op-amps, the 5532 being definitely the best and quieter by 5dB.

To calculate appropriate EINs, I built a spreadsheet mathematical model of the car-

### Filtering subsonics

This stage is a third-order Butterworth high-pass filter, modified for a slow initial rolloff that implements the IEC amendment. This is done by reducing the value of  $R_{27}+R_{28}$  below that for maximal flatness. The stage also buffers the high-frequency correction pole, and gives the capability to drive a 600Ω load, if you can find one.

Capacitor distortion<sup>10</sup> in electrolytics is – or should be – by now a well-known phenomenon. It is perhaps less well known that non-electrolytics can also generate distortion in filters like these. This has nothing to do with Subjectivist musicality, but is very real and measurable.

The only answer appears to be using the highest-voltage capacitors possible; 100V polyester generates ten times less distortion than the 63V version.

tridge input, called MAGNOISE. The basic method is as in ref. 9. The audio band 50-22kHz is divided into nine octaves, allowing RIAA equalisation to be applied, and the equivalent generators of voltage noise ( $e_n$ ) and current noise ( $i_n$ ) to be varied with frequency.

Noise generated by the 47kΩ resistor  $R_{in}$  is modelled separately from its loading effects so its effect can be clearly seen. I switched off the bottom three octaves to make the results comparable with real cartridge measurements that require a 400Hz high-pass filter to eliminate hum, and 1/f effects are therefore neglected. No psychoacoustic weighting was used, and cartridge parameters were set to 610Ω+470mH, the measured values for the Shure M75ED.

The results match well with my 5532 and TL072 measurements, and I think the model is a usable tool. Table 2 shows some interesting cases; output noise is calculated for gain of +29.55dB at 1kHz, and signal-to-noise ratio for a 5mVrms input at 1kHz.

I draw the following conclusions. The minimum equivalent input noise from this particular cartridge, without the extra thermal noise from the 47kΩ input loading, is -133.5dBu,

no less than 7dB quieter than the loaded cartridge. (Case 1) It is the quietest possible condition. The noise difference between 10MΩ and 1MΩ loading is still 0.2dB, but as loading resistance is increased further to 1000MΩ the EIN asymptotes to -133.5dBu. A 47kΩ loading is essential for correct cartridge response.

With 47kΩ load, the minimum EIN from this cartridge is -126.5dBu. (Case 5) All other noise sources, including  $R_0$ , are ignored. This is the appropriate noise reference for this preamp design.

Resistor  $R_0$ , the 220Ω resistor in the bottom arm of negative feedback network, adds little noise. The difference between Case 5 and Case 7 is only 0.3dB.

A disc preamp stage using a good discrete bipolar device such as the remarkable 2SB737 transistor ( $r_b$  only 2Ω typ) is potentially 2.8dB quieter than a 5532, when the noise from  $R_0$  and the input load are included. Compare Cases 11 and 16.

The calculated noise figure for a 5532 is 4.5dB. Measured noise output of the moving magnet stage is -92.3dBu (1kHz gain +29.5dB) and so the equivalent input noise is -121.8dBu, and the real noise figure is 4.7dB,

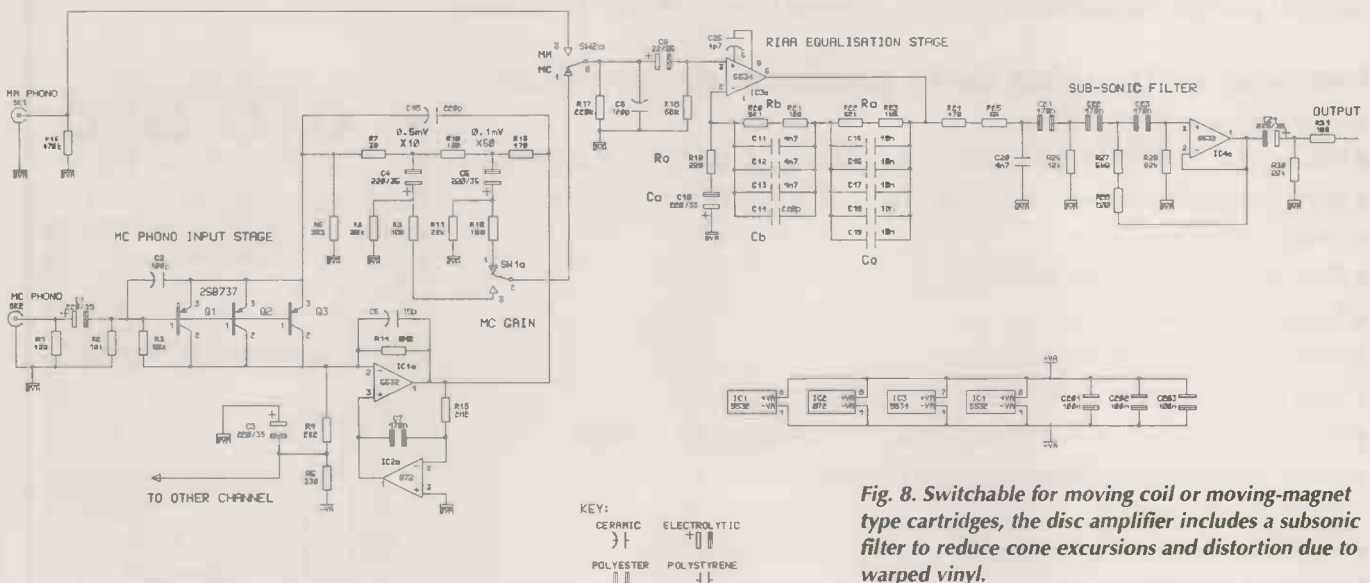


Fig. 8. Switchable for moving coil or moving-magnet type cartridges, the disc amplifier includes a subsonic filter to reduce cone excursions and distortion due to warped vinyl.

which is not too bad. Noise from the subsonic filter is negligible.

Taking  $e_n$  and  $i_n$  from data books, it looks as though the 5534/5532 is the best op-amp possible for this job. Other types – such as OP-27 – give slightly lower calculated noise, but measure slightly higher. This is probably due to extra noise generated by bias current-cancellation circuitry<sup>8</sup>.

There is an odd number of half-5532s, so the single 5534 is placed in the moving-magnet stage, where its slightly lower noise is best used. The RIAA-equalised noise output from the disc stage in moving-coil mode is -93.9dBu for 10× times gain, and -85.8dBu for 50× times. In the 10× case the moving-coil noise is actually 1.7dB lower than moving-magnet mode.

### Circuit details

The complete circuit of the disc amplifier and subsonic filter is Fig. 8. Circuit operation is

largely described above, but a few practical details are added here. Resistors  $R_9$  and  $R_{12}$  ensure stability of the moving-coil stage when faced with moving-magnet input capacitance  $C_8$ , while  $R_8$  and  $R_{11}$  are dc drains.

The 5534 moving-magnet stage has a minimum gain of about 3×, so compensation should not be required; if it is, a position is provided ( $C_{26}$ ) for external capacitance to be added; 4.7pF should be ample. The moving-magnet stage feedback arm  $R_{20-23}$  has almost exactly the same dc resistance as the input bias resistor  $R_{18}$ , minimising the offset at the output of  $IC_3$ . The hf correction pole is  $R_{24}+R_{25}$  and  $C_{20}$ .

Capacitor  $C_{24}$  is deliberately oversized so low loads can be driven. Resistor  $R_{31}$  ensures stability into high-capacitance cables. ■

### References

1. D. Self, 'A precision preamplifier', *Wireless World*, Oct 1983, p 31.
2. D. Self, 'Design of moving-coil head

amplifiers', *Electronics & Wireless World*, Dec 1987, p 1206.

3. D. Self, 'An advanced preamplifier design', *Wireless World*, Nov 1976, p 41.
4. D. Self, 'High-performance preamplifier', *Wireless World*, Feb 1979, p 43.
5. M. Jones, 'Designing valve preamps', *Electronics World*, March 1996, p 192.
6. S. Lipshitz, 'On RIAA equalisation networks', *Journ Audio Eng Soc*, June 1979, p 458.
7. H.P. Walker, 'Low noise amplifiers', *Wireless World* May 1972, p 233.
8. M van de Gevel, Private communication, Feb 1996.
9. J. Sherwin, 'Noise specs confusing?', National Semiconductor Application Note AN-104, Linear Applications Handbook 1991.
10. D. Self, 'Capacitor distortion', 'Views', *HiFi News & RR*, Nov 1985, p 23.

## High-quality circuit boards for Douglas Self's precision preamplifier '96

A high quality double-sided circuit board is available for Doug Self's precision preamplifier, exclusively via *Electronics World*. The board takes the full stereo preamplifier, including all power supply components except the transformer. Its layout is optimised to provide exceptionally low crosstalk.

Co-designed by Gareth Connor, the board is glass-fibre with plated-through holes and roller-tinned. It features solder masking and full component identification. Component lists and assembly notes – containing extra information about the preamplifier – are supplied with each order.

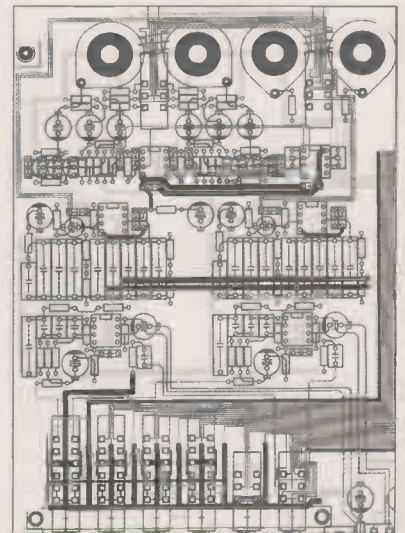
Each board is £59 inclusive of package, VAT and recorded postage. Please include a cheque or postal order

with your request, payable to Reed Business Publishing. Alternatively, send your credit card details – i.e. card type, number and expiry date. Include the delivery address in the order, which in the case of credit card holders must be the address of the card holder. Add a daytime telephone and/or fax number if you have one.

Send your order to Electronics World Editorial, PCBs, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Alternatively fax us on 0181 652 8956 or e-mail a jackie.lowe@rbp.co.uk. Credit card details can be left on the answering machine on 0181 652 3614. Please allow 28 days for delivery.

### Features of Douglas Self's precision preamplifier

- Very low noise and distortion.
- Moving-coil – sensitivity switchable 0.1 or 0.5mV,  $\pm 0.05$ dB RIAA accuracy.
- Moving-magnet input with  $\pm 0.05$ dB RIAA accuracy, 5V rms sensitivity.
- Three 150mV line inputs.
- One dedicated compact-disc input.
- Tape-monitor switch.
- Active-balance control.
- Tone control – switch defeatable – with  $\pm 10$ dB range.
- Tone control treble and bass frequencies variable over 10:1 range.
- Active volume control for optimal noise/headroom and enhanced interchannel matching.
- Intelligent relay muting on outputs.
- CD input sensitivity 1V rms.



# HART AUDIO KITS - YOUR VALUE FOR MONEY ROUTE TO ULTIMATE HI-FI

Hart Audio Kits and factory assembled units use the unique combination of circuit designs by the renowned John Linsley Hood, the very best audiophile components, and our own engineering expertise, to give you unbeatable performance and unbelievable value for money. We have always led the field for easy home construction to professional standards, even in the sixties we were using easily assembled printed circuits when Heathkit in America were still using tagboards! Many years of experience and innovation, going back to the early Dinsdale and Bailey classics gives us incomparable design background in the needs of the home constructor. This simply means that building a Hart kit is a real pleasure, resulting in a piece of equipment that not only saves you money but you will be proud to own. Why not buy the reprints and construction manual for the kit you are interested in to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.

## K1100 AUDIO DESIGN 80 WATT POWER AMPLIFIER.



This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hi-fi system. This kit is your way to get UK performance at bargain basement prices. Unique design features such as fully FET stabilised power supplies give this amplifier World Class performance with startling clarity and transparency of sound, allied to the famous HART quality of components and ease of construction.

Useful options are a stereo LED power meter and a versatile passive front end giving switched inputs, with ALPS precision Blue Velvet low-noise volume and balance controls. Construction is very simple and enjoyable with all the difficult work done for you, even the wiring is pre-terminated, ready for instant use! All versions are available with Standard components or specially selected Super Audiophile components at £29.60 extra per channel, plus £2.40 if you want to include Gold Plated speaker terminals.

- K1100B Complete STANDARD Amplifier Kit..... £395.21
- A1100B Factory Assembled..... £499.21
- K1100SC Complete SLAVE Amplifier Kit..... £333.62
- A1100SC Factory Assembled..... £422.62
- K1100M Complete MONOBLOC Amplifier Kit..... £261.20
- A1100M Factory Assembled..... £329.20
- RLH11 Reprints of latest Amplifier articles..... £1.80
- K1100CM Construction Manual with full parts lists..... £5.50

## "CHIARA" SINGLE ENDED CLASS "A" HEADPHONE AMPLIFIER.



This unit provides a high quality headphone output for 'stand alone' use or to supplement those many power amplifiers that do not have a headphone facility. Easily installed with special link-through feature the unit draws its power from our new Andante Ultra High Quality linear toroidal supply. Housed in the neat, black finished, Hart minibox it features the wide frequency response, low-distortion and 'musicality' that one associates with designs from the renowned John Linsley Hood. Pre-terminated interconnecting leads and PCB mounted sockets prevent supply polarity reversal and on-board diagnostics provide visual indication of supply line integrity. Volume and balance controls are Alps "Blue Velvet" components. Very easily built, even by beginners, since all components fit directly on the single printed circuit board. The kit has very detailed instructions, and even comes with a complementary roll of Hart audiograde silver solder, it can also be supplied factory assembled and tested. Selling for less than the total cost of all the components, if they were bought separately, this unit represents incredible value for money and makes an attractive and harmonious addition to any hi-fi system.

- K2100 Complete Kit..... £109.50
- K2100SA Series Audiophile version with selected audiophile components..... £112.46
- A2100SA Series Audiophile version, factory Assembled..... £149.46
- K3565 "Andante" Power Supply Kit to suit "Chiara"..... £85.42
- K3565 Power Supply, Factory Assembled..... £128.42
- CM2100 Construction Manual..... £2.50
- SPECIAL OFFER. Both units together, Kit Form..... £184.92
- Factory Assembled and Tested..... £267.88

## "Andante" SERIES 20VA AUDIOPHILE POWER SUPPLIES

Specially designed for exacting audio use requiring absolute minimum noise, low hum field and total freedom from mechanical noise this unit is a logical development from our highly successful 1550 series.

Utilising linear technology throughout for smoothness and musicality makes it the perfect partner for any module requiring fully stabilised  $\pm 15v$  supplies.

Two versions are available. K3550 has 2  $\pm 15v$  supplies and a single 15v for relays etc. and can be used with our K1400 preamp and our K1450 RIAA pickup preamp, as well as other useful modules soon to be introduced. The K3565 is identical in appearance but only has the  $\pm 15v$  lighter current supply for use with the K1450 RIAA pickup pre amplifier or "Chiara" headphone amplifier.

- K3550 Full Supply with all outputs..... £93.75
- K3565 Power Supply for K1450 & K2100..... £85.42

## ALPS "Blue Velvet" PRECISION AUDIO CONTROLS.



Now you can throw out those noisy ill-matched carbon pots and replace with the famous Hart exclusive ALPS "Blue Velvet" range components only used selectively in the very top flight of World class amplifiers. The improvement in track accuracy and matching really is incredible giving better tonal balance between channels and rock solid image stability. Motorised versions have 5v DC motor.

- MANUAL POTENTIOMETERS**
- 2-Gang 100K Lin..... £15.67
- 2-Gang 10K, 50K or 100K Log..... £16.40
- 2-Gang 10K Special Balance, zero crosstalk and zero centre loss..... £17.48
- MOTORISED POTENTIOMETERS**
- 2-Gang 20K Log Volume Control..... £26.20
- 2-Gang 10K RD Special Balance, zero crosstalk and less than 10% loss in centre position..... £26.98

## TECHNICAL BOOKSHELF

NEW! Another Classic by John Linsley Hood. "AUDIO ELECTRONICS" Following the enormous ongoing success of his "Art of Linear Electronics" the latest offering is the all-new edition of "Audio Electronics", now entirely re-written by the master himself. Underlying audio techniques and equipment is a world of electronics that determines the quality of sound. For anyone involved in designing, adapting or using digital or analogue audio equipment understanding electronics leads to far greater control over the reproduced sound. The subjects covered include tape recording, tuners, power output stages, digital audio, test instruments and loudspeaker crossover systems. John's lifetime of experience and personal innovation in this field allow him to apply his gift of being so familiar with his subject that he can write clearly about it and make it both interesting and comprehensible to the reader. Containing 240 pages and over 250 line illustrations this new book represents great value for money at only..... £18.99

## "THE ART OF LINEAR ELECTRONICS."

The definitive linear electronics and audio book by John Linsley Hood. This 300+ page book will give you an unparalleled insight into the workings of all types of audio circuits. Learn how to read circuit diagrams and understand amplifiers and how they are designed to give the best sound. The virtues and vices of passive and active components are examined and there are separate sections covering power supplies and the sources of noise and hum. As one would expect from this writer the history and derivation of audio amplifier circuitry have an entire chapter, as does test and measurement equipment. Copiously illustrated this book is incredible value for the amount of information it contains on the much neglected field of linear, as opposed to digital, electronics. Indeed it must be destined to become the standard reference for all who work, or are interested in, this field. Latest reprinted edition with extended index. 1994 344 Pages. 247 x 190. 1Kg. 0-7506-0868-4..... £16.95

- "DIGITAL AUDIO AND COMPACT DISC TECHNOLOGY" 0-7506-0614-2..... £17.95
- INTRODUCING DIGITAL AUDIO CD, DAT AND SAMPLING. ISBN 1870775 22 8..... £7.95
- "THE ART OF SOLDERING" 0-85935-324-3, 0..... £3.95
- "TOWERS' INTERNATIONAL TRANSISTOR SELECTOR" 0-572-01062-1..... £19.95
- "AUDIO" FA Wilson, BP111..... £3.95
- "HOW TO USE OSCILLOSCOPES & OTHER TEST EQUIPMENT" R.A. Penfold, BP267..... £3.50
- "THE LOUDSPEAKER DESIGN COOKBOOK" Vance Dickason..... £22.95

- (4th Edn.) 0-9624-191-7-6..... £22.95
- ELECTROSTATIC LOUDSPEAKER DESIGN AND CONSTRUCTION Ronald Wagner BKT6..... £18.95
- "AN INTRODUCTION TO LOUDSPEAKERS & ENCLOSURE DESIGN" V. Capel, BP256..... £2.95
- "LOUDSPEAKERS FOR MUSICIANS" BP297..... £3.95
- "THE HART PRINTED CIRCUIT BOARD CONSTRUCTION GUIDE."..... £2.50

## VALVE & EARLY CLASSIC BOOKS

- THE VTL BOOK David Manley BKV1..... £17.95
- LOUDSPEAKERS; THE WHY AND HOW OF GOOD REPRODUCTION. G. Briggs. 1949 0-9624-1913-3..... £8.95
- MULLARD TUBE CIRCUITS FOR AUDIO AMPLIFIERS BKAA27..... £13.95
- "THE WILLIAMSON AMPLIFIER." 0-9624-1918-4..... £6.95
- AN APPROACH TO AUDIO FREQUENCY AMPLIFIER DESIGN. GEC 1957, 1-882580-05-2..... £18.95
- AUDIO ANTHOLOGIES, articles from Audio Engineering. Six volumes covering the days when audio was young and valves were king! BKAA3/1 to 6. All..... £13.95 each.
- "A SIMPLE CLASS A AMPLIFIER" J.L. Linsley Hood M.I.E.E. 1969. RLH12..... £2.50

Postage on all books, unless starred, is only  $\pounds 1.50$  per book, maximum  $\pounds 4.50$  for any number, any size! Starred items are heavy books costing..... £2.50 to send. No waiting! All listed books are normally in stock! SPECIAL OFFER. All book orders over  $\pounds 15$  will receive a FREE John Linsley Hood monograph entitled "Digital versus Analogue, Black Disks or Silver?"

## SPECIAL OFFER PRECISION Triple Purpose TEST CASSETTE TC1D.

Are you sure your tape recorder is set up to give its best? Our latest triple purpose test cassette checks the three most important tape parameters without test equipment. Ideal when fitting new heads. A professional quality, digitally mastered test tape at a price anyone can afford. Test Cassette TC1D. Our price only..... £9.99.



## HC80 Replacement Stereo Cassette Head.

The excellent performance of modern cassette recorders depends totally on the quality of the R/P head. Even the slightest amount of wear can impair the frequency response and distortion levels. Our HC80 is atop quality head from one of the foremost manufacturers in Japan, easily fitted to most standard stereo recorders (except Sony) and will transform the performance over a worn head. Only the fact that we buy these in vast quantities enables us to offer them at the amazing price of only  $\pounds 11.70$  each or 2 for  $\pounds 17.60$ . We also stock a range of other heads, including "reel-to-reel stereo heads.

## SOLDERING

The size of modern components makes the right soldering equipment essential for good results. Everything we offer we actually use in our own workshops! See our Lists for the full range. 845-820 XS240 ANTEX 240v 25w Soldering Iron. This is the ideal Multi-purpose iron as the bit is designed to totally surround the element giving the best heat transfer. This excellent design also means that although it is small and handy enough for modern components its heating capacity is better than larger irons of conventional construction. Excellent Value..... £9.93
- 845-080 ST4 Lightweight Soldering Iron Stand. This has provision for the classic clamp sponge for bit wiping..... £3.95

## HART SUPER AUDIOGRADE SILVER SOLDER.

Hart Super Audiograde Silver Solder has been specially formulated for the serious audiophile. Not only does it give beautiful easy-to-make joints but it is designed to melt at normal soldering temperatures avoiding the possibility of thermal damage to components or the need for special high temperature irons. A very low residue flux makes perfect joints easy but eliminates the need for board cleaning after assembly.

- 845-007 3mtrs 22SWG in Hart Mini Tube..... £3.90
- 845-008 100g. Reel Special Valve Grade, 20swg..... £12.90
- 845-009 100g. Precision PCB Grade, 22swg..... £14.75
- 845-110 100g Reel Superline 24swg for ultra precise control and easy working..... £21.45

QUALITY AUDIO KITS

24 hr. SALES LINE (01691) 652894

ALL PRICES INCLUDE UK/EC VAT

CIRCLE NO. 111 ON REPLY CARD

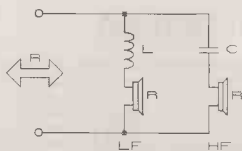
# CROSSOVER NETWORKS MADE SIMPLE

Bill Teleki's short C program takes the effort out of selecting components for various orders of Butterworth loudspeaker crossover networks.

Recently, while browsing through one of my components catalogues, I came across the section that had the audio crossover networks in. I noticed two things:

- They use various combinations of first, second and third order networks, Figs. 1,2,3.
- They are all expensive for what is not much more than 12 passive components on a pcb.

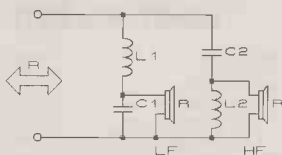
The most expensive was in the region of £100 for a second, first, third-order combination. The expensive types incorporate overload protection circuits in the form of varistors that attenuate the signal when it reaches a certain overload level.



$$L = \frac{R}{2\pi F_c}$$

$$C = \frac{1}{2\pi F_c R}$$

Fig. 1. First order 6dB/octave two-way crossover needs good drivers to perform well.



$$L_1 = \frac{R}{\sqrt{2} \times \pi \times F_c} \quad L_2 = \frac{R}{2 \times \sqrt{2} \times \pi \times F_c}$$

$$C_1 = \frac{1}{\sqrt{2} \times \pi \times F_c \times R} \quad C_2 = \frac{1}{2 \times \sqrt{2} \times \pi \times F_c \times R}$$

Fig. 2. Second-order two-way crossover has 12dB/octave cut-offs so driver requirements are less stringent.

A glance through my final year notes on audio design showed that the realisation of these units was nearly a trivial task. Further reading showed that the first and second-order sections are inappropriate for high-fidelity sound.

### Passive crossover networks

A passive crossover network consists of a high power Butterworth filter that splits the audio signal into various frequency bands, the different bands being fed to the relevant loudspeaker. Active crossover networks exist, but these incorporate ordinary op-amps so one power amplifier is needed for each speaker.

The simplest and cheapest form of crossover is a first-order two-way network, Fig. 1. This type of crossover is often found in low-budget hi-fi. It is capable of producing good results. However, it has a 6dB/octave roll-off. To perform well, it needs wide-range drivers with a defined spacing, and having a common radiation plane and dispersion. These are not cheap.

Next, comes the second order network, Fig. 2. This has a 12dB/octave roll-off, so signal separation is better. But there are still problems. The outputs are in anti-phase at the crossover point, Fig. 2a. This situation can be

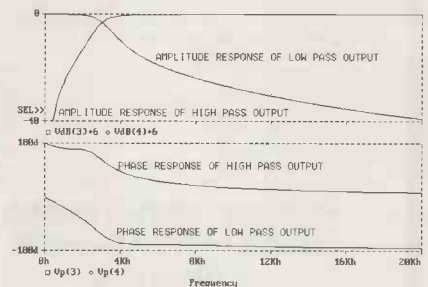


Fig. 2a. Responses of second-order 12dB/octave two-way crossover. Phase difference throughout the band is approximately 180°.

corrected by reversing the leads to the treble driver. Unfortunately, this results in displacement elsewhere.

Finally, we come to the third order version, Fig. 3. This has an 18dB/octave roll-off in the stopband, so signal separation is better. Also, the phase response is superior through the crossover region, being at approximately 90° throughout the band, Fig. 3a.

Applying the relevant equations is a trivial task, but to speed things up, a piece of software can be written. This not only prevents errors due to kak-handedness on a calculator keyboard, but also enables a permanent record of a design to be kept for future reference. The C program, Listing 1, calculates the components for a two way or three way crossover and then optionally save them to a disk file. Listing 2 is a typical output run from the program.

Suppose you want to build a three-way net-

Listing 1. Simple crossover network component calculator in C.

```

/* CROSS.C 28:02:96 ; Final version - for now */
#include <stdio.h>
#include <stdlib.h>
#include <math.h>
#include <float.h> /* include libraries */
#include <conio.h>
#include <dos.h>

#define pi 3.141592654 /* all variables are global */

char *mts[] = {"", "JAN", "FEB", "MAR", "APR", "MAY", "JUN", "JUL",
              "AUG", "SEP", "OCT", "NOV", "DEC", ""};

char *tday[] = {"SUN", "MON", "TUE", "WED", "THU", "FRI", "SAT", ""};

float fc1, fc2, r, l1, l2, l3, c1, c2, c3, l1a, l2a, l3a, c1a, c2a, c3a;
char tipe, qsave;
char name[8], aname[15];
union REGS reg;
FILE *tofile;

void get_param(void); /* prototypes */
void do_calculations(void);
void do_printout(void);
void save_stuff(void);

void main () /* main function */
{
    get_param();
    do_calculations();
    do_printout();
    save_stuff();
}

void get_param(void) /* get the parameters */
{
    printf("\nDual OR T]hree way crossover = ? ");
    tipe = toupper(getche());
    if (tipe == 'D')
    {
        printf("\nCrossover frequency (Hz)= ? ");
        scanf("%f", &fc1);
    } else
    {
        printf("\nFirst Crossover Frequency (Hz)= ? ");
        scanf("%f", &fc1);
        printf("\nSecond Crossover Frequency (Hz)= ? ");
        scanf("%f", &fc2);
    }
    printf("\nNominal Resistance = ? ");
    scanf("%f", &r);
}

void do_calculations(void) /* calculate component values */
{
    l1 = 3*r/(4*pi*fc1);
    l2 = l1/3;
    l3 = l1/2;
    c1 = 2/(3*pi*fc1*r);
    c2 = c1/2;
    c3 = c1*3/2;
    if (tipe == 'T')
    {
        l1a = 3*r/(4*pi*fc2);
        l2a = l1a/3;
        l3a = l1a/2;
        c1a = 2/(3*pi*fc2*r);
        c2a = c1a/2;
        c3a = c1a*3/2;
    }
}

void do_printout(void) /* print results to monitor */
{
    printf("L1 = %e %s\n", l1, "H");
    printf("L2 = %e %s\n", l2, "H");
    printf("L3 = %e %s\n", l3, "H");
    printf("C1 = %e %s\n", c1, "F");
    printf("C2 = %e %s\n", c2, "F");
    printf("C3 = %e %s\n", c3, "F");
    if (tipe == 'T')
    {
        printf("L1a = %e %s\n", l1a, "H");
        printf("L2a = %e %s\n", l2a, "H");
        printf("L3a = %e %s\n", l3a, "H");
        printf("C1a = %e %s\n", c1a, "F");
        printf("C2a = %e %s\n", c2a, "F");
        printf("C3a = %e %s\n", c3a, "F");
    }
}

void save_stuff(void) /* save design to disk */
{
    printf("DO YOU WANT TO SAVE DESIGN ? Y/N ");
    qsave = toupper(getche());
    if (qsave == 'Y')
    {
        printf("\nSAVE DESIGN AS ? ");
        scanf("%s", &name);
        printf("YOUR NAME ? ");
        scanf("%s", &aname);
        if ((tofile = fopen(name, "w")) == NULL)
        {
            printf("Error opening text file for writing\n");
            exit(0);
        }
        fprintf(tofile, "%s %s\n", "FILENAME :", name);
        fprintf(tofile, "%s %s\n", "DESIGNED BY :", aname);
        reg.x.ax = 0x2A00;
        intdos(&reg, &reg);
        fprintf(tofile, "DATE : %s, %s %d, %d\n", tday[reg.h.dl],
            mts[reg.h.dh], reg.h.dl, reg.x.cx);
        fprintf(tofile, "%s\n", " ");
        fprintf(tofile, "%s %e %s\n\n", "SPEAKER IMPEDANCE : ", r, "OHMS");
        fprintf(tofile, "%s %e %s\n", "CROSSOVER FREQUENCY : ", fc1, "Hz");
        fprintf(tofile, "L1 = %e %s\n", l1, "H");
        fprintf(tofile, "L2 = %e %s\n", l2, "H");
        fprintf(tofile, "L3 = %e %s\n", l3, "H");
        fprintf(tofile, "C1 = %e %s\n", c1, "F");
        fprintf(tofile, "C2 = %e %s\n", c2, "F");
        fprintf(tofile, "C3 = %e %s\n", c3, "F");
        if (tipe == 'T')
        {
            fprintf(tofile, "\n %s %e %s\n", "CROSSOVER FREQUENCY : ",
                fc2, "Hz");
            fprintf(tofile, "L1a = %e %s\n", l1a, "H");
            fprintf(tofile, "L2a = %e %s\n", l2a, "H");
            fprintf(tofile, "L3a = %e %s\n", l3a, "H");
            fprintf(tofile, "C1a = %e %s\n", c1a, "F");
            fprintf(tofile, "C2a = %e %s\n", c2a, "F");
            fprintf(tofile, "C3a = %e %s\n", c3a, "F");
        }
    }
    fclose(tofile);
}

```

work. Simple, you just add on another network to the output of the high-frequency path of the two-way crossover, Fig. 4. Because we're dealing with equiterminated networks here, there are no problems with impedance mismatches. Listing 3 is hard copy of an output run.

Figure 4a is the response of the three outputs from the network. To make sure that the correct part of the signal spectrum reaches the appropriate speaker it is necessary to recalculate the component values.

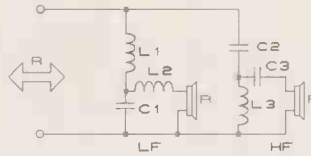
**Implementation considerations**

Build a crossover network requires careful component selection. All capacitors should be non-polarised electrolytics of the highest possible voltage rating. It is likely that the values available will not equal the design values. In this case, two or three can be put in parallel depending on what component tolerances you want to work to.

To put this in perspective, according to some sources, because the impedance of the loudspeaker varies with frequency, capacitors can be up to 50% away from their design value. Inductors can be air cored. Alternatively, if you don't have miles of wire to spare, iron-powder toroids can be used. Note that air cored inductors will interact with each other depending on their separation. So a crossover network using these, will take up more pcb space.

There are no proximity problems with toroids due to their closed magnetic circuit. However, toroids saturate at a certain power level. It is important to use high power toroids or types specifically made for emi or power filters. I ruled pot cores out because of their cost.

The best toroid type is A1=93 from Cirkit (part no = 55-10626). These are type T106-26. For a given inductance, the required number



$$L_1 = \frac{3R}{4\pi F_c} \quad L_2 = \frac{L_1}{3} \quad L_3 = \frac{L_1}{2}$$

$$C_1 = \frac{2}{3\pi F_c R} \quad C_2 = \frac{C_1}{2} \quad C_3 = \frac{C_1 \times 3}{2}$$

Fig. 3. Third order 18dB/octave two way crossover.

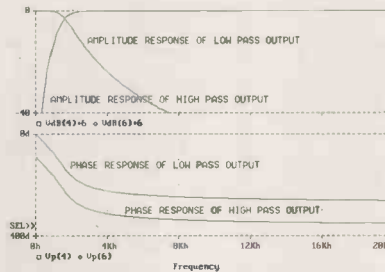


Fig. 3a. Responses of third-order 18dB/octave two-way crossover. Phase difference throughout the band is approximately 100°.

of turns is calculated from  $N = \sqrt{L/A\mu}$ , where L is in nanohenries. At 37p each, plus the cost of the capacitors, connectors and pcb, a pair of two way crossovers can be built for less than £10, which compares very favourably with commercial units.

My prototype has an experimental overload protection circuit in the form of a triac across the input terminals. Normally breakdown diodes are employed here, but at the time I only had the triac available. The gate of the triac is fed from a voltage divider across the input signal, the voltage divider selecting the input level at which the triac fires. The main terminals of the triac are connected to the input signal via a high power 8Ω resistor and to ground.

Unfortunately tests could not proceed normally with this because at the volume where the windows were about to fall out of their frames, smoke started to issue from the power resistor. So to avoid setting fire to the place, I had to turn the volume down. I suspect that the gate drive was at fault somewhere.

If two identical second order Butterworth networks had been cascaded, then the result

Listing 2. Hard copy of an output run from the calculator program crossover network components.  
 FILENAME : CROSS1  
 DESIGNED BY : B.TELEKI  
 DATE : TUE,MAR 26,1996

SPEAKER IMPEDANCE : 8.000000e+00 OHMS  
 Crossover Frequency : 1.600000e+03 Hz  
 L1 = 1.193662e-03 H  
 L2 = 3.978873e-04 H  
 L3 = 5.968310e-04 H  
 C1 = 1.657864e-05 F  
 C2 = 8.289320e-06 F  
 C3 = 2.486796e-05 F

Listing 3. Hard copy from the crossover calculator for a third-order filter.  
 FILENAME : THREE  
 DESIGNED BY : J.T.  
 DATE : WED,MAR 27,1996

SPEAKER IMPEDANCE : 8.000000e+00 OHMS  
 Crossover Frequency : 2.500000e+02 Hz  
 L1 = 7.639437e-03 H  
 L2 = 2.546479e-03 H  
 L3 = 3.819719e-03 H  
 C1 = 1.061033e-04 F  
 C2 = 5.305165e-05 F  
 C3 = 1.591549e-04 F  
 Crossover Frequency : 3.500000e+03 Hz  
 L1a = 5.456741e-04 H  
 L2a = 1.818914e-04 H  
 L3a = 2.728370e-04 H  
 C1a = 7.578807e-06 F  
 C2a = 3.789403e-06 F  
 C3a = 1.136821e-05 F

would have been a Linkwitz-Riley network. These have the advantage of having a constant phase shift between the two outputs. This is at the cost of requiring much higher tolerance components, otherwise the response will revert to a cross between a Linkwitz and Butterworth.

I don't know of anywhere that sells E24 non-polarised electrolytics to 1% tolerance, nor how much they might cost.

**Debatable improvements**

Further improvements to the circuit can be implemented, such as delay equalising the outputs or employing some sort of resistive damping, but the improvements that can be obtained with such measures are questionable and open to debate.

**Further reading**

- Williams & Taylor, Electronic Filter Design Handbook.
- F.R. Conner, Networks.
- R.M. Marston, Power control circuits manual.
- Linkwitz Filters, *Electron Electronics*, April 1987.

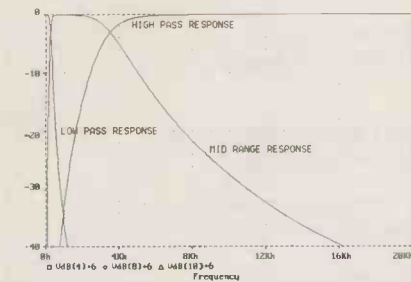


Fig. 4a. Response of third-order 18dB/octave three way crossover.

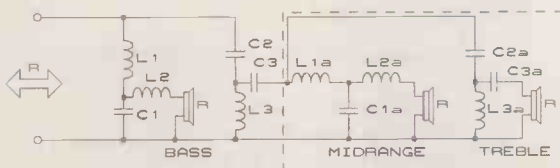


Fig. 4. Third order 18dB/octave three-way crossover. Simply adding another third-order section to the high-frequency output of the two way network, creates a three way network. No impedance mismatch occurs since load is still R. But component values have to be redesigned to redistribute the signal spectrum. Use equations as in Fig. 3.



# MICROMASTER LV PROGRAMMER



**APPROVED**

by major manufacturers including

**AMD  
MICROCHIP  
ATMEL**

from only

**£495**

THE ONLY PROGRAMMERS  
WITH TRUE 3 VOLT SUPPORT

## The Only True 3V and 5V Universal Programmers

ICE Technology's universal programming solutions are designed with the future in mind. In addition to their comprehensive, ever widening device support, they are the only programmers ready to **correctly** programme and verify 3 volt devices NOW. Operating from battery or mains power, they are flexible enough for any programming needs.

The Speedmaster LV and Micromaster LV have been rigorously tested and **approved** by some of the most well known names in semiconductor manufacturing today, something that very few programmers can claim, especially at this price level!

Not only that, we give free software upgrades so you can dial up our bulletin board any time for the very latest in device support.

Speedmaster LV and Micromaster LV - they're everything you'll need for programming, chip testing and ROM emulation, now and in the future.

### Speedmaster LV £495

Programmes 3 and 5V devices including memory, programmable logic and 8748/51 series micros. Complete with parallel port cable, software, re-charger and documentation.

### 8 bit Emulator card £125

Expansion card for Speedmaster LV/ Micromaster LV containing 8 bit wide ROM/ RAM emulator. Emulates 3V and 5V devices. Includes cable and software. Configuration: 128K x 8 expandable to 512K by 8.

### Micromaster LV £625

As above plus support for over 130 different Microcontrollers, without adaptors, including PICs, 89C51, 68HC705/711, ST6, Z8 etc.

### 16 bit Emulator card £195

As above but containing 16 bit ROM/RAM emulator. Configuration: 128K by 16, 256K by 8, 2 by 128K 8, expandable to 512K by 16/1024K by 8.

## FEATURES

- Widest ever device support including EPROMs, EEPROMs, Flash, Serial PROMs, BROMs, PALs, MACH, MAX, MAPL, PEELs, EPLDs, Microcontrollers etc.
- Correct programming and verification of 3 volt devices.
- Approved by major manufacturers.
- High speed: programmes and verifies National 27C512 in under 11 seconds.
- Full range of adaptors available for up to 84 pins.
- Connects directly to parallel port - no PC cards needed.
- Built in chiptester for 7400, 4000, DRAM, SRAM.
- Lightweight and mains or battery operation.
- FREE software device support upgrades via bulletin board.
- Next day delivery.

For a copy of our catalogue giving full details of programmers, emulators, erasers, adaptors and logic analysers call, fax or dial the BBS numbers below.



ICE Technology Ltd. Penistone Court, Station Buildings,  
Penistone, South Yorkshire, UK S30 6HG  
Tel: +44 (0)1226 767404 Fax: +44 (0)1226 370434  
BBS: +44 (0)1226 761181 (14400, 8N1)

CIRCLE NO. 112 ON REPLY CARD



# Cmeter resolves to 0.1 pF

**Emil Vladkov's meter spans 0.1 pF–1.999 μF and has autoranging. Based on the comparison of two frequencies, the design can be trimmed to achieve a basic accuracy of 0.1%.**

It is sometimes necessary to measure capacitors, if their value is unknown or suspect. In my experience, most problems occur with small capacitors in the pico-farad range. Many universal digital multimeters that measure capacitance start at 1nF, and even read this value with a significant error.

For low-volume applications, high performance LRC bridges measure not only capacitance but also losses in the dielectric of the capacitor. But such bridges are expensive. For the above reasons, I decided to design a precise and convenient capacitance meter that measures down to picofarads yet is low cost.

### Measuring principle

The principle of my design is illustrated with in Fig. 1. It is based on two equal timers working in monostable mode. This means that the timing RC circuit of each are identical.

It is not possible to measure capacitances in the range of 0.1pF using only one timer in monostable mode. This is because of the parasitic capacitance of the leads of the ic, which can not be compensated for with one timer.

The p-n junctions within the timer also have significant parasitic capacitance. Without an external unknown capacitor, the monostable multivibrator generates a short pulse due to these capacitances, making the measurement of picofarad values impossible.

For the above reason, I decided to use two timers. With no unknown capacitor connected, the two monostable timers generate pulses with the same  $\Delta t$  width. The timing diagram of the compensating reference timer is Fig. 1 a) and the measuring timer is labelled b).

Variable  $T_0$  is the period of the triggering pulses. Pulses generated by the monostable timers are applied to an exclusive-or gate. Output of this gate goes high only if there is a difference between the two pulses.

So without an external capacitance, as tim-

ing diagram 3 shows, there is no pulse at the output of the XOR gate. If an unknown capacitor is set in the timing network of the measuring timer, it generates a pulse with an additional duration of,

Ranges:	Accuracy	Resolution
0.1pF–199.9pF	$\pm(0.1\%+1 \text{ digit})$	0.1pF
0.199nF–1.999nF	$\pm(0.05\%+1 \text{ digit})$	1pF
1.999nF–19.99nF	$\pm(0.05\%+1 \text{ digit})$	10pF
19.99nF–199.9nF	$\pm(0.1\%+1 \text{ digit})$	100pF
0.199μF–1.999μF	$\pm(0.1\%+1 \text{ digit})$	1nF

$T = 1.1RC_x$ ,

$$T = 1.1RC_x$$

as shown in c). This additional duration is exactly proportional to the unknown value of the capacitance to be measured. The 555 timer is chosen, because its pulse duration does not depend on the supply voltage. This can be a source of errors. Output of the XOR gate goes high for exactly this duration  $T$ .

The principle of the system is to measure the dc component of the signal at the output of the XOR gate. Because of the positive voltage level of the logic zero, i.e. a low level, at the XOR output and the voltage drop on the additional diodes,  $D_2$  and  $D_3$  in Fig. 2, there is a parasitic dc component. This is added to the useful dc component proportional to  $C_x$  and must be removed.

The useful signal with removed parasitic dc component is shown in d), together with the useful dc component, proportional to  $C_x$ .

### Circuitry of the measuring unit

Figure 3 is the measuring module schematic. It consists of the compensating timer  $IC_{13}$ , the measuring timer  $IC_{14}$  and an additional monostable-mode timer, based on a 74LS123,  $IC_{12B}$ . It has the task of measuring capacitances in the range between 19.99nF and 1.999μF.

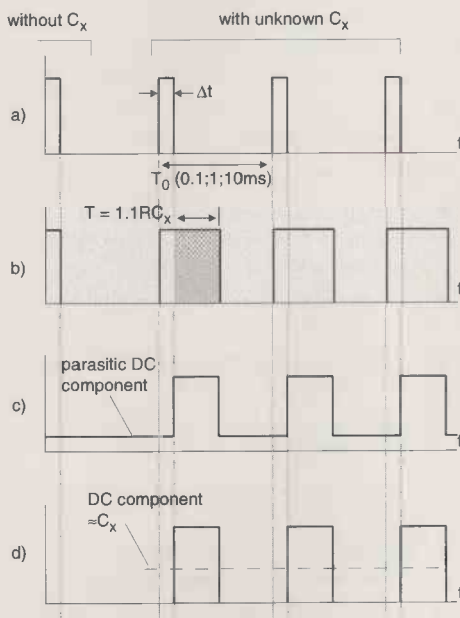


Fig. 1. Principle of the low capacitance meter, which involves a comparison between fixed and variable timers.

Component list

Integrated circuits

IC <sub>1</sub> , IC <sub>9</sub> , IC <sub>22</sub> ,	74LS00
IC <sub>2</sub> , IC <sub>3</sub> , IC <sub>4</sub> , IC <sub>5</sub>	74LS90
IC <sub>6</sub>	74LS164
IC <sub>7</sub> , IC <sub>8</sub>	74LS01
IC <sub>10</sub> , IC <sub>13</sub> , IC <sub>14</sub>	TDB 555 (Siemens)
IC <sub>11</sub>	74LS08
IC <sub>12</sub>	74LS123
IC <sub>15</sub>	7486
IC <sub>16</sub>	74LS27
IC <sub>17</sub>	74LS02
IC <sub>18</sub>	CD 4049
IC <sub>19</sub>	ICL 7107 (Harris)
IC <sub>20</sub> , IC <sub>21</sub>	VQE24

Diodes

D <sub>1</sub> , D <sub>2</sub> , D <sub>3</sub> , D <sub>8</sub> , D <sub>9</sub>	1N4148
D <sub>4</sub>	BZX79C 3V3 (Philips)
D <sub>5</sub> , D <sub>6</sub> , D <sub>7</sub>	LEDs, any colour

Resistors

R <sub>1</sub>	110Ω
R <sub>2</sub>	560Ω
R <sub>3</sub> , R <sub>6</sub> , R <sub>16</sub>	1.1kΩ
R <sub>4</sub>	130kΩ
R <sub>5</sub>	43kΩ
R <sub>7</sub>	6.2kΩ
R <sub>8</sub>	100Ω linear potentiometer
R <sub>9</sub> , R <sub>12</sub> , R <sub>17</sub> , R <sub>18</sub> , R <sub>19</sub>	470Ω
R <sub>10</sub> , R <sub>11</sub>	383kΩ (0.1%) or selected 384kΩ
R <sub>13</sub>	56kΩ
R <sub>14</sub> , R <sub>21</sub>	10kΩ linear pot
R <sub>15</sub>	10kΩ
R <sub>20</sub> , R <sub>22</sub>	4.3kΩ
R <sub>23</sub>	1.0MΩ
R <sub>24</sub>	470kΩ
R <sub>25</sub> -R <sub>50</sub>	820Ω

Capacitors

C <sub>1</sub>	330pF or smaller (adj.), depends on G <sub>1</sub>
C <sub>2</sub> , C <sub>10</sub> , C <sub>15</sub>	47nF
C <sub>3</sub>	1.0nF
C <sub>4</sub> , C <sub>11</sub>	10μF
C <sub>5</sub>	27pF
C <sub>6</sub> , C <sub>7</sub>	5.6pF
C <sub>8</sub>	1μF
C <sub>9</sub>	3.9pF
C <sub>12</sub>	100nF
C <sub>13</sub>	10nF
C <sub>14</sub>	220nF

Resonators

G <sub>1</sub>	1MHz Quartz
----------------	-------------

The 555 timers are used for the low-value ranges 0.1pF to 199.9pF, 0.199nF to 1.999nF and 1.999nF to 19.99nF. Exclusive-or gate IC<sub>15B</sub> compares the measured signal, proportional to C<sub>x</sub>, and the compensating signal.

Gates IC<sub>15C</sub> and IC<sub>8B</sub> apply the signals of the three low and two high ranges to the same RC filter, R<sub>13</sub>/C<sub>8</sub>. For low capacitances, the autoranging circuit transmits the pulses from

the 555 timers through IC<sub>15C</sub> and D<sub>2</sub>. Part of the autoranging circuit, IC<sub>16A</sub>, goes low if any one of the Q<sub>3</sub>, Q<sub>4</sub> or Q<sub>5</sub> lines goes high.

The duration of the diode's inverse bias is proportional to C<sub>x</sub>. During this time, a stable voltage derived from 3.3V zener diode D<sub>4</sub>, is applied to the input of the RC filter. This makes the measurement independent of the high-level output voltage of the IC.

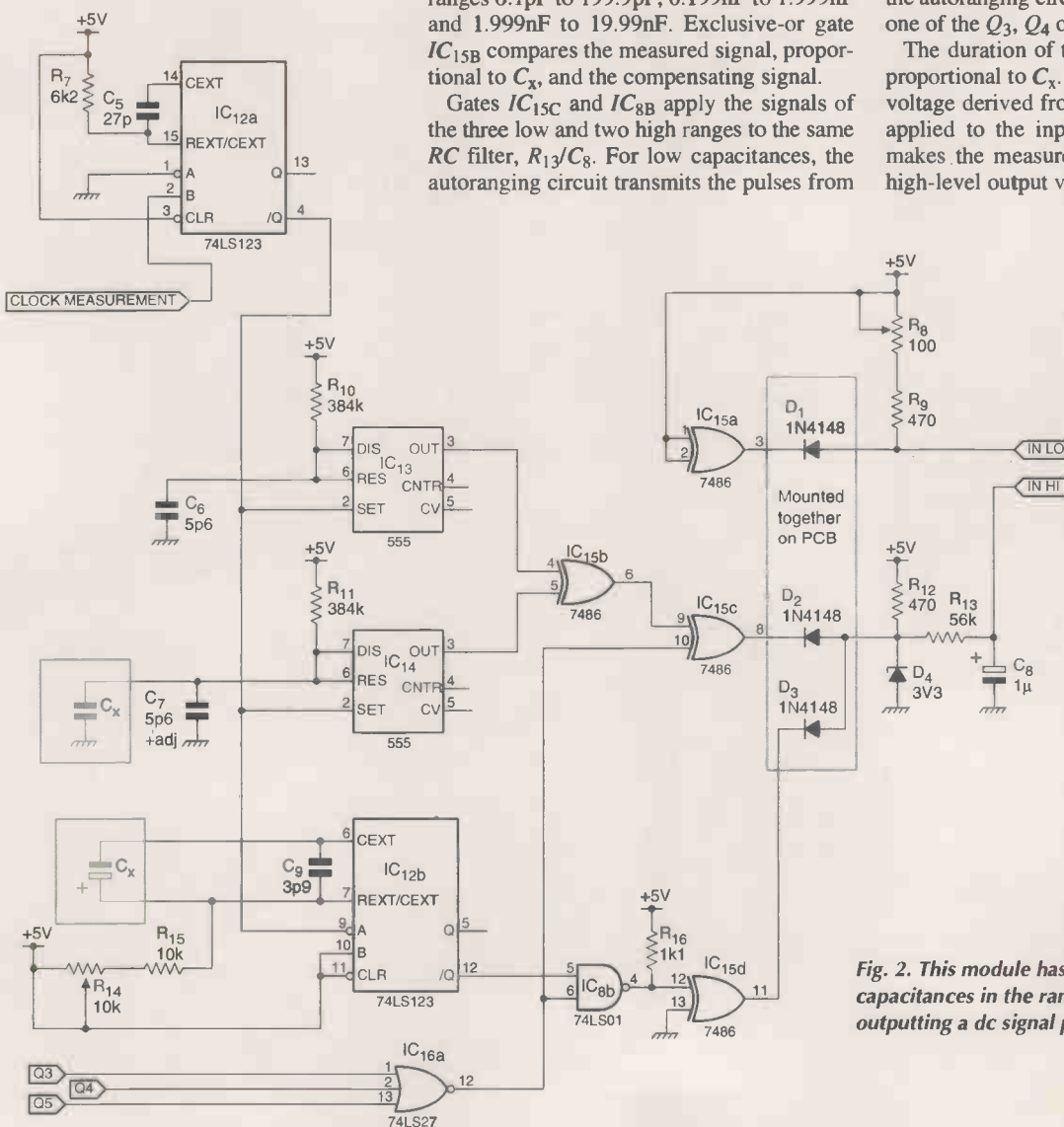


Fig. 2. This module has the task of comparing capacitances in the range 0.1pF and 1.999μF, outputting a dc signal proportional to C<sub>x</sub>.

If the high capacitance ranges are chosen by the autoranging circuit,  $IC_{15C}$  goes high, because there are no pulses from the 555 timers circuit and the output of  $IC_{16A}$  is set high. In this case there is no unknown  $C_x$  in the timing network of the timer  $IC_{14}$ ; it is in the timing network of  $IC_{12B}$ . So diode  $D_2$  is switched off.

Pulses of the monostable timer  $IC_{12B}$  are transmitted to diode  $D_3$  through the gates  $IC_{8B}$  and  $IC_{15D}$  and then to the RC filter. Together with  $D_1$ ,  $IC_{15A}$  forms the parasitic dc voltage compensation, which is applied to the low-level input pin of the integrated analogue-to-digital converter  $IC_{19}$ . This device measures the voltage  $V_{in}$ , which is  $V_{in\ hi} - V_{in\ lo}$ .

Direct-current component subtracted from the useful signal is set by potentiometer  $R_8$ . The dc compensating circuit around  $IC_{15A}$  is designed so that it looks similar to the measuring circuit,  $IC_{15C}$  and  $IC_{15D}$ , so giving the best performance in dc compensation and temperature compensation. If the pcb is placed in

a metal case, it will be useful to arrange some heating of the diodes by a 100Ω resistance, connected to the supply voltage. In this way the influence of the case, which acts as a heatsink to the diodes, can be limited.

Resistors  $R_{10,11}$  in the timing circuits of the timers 555 determine performance of the circuit and must be well matched. Capacitors  $C_{6,7}$  must be adjusted so that no pulse occurs at the output of  $IC_{15B}$  when no external capacitance is connected.

Values of 5.6pF or smaller are favourable and the adjustment can be completed by using a piece of wire or small copper plate, with a capacitance the same as the tolerance of the small value capacitors  $C_6$  and  $C_7$ . The monostable multivibrator, comprising  $IC_{12A}$ , triggers the measuring multivibrators. It produces a short negative pulse with the duration,

$$T(\text{trigger})[\text{ns}] = 0.45 R_7[\text{k}\Omega] C_5[\text{pF}] = 75\text{ns},$$

greater than the minimum pulse width,

required to trigger the other monostable multivibrators. Triggering of  $IC_{12A}$  is caused by the active high-going edge input B, connected to the module-port clock measurement signal.

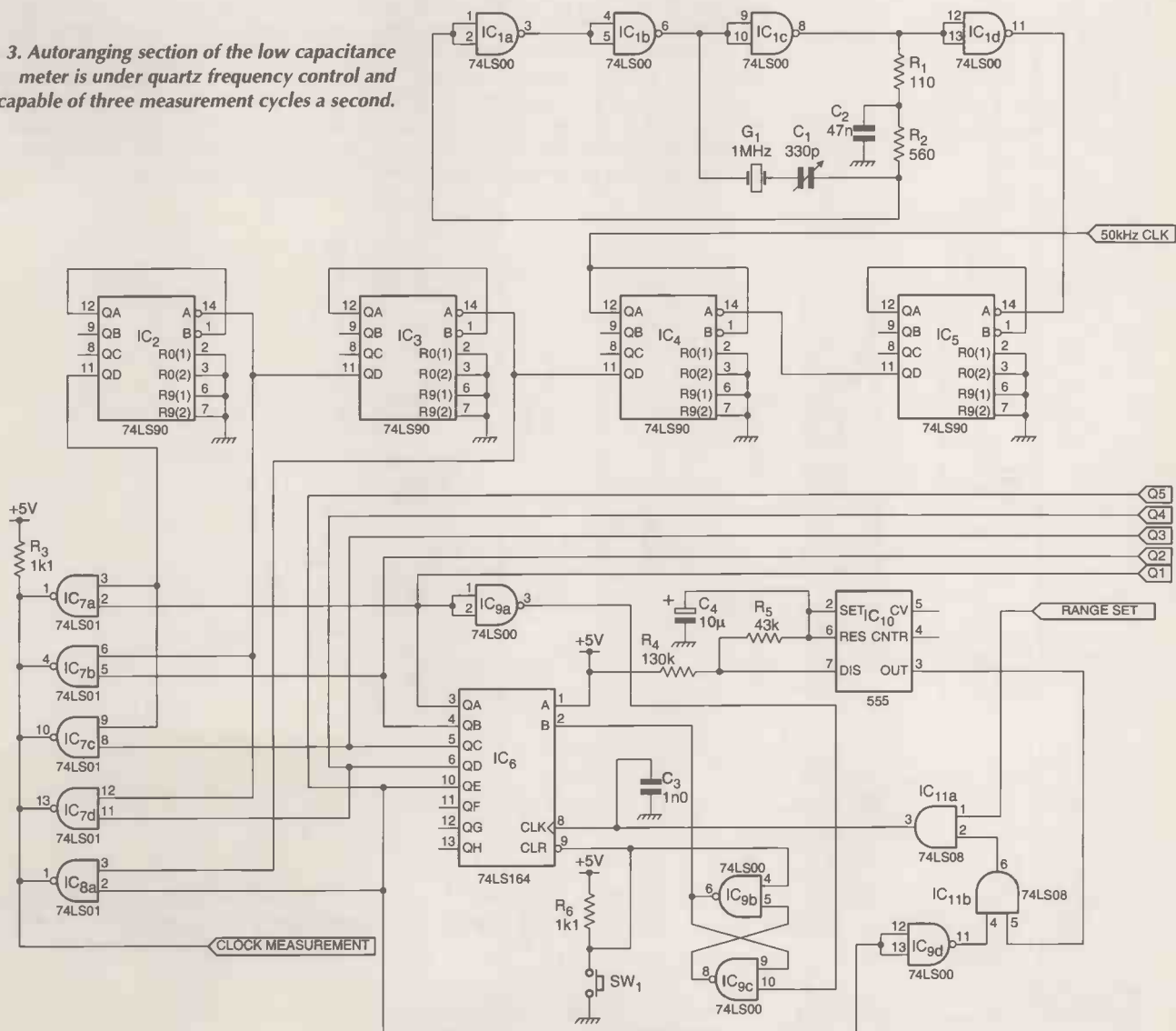
**Autoranging capability**

The clock measurement signal is produced by the autoranging circuit, shown in Fig. 3. The principle of autoranging is based on the use of a stable 1MHz oscillator based on  $IC_{1A-D}$ , divided by ten by counters  $IC_{2-5}$ .

For the range 0.199μF–1.999μF, at the beginning of the measurement cycle, a frequency of 100Hz is applied to the pulse former  $IC_{12A}$  in Fig. 3. From there it feeds the first measuring module  $IC_{12B}$ .

Information for the seven-segment code outputs of the a-to-d converter  $ICL7107$ ,  $IC_{19}$  of Fig. 4, is analysed. If the digital code of the input voltage of  $IC_{19}$  is identified as smaller than 0200, this means the measurement can be completed in the lower range. So the next greater frequency of 1kHz, i.e. a range of

Fig. 3. Autoranging section of the low capacitance meter is under quartz frequency control and capable of three measurement cycles a second.



19.99nF to 199.9nF, is applied to the measuring unit, IC<sub>12B</sub>. This means that the dc component applied to the converter is given by,

$$I_{C_{in}} = 0.45 C_x [pF] (R_{14} + R_{15}) [k\Omega] / T_o [ns] (I_{C_{zener}} - I_{C_{dc\_compens.}})$$

for IC<sub>12B</sub> is multiplied by ten because of the division of T<sub>o</sub> by ten. Here, I<sub>C<sub>zener</sub></sub> is 3.3V. If the digital seven-segment code of the input voltage is lower than 0200 again, a frequency of 100Hz, representing a range of 1.999nF to 19.99nF, is applied to the second measuring unit, IC<sub>13</sub> and IC<sub>14</sub>. Capacitor C<sub>x</sub> has to be

placed in the timing circuit of the small ranges measuring unit IC<sub>13</sub> and IC<sub>14</sub>. The dc component in this case is given by,

$$I_{C_{in}} = 1.1 R_{11} C_x / T_o (I_{C_{zener}} - I_{C_{dc\_compens.}})$$

After analysis of the digital code, the decision is made whether or not to apply the next frequency of 1kHz, giving a range of 0.199nF to 1.999nF. After that, the 10kHz frequency, is applied for the 0.1pF to 199.9pF range.

The range changes take place at a frequency determined by the astable timer IC<sub>10</sub>. Its values are R<sub>5</sub>=43kΩ, R<sub>4</sub>=130kΩ and C<sub>4</sub>=10μF.

This means frequency change is

$$1.49 / (R_4 + 2R_5) C_4, \text{ or } 0.68\text{Hz.}$$

A greater frequency than 3Hz is not recommended, because the converter, IC<sub>19</sub>, measures the input voltage three times per second. This frequency f<sub>(change)</sub> is the clock for the shift register IC<sub>6</sub>, based on ic 74LS164, which must be reset at the beginning of every measuring cycle using push-button SW<sub>1</sub>.

Outputs of the register Q<sub>A-E</sub> go high one by one, transmitting the different frequencies through open-collector gates IC<sub>7A</sub>-IC<sub>8A</sub> to the

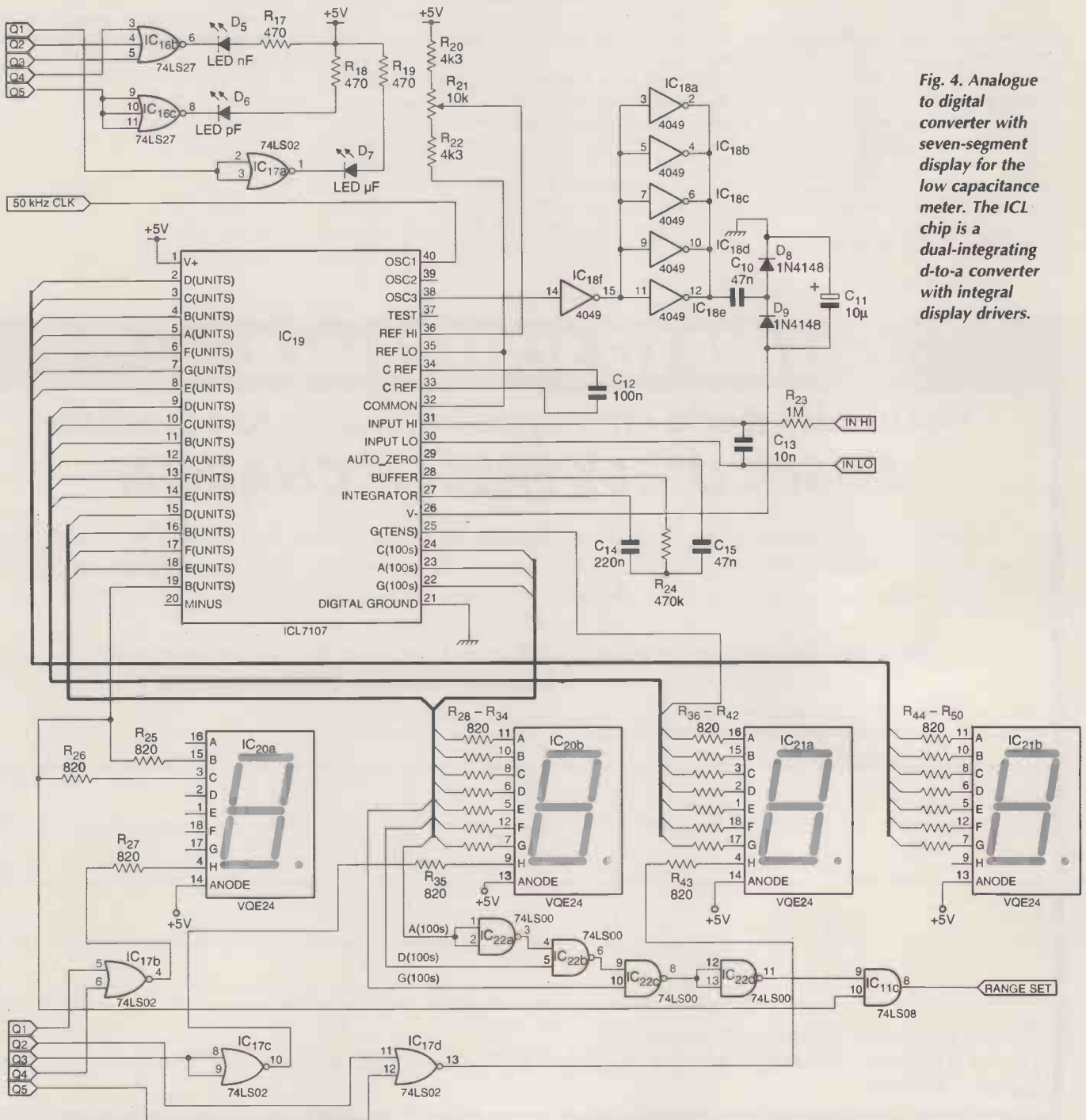


Fig. 4. Analogue to digital converter with seven-segment display for the low capacitance meter. The ICL chip is a dual-integrating d-to-a converter with integral display drivers.

clock-measurement-module port.

The same outputs, named module ports Q<sub>1-5</sub>, have other functions too, such as determining which measuring unit is chosen, and changing the place of the decimal point. Reaching the optimal range forces the range-set module port low and so the clock to IC<sub>6</sub> is stopped due to the IC<sub>11A</sub> gate.

Gate IC<sub>11B</sub> has the same function as IC<sub>11A</sub>. It stops the clock if the minimal range 0.1pF to 199.9pF is reached, since Q<sub>E</sub> is high. As a result, the output of IC<sub>9D</sub> is set low. Gate IC<sub>9A</sub> and the RS trigger, comprising IC<sub>9B</sub> and IC<sub>9C</sub>, are used to load the shift-register 74LS164 through the serial data entry B with logic one. This occurs during the first autoranging clock cycle of IC<sub>10</sub> only.

**A-to-d-conversion and control**

The converter and some of the control circuits are shown in Fig. 4. DC component of the pulses, generated by the monostable multivibrators, is transferred to the converter IC<sub>19</sub> via the input module ports IN-HI and IN-LO. The internal oscillator of ICL 7107 is not used. Rather, a 50kHz clock with quartz stability is applied to pin 40 of the ic, improving the measurement accuracy.

As Fig. 2 shows, the 50kHz clock signal

passes via dividers in the range setting circuitry. This results in a repetition rate of three measurement cycle a second. The same clock, internally buffered and appearing on pin 38 of IC<sub>19</sub>, produces the negative voltage of about -3V, necessary for the correct operation of the converter. The circuit producing this negative voltage consists of a 4049 buffer, with IC<sub>18</sub>, capacitors C<sub>10,11</sub> and the diodes D<sub>8,9</sub>, performing the work of a charge pump.

Capacitor C<sub>15</sub> is the auto-zero capacitor. It provides compensation for the offset voltages of the input amplifier, the integrator and the comparator of IC<sub>19</sub>. The ICL7107 is an integrating a-to-d converter, with C<sub>14</sub> acting as the integrating capacitor and R<sub>24</sub> is the integrating resistance. Reference capacitor C<sub>12</sub> is used for the deintegration or integration of the reference voltage toward 0V in the last phase of the measuring cycle of the converter. This technique is known as the dual integration principle.

Reference voltage of IC<sub>19</sub> is set and adjusted via R<sub>20-22</sub>. Tuning of the low ranges 0.1pF to 199.9pF, 0.199nF to 1.999nF and 1.999nF to 19.99nF is completed with potentiometer R<sub>21</sub>. Tuning of the high ranges 19.99nF to 199.9nF and 0.199µF to 1.999µF is accomplished via potentiometer R<sub>14</sub> in Fig. 3.

Indication of the measured voltage and so of

capacitance C<sub>x</sub>, takes place by means of the four 7-segment indicators IC<sub>20A,B</sub>, IC<sub>21A,B</sub> (VQE24). Range-setting circuitry, which decides if the digital code is greater than 0199 or not, is based on IC<sub>22</sub> and IC<sub>11C</sub>, the latter connected to module port called range set.

The position of the decimal point for the different ranges is selected by IC<sub>17B-D</sub>. Indication of the measuring units picofarads, nanofarads or microfarads, is achieved by means of IC<sub>16B</sub>, IC<sub>16C</sub> and IC<sub>17A</sub>. These devices light the three leds, D<sub>5-7</sub>.

The whole device is supplied from a +5V single supply delivering 400mA. Although the error of the 555 timer in monostable mode is typically 0.5%, in this case, accuracy can be compensated to 0.1%. The differential measurement technique helps improve accuracy and components can be tweaked to obtain best performance. ■

**FREE TO SUBSCRIBERS**

**Electronics World offers you the chance to advertise ABSOLUTELY FREE OF CHARGE!**

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words (remember to include your telephone number as one word). You must include your latest mailing label with your form, as this **free** offer applies to private subscribers only. Your ad will be placed in the first available issue.

This offer applies to private sales of electrical and electronic equipment only. Trade advertisers should call **Malcolm Wells on 0181-652 3620**

All adverts will be placed as soon as possible. However, we are unable to guarantee insertion dates. We regret that we are unable to enter into correspondence with readers using this service, we also reserve the right to reject adverts which do not fulfil the terms of this offer.


Please send your completed forms to:  
 Free Classified Offer: Electronics World, L329, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

Surplus always wanted for cash!

# THE ORIGINAL SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

## LOW COST PC's -

### SPECIAL BUY 'AT 286'

40Mb HD + 3Mb Ram



LIMITED QUANTITY only of these 12Mhz HI GRADE 286 systems Made in the USA to an industrial specification, the system was designed for total reliability. The compact case houses the motherboard, PSU and EGA video card with single 5 1/4" 1.2 Mb floppy disk drive & integral 40Mb hard disk drive to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with enhanced keyboard, 640K + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee. **Ready to Run!** Order as HIGRADE 286 **ONLY £129.00 (E)**

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3 1/2" floppy disk drive (instead of 1.2 Mb)	£19.95
Wordperfect 6.0 for Dos - when 3 1/2" FDD option ordered	£22.50
NE2000 Ethernet (thick, thin or twisted) network card	£29.00

## LOW COST 486DX-33 SYSTEM

Limited quantity of this 2nd user, superb small size desktop unit. Fully featured with standard slmm connectors 30 & 72 pin. Supplied with keyboard, 4 Mb of RAM, SVGA monitor output, 256k cache and integral 120 Mb IDE drive with single 1.44 Mb 3.5" floppy disk drive. Fully tested and guaranteed. Fully expandable. Only **£399.00 (E)** Many other options available - call for details.

## FLOPPY DISK DRIVES 3 1/2" - 8"

5 1/4" or 3 1/2" from only £18.95!

Massive purchases of standard 5 1/4" and 3 1/2" drives enables us to present prime product at industry beating low prices! All units (unless stated) are BRAND NEW or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. All are IBM-PC compatible (if 3 1/2" supported on your PC).

3 1/2" Panasonic JU363/4 720K or equivalent RFE	£24.95(B)
3 1/2" Mitsubishi MF355C-L 1.4 Meg. Laptops only	£25.95(B)
3 1/2" Mitsubishi MF355C-D 1.4 Meg. Non laptop	£18.95(B)
5 1/4" Teac FD-55GFR 1.2 Meg. (for IBM PCs) RFE	£18.95(B)
5 1/4" Teac FD-55F-03-U 720K 4080 (for BBC's etc) RFE	£29.95(B)
5 1/4" BRAND NEW Mitsubishi MF501B 360K	£22.95(B)
Table top case with integral PSU for HM 5 1/4" Floppy or HD	£29.95(B)
8" Shugart 801/801 8" SS refurbished & tested	£195.00(E)
8" Shugart 810 8" SS HH Brand New	£195.00(E)
8" Shugart 851 8" double sided refurbished & tested	£250.00(E)
Mitsubishi M2894-63 8" double sided NEW	£275.00(E)
Mitsubishi M2896-63-02U 8" DS slimline NEW	£285.00(E)
Dual 8" cased drives with integral power supply 2 Mb	£499.00(E)

## HARD DISK DRIVES

End of line purchase scoop! Brand new NEC D2246 8" 85 Mbyte drive with Industry standard SMD Interface, replaces Fujitsu equivalent model. Full manual. Only £299.00 or 2 for £525.00 (E)

3 1/2" FUJI FK-309-26 20mb MFM I/F RFE	£59.95(C)
3 1/2" CONNER CP3024 20 mb IDE I/F (or equiv.) RFE	£59.95(C)
3 1/2" CONNER CP3044 40mb IDE I/F (or equiv.) RFE	£69.00(C)
3 1/2" RODIME R030575 45mb SCSI I/F (Mac & Acorn)	£69.00(C)
3 1/2" WESTERN DIGITAL 850mb IDE I/F Brand New	£185.00(C)
5 1/4" MINISCRIPT 3425 20mb MFM I/F (or equiv.) RFE	£49.95(C)
5 1/4" SEAGATE ST-238R 30 mb RLL I/F Refurb	£69.95(C)
5 1/4" CDC 94205-51 40mb HH MFM I/F RFE tested	£69.95(C)
5 1/4" HP 9754B 850 Mb SCSI RFE tested	£89.00(C)
5 1/4" HP C3010 2 Gbyte SCSI differential RFE tested	£195.00(C)
5 1/4" FUJITSU M2322C 160Mb SMD I/F RFE tested	£195.00(E)

Hard disc controllers for MFM, IDE, SCSI, RLL etc. from £16.95

## THE AMAZING TELEBOX

Converts your colour monitor into a QUALITY COLOUR TV!!



TV SOUND & VIDEO TUNER CABLE COMPATIBLE

The TELEBOX is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD etc. The composite video output will 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 tuneable 'off air' UHF colour television channels. TELEBOX MB covers virtually all television frequencies VHF and UHF including the HYPERBAND as used by most cable TV operators. A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop computer video systems. 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.

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

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

## DC POWER SUPPLIES

Virtually every type of power supply you can imagine. Over 10,000 Power Supplies Ex Stock. Call for info / list.

## IC's - TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK

6,000,000 items EX STOCK

For MAJOR SAVINGS - CALL FOR SEMICONDUCTOR HOTLIST

## VIDEO MONITOR SPECIALS

One of the highest specification monitors you will ever see - At this price - Don't miss it!

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, supplied in EXCEL-

LENT little used condition. Tilt & Swivel Base £4.75. Only £119 (E) Order as MITS-SVGA. VGA cable for IBM PC Included. External cables for other types of computers CALL

As New - Used on film set for 1 week only!! 15" 0.28 SVGA 1024 x 768 res. colour monitors. Swivel & tilt etc. Full 90 day guarantee. £145.00 (E)

Just In - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with both 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. Dimensions: W14" x H12 3/4" x 15 1/2" D. Only £95 (E)

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 bums). In attractive square black plastic case measuring W10" x H10" x 13 1/2" D. 240 V AC mains powered. Only £79.00 (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.625 kHz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13 1/2" x 12" x 11". Good used condition. Only £125 (E)

## 20" 22" and 26" AV SPECIALS

Superbly made UK manufacture. P.I.L all solid state colour monitors, complete with composite video & optional sound input. Attractive leak style case. Perfect for Schools, Shops, Disco, Clubs, etc. In EXCELLENT little used condition with full 90 day guarantee.

20"....£135 22"....£155 26"....£185 (F)

## SPECIAL INTEREST ITEMS

MTS. FA3445ETKL 14" Industrial spec SVGA monitors	£245
2KW to 400 kW - 400 Hz 3 phase power sources - ex stock	£POA
IBM 8230 Type 1, Token ring base unit driver	£950
IBM 53F5501 Token Ring ICS 20 port lobe modules	£750
IBM MAU Token ring distribution panel 8228-23-5050N	£95
AIM 501 Low distortion Oscillator 9Hz to 330KHz, IEEE	£550
Trend DSA 274 Data Analyser with G703(2M) 64 i/o	£POA
Marconi 6310 Programmable 2 to 22 GHz sweep generator	£6500
HP1650B Logic Analyser	£3750
HP3781A Pattern generator & HP3782A Error Detector	£POA
HP APOLLO RX700 system units	£950
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts	£1800
HP3081A Industrial workstation ch Barcode swipe reader	£175
HP6264 Rack mount variable 0-20V @ 20A metered PSU	£675
HP54121A DC to 22 GHz low channel test set	£POA
HP7580A A1 8 pen HPGL high speed drum plotter	£1850
EG+G Brookdale 95035C Precision lock in amp	£650
View Eng. Mod 1200 computerised inspection system	£POA
Ling Dynamics 2kW programmable vibration test system	£POA
Computer controlled 1056 x 560 mm X Y table & controller	£1425
Kelthley 590 CV capacitor / voltage analyser	£POA
Racal ICR40 dual 40 channel video recorder system	£3750
Fiskers 45KVA 3 ph On Line UPS - New batts Dec.1995	£9500
ICI R5030UV34 Cleanline ultrasonic cleaning system	£POA
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£1200
Zeta 3220-05 A0 4 pen HPGL fast drum plotters	£1150
Nikon HFX-11 (Ephiphot) exposure control unit	£1450
Motorola VME Bus Boards & Components List. SAE / CALL	£POA
Trilo 0-18 vdc linear, metered 30 amp bench PSU. New	£550
Fujitsu M3041R 600 LPM band printer	£1950
Fujitsu M3041R 600 LPM printer with network interface	£1250
Perkin Elmer 2998 Infrared spectrophotometer	£POA
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3750
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager)	£950
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
TAYLOR HOBSON/Tallysurf amplifier / recorder	£750
System Video 1152 PAL wavform monitor	£485
Test Lab - 2 mtr square quietest acoustic test cabinets	£300
Kenwood 9601 PAL Vectorscope - NEW	£650

Please call for further details on the above items

## 19" RACK CABINETS

Superb quality 6 foot 40U Virtually New, Ultra Smart Less than Half Price!

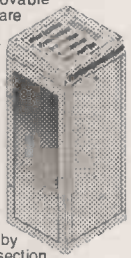


Top quality 19" rack cabinets made in UK by Optima Enclosures Ltd. Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 pin socket switched mains distribution strip make these racks some of the most versatile we have ever sold. Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays. Overall dimensions are: 77 1/2" H x 32 1/2" D x 22" W. Order as:

OPT Rack 1 Complete with removable side panels.	£335.00 (G)
OPT Rack 2 Rack, Less side panels	£225.00 (G)

## 32U - High Quality - All steel RakCab

Made by Eurocraft Enclosures Ltd to the highest possible spec, rack features all steel construction with removable side, front and back doors. Front and back doors are hinged for easy access and all are 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 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 louvers. 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. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23 3/4" W) Sold at LESS than a third of makers price !!



## A superb buy at only £195.00 (G)

Over 1000 racks - 19" 22" & 24" wide 3 to 44 U high. Available from stock !! Call with your requirements.

## TOUCH SCREEN SYSTEM

The ultimate in 'Touch Screen Technology' made by the experts - MicroTouch - but sold at a price below cost !! System consists of a flat translucent glass laminated panel measuring 29.5 x 23.5 cm connected to an electronic controller PCB. The controller produces a standard serial RS232 or TTL output which continuously gives simple serial data containing positional X & Y co-ordinates as to where a finger is touching the panel - as the finger moves, the data instantly changes. The X & Y information is given at an incredible matrix resolution of 1024 x 1024 positions over the entire screen size !! A host of available translation software enables direct connection to a PC for a myriad of applications including: control panels, pointing devices, POS systems, controllers for the disabled or computer un-trained etc. Imagine using your finger with 'Windows', instead of a mouse !! (a driver is indeed available !!) The applications for this amazing product are only limited by your imagination!! Complete system including Controller, Power Supply and Data supplied at an incredible price of only: £145.00 (B) Full MICROTOUCH software support pack and manuals for IBM compatible PC's £29.95 RFE - Tested

## LOW COST RAM & CPU'S

INTEL 'ABOVE' Memory Expansion Board. Full length PC-XT and PC-AT compatible card with 2 Mbytes of memory on board. Card is fully selectable for Expanded or Extended (286 processor and above) memory. Full data and driver disks supplied. RFE. Fully tested and guaranteed. Windows compatible. £59.95(A1) Half length 8 bit memory upgrade cards for PC AT XT expands memory either 256k or 512k in 64k steps. May also be used to fill in RAM above 640k DOS limit. Complete with data. Order as: XT RAM UG. 256K. £34.95 or 512K £39.95 (A1)

## FANS & BLOWERS

EPSON DO412 40x40x20 mm 12v DC	£7.95 10 / £65
PAPST TYPE 612 60x60x25 mm 12v DC	£8.95 10 / £75
MITSUBISHI MMF-D6D12DL 60x60x25 mm 12v DC	£4.95 10 / £42
MITSUBISHI MMF-08C12DM 80x80x25 mm 12v DC	£5.25 10 / £49
MITSUBISHI MMF-09B12DH 92x92x25 mm 12v DC	£5.95 10 / £53
PANCAKE 12-3.5 92x92x18 mm 12v DC	£7.95 10 / £69
EX-EQUIP AC fans. ALL TESTED 120 x 120 x 38 mm specify 110 or 240 v £6.95. 80 x 80 x 38 mm - specify 110 or 240 v £5.95	
IMHOF B26 1900 rack mnt 3U x 19" Blower 110/240v NEW	£79.95

Shipping on all fans (A). Blowers (B). 50,000 Fans Ex Stock CALL

Issue 13 of Display News now available - send large SAE - PACKED with bargains!

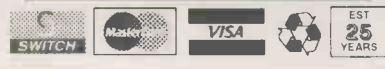
# DISPLAY ELECTRONICS

ALL MAIL & OFFICES  
Open Mon-Fri 9.00-5.30  
Dept WW. 32 Biggin Way  
Upper Norwood  
LONDON SE19 3XF

LONDON SHOP  
Open Mon - Sat 9:00 - 5:30  
215 Whitehorse Lane  
South Norwood  
On 68A Bus Route  
N. Thornton Heath &  
Selhurst Park SR Rail Stations

DISTEL ©  
The Original  
FREE On line Database  
Info on 20,000+ stock items!  
RETURNING SOON!

ALL ENQUIRIES  
0181 679 4414  
FAX 0181 679 1927



All prices for UK Mainland UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona Fide account orders accepted from Government, Schools, Universities and Local Authorities - minimum account order £50. Cheques over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£4.00, (B)=£5.50, (C)=£8.50, (D)=£12.00, (E)=£15.00, (F)=£18.00, (G)=CALL. Allow approx 6 days for shipping - faster CALL. Scotland surcharge CALL. All goods supplied to our Standard Conditions of Sale and unless stated guaranteed for 90 days. All guarantees on a return to base basis. All rights reserved to change prices / specifications without prior notice. Orders subject to stock. Discounts for volume. TOP CASH prices paid for surplus goods. All trademarks etc acknowledged © Display Electronics 1996. E & OE 06/6

CIRCLE NO. 113 ON REPLY CARD

Ian Hickman explains various graphical methods of displaying circuit operation – including vector diagrams, Bode plots and poles and zeros.

# In the Picture

For those of us not too mathematically gifted, graphical representations provide more insight than equations into how a circuit or device functions.

Some designers prefer vector diagrams, others Bode plots, and yet others circle diagrams or perhaps pole-zero plots. This article is intended to pull them all together, showing how they relate to each other, and illustrating how the same thing can be expressed in different ways.

If you are used to using just one of these mental props, please be assured that becoming familiar with all of them is definitely worth the effort. Each illuminates the others in ways that are not immediately obvious.

In this article, I shall be concentrating on the frequency response of circuits, that is, their response to a continuously applied sinewave of whatever frequency.

### Some simple circuits

Figure 2a shows a simple resistive voltage divider. Output voltage  $v_o$  is given by  $v_o/v_i=R_2/(R_1+R_2)$ . Since  $I=V/R$ , this is the case whether the input  $v_i$  is dc or ac of any frequency. Figure 2b shows the case where  $R_2$  is replaced by a capacitor, of value  $C\mu\text{F}$ . The same formula for  $v_o$  holds, except that the value of  $R_2$ , in ohms, must be replaced by the 'reactance' of  $C$ , which is also measured in ohms. There is a minor complication, though, in that the value of the reactance of  $C$  depends upon what frequency you are considering. At 0Hz (dc) it is infinite, so that  $v_o=v_i$ , while at infinite frequency it is zero, so  $v_o$  is zero. At any frequency  $f\text{Hz}$ , the reactance  $X_c$  of the capacitor is given by  $X_c=1/(2\pi fC)=1/(\omega C)$  in ohms.

### The maths approach

Rather more of a complication is the fact that, unlike the case of a resistor, in an ac circuit the voltage drop across a capacitor is not in phase with the current through it.

Voltage across a capacitor is proportional to the integral of current. This means, if one is talking of sinewaves, that the voltage lags the current by  $90^\circ$ . This is indicated by the  $-90^\circ$

angle between  $i$  and  $v_o$  in Figure 3, but as shown earlier, a  $-90^\circ$  displacement of a vector is effected by multiplying by  $-j$ . So the reactance of capacitor  $C$  becomes  $-j/(\omega C)$ , which is  $1/(j\omega C)$ , since  $-j$  is  $1/j$ .

By tacking the operator  $j$  onto the expression for the reactance of a capacitor in this way, one keeps tabs on the phase angle between the voltage and current automatically – the maths looks after it for you. Taking this on board,

$$\text{Eqn 1: } v_o/v_i = \frac{1/(j\omega C)}{R+1/(j\omega C)} = \frac{1}{1+j\omega CR}$$

### The vector diagram approach

Figure 3 shows vector diagrams for the simple  $CR$  low-pass ('top cut') circuit of Fig. 2b. Since this is a series circuit, it is simpler to start with the current, as this is common to both components.

So draw in a unit current vector  $i$ , pointing to the right from the reference or ground point, here labelled  $C$  for common. This current flows through a reactance  $1/(j\omega C)$  or  $-j/(\omega C)$ , the  $-j$  indicating a  $-90^\circ$  displacement of the resultant voltage  $v_o=iX_c$ , which is marked in as  $CA$ . Added to this is the volt drop  $iR$  across the resistor, which is in phase with the current. This brings one to point  $B$ , the input;  $v_i$  being indicated by the vector  $CB$ . The vector diagram has been drawn for the case where  $X_c=R$ , and since  $X_c$  is  $1/(\omega C)$ , in this particular instance,  $\omega=1/(CR)$ ; let this value be  $\omega_0$ . This value expressed in hertz is given by  $1/(2\pi CR)$ ; let this be  $f_0$ .

Thus in the right-angled triangle  $CAB$ ,  $CA=AB$  so that if  $v_o=1$  then  $v_i=1.414$ , or  $\sqrt{2}$ , indicating that the output is 0.707 of the input or 3dB down. Output  $v_o$  lags the current drawn from the source by exactly  $90^\circ$  but as the circuit as a whole is not purely capacitive, but partly resistive,  $v_i$  lags  $i$  by less than  $90^\circ$ .

If the radian frequency were doubled to  $2/CR$ , then assuming  $i$  were unchanged – which would not in fact be the case –  $v_o$  would become  $CA' = CA/2$  as shown, and  $v_i$  would lag  $i$  by a smaller angle, since now resistance dominates the circuit's input impedance.

Conversely, at lower and lower frequencies,

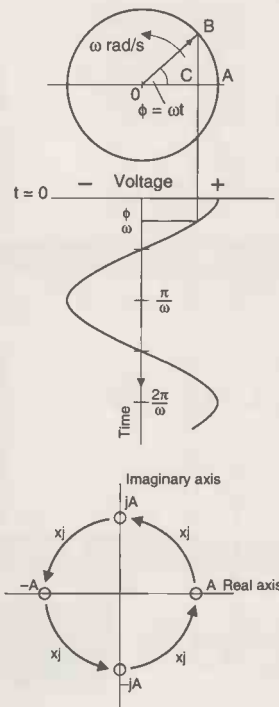


Fig. 1a) Showing how a rotating vector can represent a sinusoidal wave. b) Showing the effect of the operator 'j'.

$\phi$  would get smaller and smaller as  $v_i$  became ever closer to equality (in magnitude and phase) to  $v_o$ .

### The Bode diagram alternative

Vector diagrams show circuit response at one particular frequency. You can superimpose the response at another frequency, as in Fig. 3, but the diagram cannot show the response at all frequencies.

The Bode diagram accommodates this, by separating out the amplitude and phase components of the response.

Amplitude and phase of  $v_o$ , the output for an input of unity, is expressed as  $M\angle\phi$ ,  $M$  (for 'modulus' or magnitude, written  $|v_o|$ ) being the amplitude and  $\phi$  (for 'argument', written arg



## Back to basics

A sinewave is the most basic waveform there is, containing energy at one frequency only. This contrasts with other regular waveforms – such as square or triangular waves. These also contain energy at harmonics of their basic frequency. Noise-like waveforms can contain energy at all sorts of unrelated frequencies.

A sinewave can be represented by a rotating 'vector'. A vector is a value having both a magnitude and direction, such as the force of the wind. In contrast, a 'scalar' quantity, such as the exchange rate of the pound to the dollar, has only magnitude.

Such a vector is shown at OA in Fig. 1a). Assume that it has unit length. Now imagine this vector rotating anticlockwise (by convention) about the origin O at a steady angular velocity  $\omega$  rad/s, so that after  $t$  seconds, it has turned through an angle  $\phi = \omega t$  radians. ( $\omega$  is called the radian frequency.)

At any instant, the voltage of the sinewave is represented by the projection onto the horizontal axis, so that at time  $t=0$ , it is represented by the unit length OA. At time  $t$  seconds after this, where  $t = \phi/\omega$ , the vector has rotated to OB, and the value of the voltage at this instant is represented by its projection onto the horizontal axis, OC. This has been plotted out beneath the vector diagram as a function of time, running vertically downwards.

You can see that the voltage is +1V at  $t=0$ , falls thereafter to zero, where it is changing most rapidly, increases to -1V. It then falls again and so on. Since the voltage equals +1V at  $t=0$ , this actually makes it a cosine wave, but the shape is known as 'sinusoidal' and it is generally called a sinewave, since in general the instant that you define as  $t=0$  is arbitrary.

Since we are dealing with a continuous sinewave, the graph of voltage against time will soon run off the bottom of the page, whereas the rotating vector OA can represent the waveform

indefinitely without running out of paper. Vector OA rotates through position OB and on, right round the circle, returning to the start position when  $\phi = \omega t = 360^\circ = 2\pi$  radians. Since each complete circle, or cycle, represents  $2\pi$  radians, the frequency of the sinewave  $f$  in cycles per second is  $\omega/(2\pi)$ , or  $1/(2\pi)$  times the radian frequency.

Now there is a simple modification that you can make to the diagram, which makes it even more useful. Imagine that (notwithstanding that it is rotating) the vector is somehow drawn on the paper. With the vector rotating at much more than a few tens of cycles per second, or hertz, it will appear as just a blur. But now imagine the paper to be rotating clockwise at  $\omega$  radians per second. The net result is that the vector will appear to stand still as though frozen in time. The utility of this will become apparent soon.

The other item to recap concerns 'j'. This is called an operator, since multiplying a vector by  $j$  performs a very specific operation upon the vector. It rotates it by  $+90^\circ$ , positive angles being measured, by convention, in the anticlockwise direction. This is illustrated in Fig. 1b), where the vector OA represents a cosinewave of  $A$  volts peak. Multiplying this by  $j$  takes us to the top of the diagram, giving a different vector  $jA$ .

Repeating the process,  $jA \times j$ , takes the vector through another right angle, so that it now represents a voltage which is at its negative peak,  $-A$ . Thus multiplying by  $j$  twice over has reversed the sign of the voltage. It follows that  $j \times j = j^2 = -1$ , so  $j$  is called the square root of  $-1$ . Multiplying by  $j$  a third time rotates the vector through  $+90^\circ$  again, giving  $-jA$ , and it can be seen from Fig. 1b) that this is the same as rotating the original vector  $A$  through  $-90^\circ$ , or multiplying by  $-j$ . Note also that  $-j \times j = -(j^2) = -(-1) = 1$ , so that (dividing both sides by  $j$ )  $-j = 1/j$ .

$v_o$ ) the phase. These are plotted against a logarithmic frequency scale, so that 0Hz, or zero frequency, is as far off the page to the left as infinite frequency is to the right.

Parameters  $M$  and  $\phi$  are plotted vertically, on separate graphs. For the phase plot,  $\phi$  is plotted to a linear scale, while for the amplitude plot,  $M$  is plotted logarithmically, ie in decibels.

Figure 4a) shows the Bode plot for the simple CR low-pass circuit of Fig. 2b), from which you can be seen that at  $f_o$ , where  $\omega = 1/CR$ , amplitude response  $M$  is 3dB down on the response at dc. At frequencies higher than  $f_o$ , it becomes asymptotic to a line passing through 0dB at  $f_o$ , with a slope of  $-6$ dB per octave or  $-20$ dB per decade.

Phase lag is seen to increase from zero at 0Hz to  $-90^\circ$  at very high frequencies, passing through  $45^\circ$  at  $f_o$ . In fact, on the logarithmic frequency scale shown, the phase curve is skew-symmetric about  $f_o$ .

### Modified Bode diagrams

The diagrams of Fig. 4a) have been replotted in Fig. 4b) with a linear frequency axis and, in addition, the vertical axis in the  $M$  plot is now also linear.

As frequency increases from 0Hz, the magnitude is initially flat, but soon starts to fall, being  $0.707$  ( $-3$ dB) at  $f_o$  and becoming asymptotic to zero at very high frequencies. Note that here  $T$  indicates the time of one cycle of the sinewave, ie its period so that  $1/T = f_o$ .

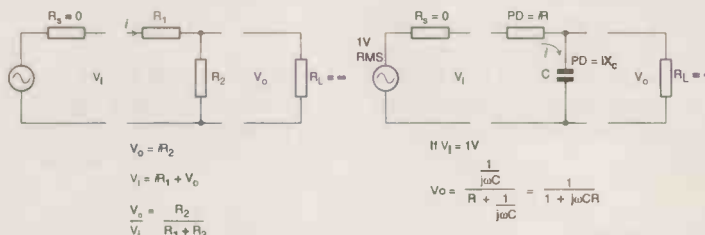


Fig. 2a) For a resistive potential divider, the output voltage is independent of frequency. b) Not so for this lowpass CR network.

On the other hand, the phase lag increases with frequency right away, levelling out all the while and reaching  $45^\circ$  at  $f_o$ , while becoming asymptotic to  $90^\circ$  at very high frequencies. Interestingly, if the initial rate of increase of phase lag were maintained,  $90^\circ$  would be reached at  $f_o \times \pi/2$ , at which frequency the phase lag is actually just one radian or  $57.3^\circ$ . I won't call these Hickman Diagrams as surely someone else has already described them, but I don't recall ever seeing them in any textbooks.

The magnitude plot,  $|v_o|$ , will reappear later on, however, in connection with pole zero diagrams.

### The circle diagram approach

Circle diagrams are widely used in the heavy electrical field, but are also very useful in light current engineering – electronics. They are an extension of vector diagrams in which it is possible to show the behaviour of a circuit at

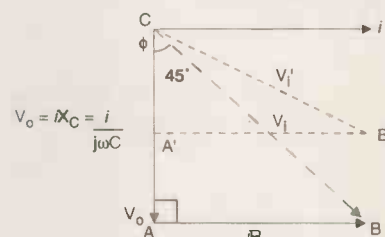


Fig. 3 Vector diagram showing the behaviour of the circuit of Figure 2b).

all frequencies, rather than just one or two.

In Fig. 2, the current was taken as the starting point, convenient in a series circuit as the same current flows through both components. Fixing the current like this is equivalent to making  $v_o - v_i$  the reference vector, since for a given current, the potential drop  $pd$  across the resistor is independent of frequency. Alternatively, either  $v_o$  or  $v_i$  could be fixed. In a circle diagram,  $v_i$  is held constant.

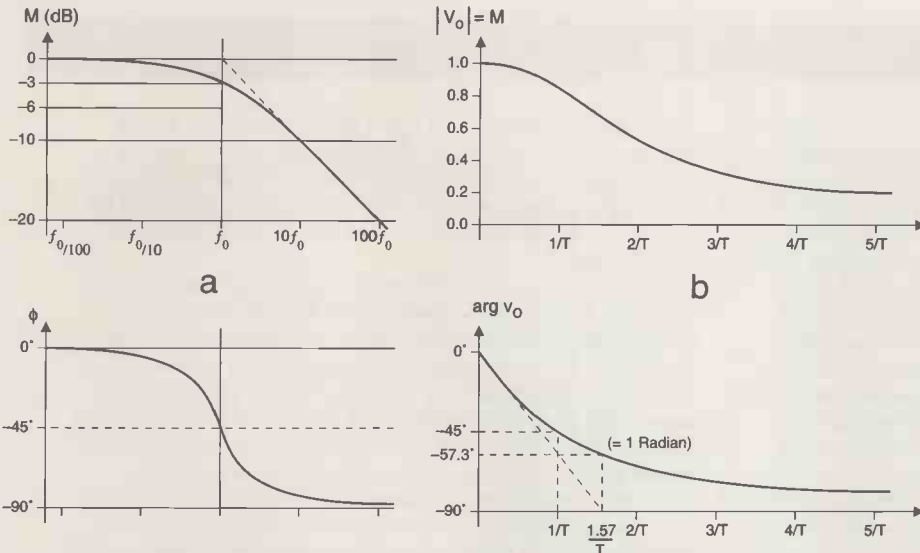


Fig. 4a) Bode diagram showing the behaviour of the circuit of Figure 2b).  
 b) Modified Bode diagram showing the behaviour of the circuit of Figure 2b).

In Fig. 3, the voltage drop across the capacitor is at right angles to (in quadrature with) that across the resistor, and this must always be so, whether you are taking the case where  $\omega=1/(CR)$  indicated by the vector CA, or  $\omega=2/(CR)=2\omega_0$ , vector CA', or any other frequency.

A right-angled triangle with its longest side formed by the diameter of a circle, will have its apex lying on the circumference. So redrawing the triangle CAB of Fig. 3 starting with  $v_i$ , the point A will lie on a semicircle as in Fig. 5a). It is shown there as  $\omega_0 (=1/CR)$ .

Output vector  $v_o$  is also shown for several other frequencies, above and below  $\omega_0$ . Thus the circle diagram plots the tip of the output vector  $v_o$ , as a function of the radian frequency  $\omega=2\pi f$ , around the circumference of the semicircle.

A useful simplification is to 'normalise' all the quantities. In Fig. 5b), the radian frequencies marked around the circumference in Fig. 5a) have all been divided by  $\omega_0$ , showing the frequencies relative to  $\omega_0$ . Normalisation can usefully be taken to the limit, with  $v_i$  fixed at 1V peak,  $R$  set to 1 $\Omega$  and  $C$  to 1F. This makes the sums very easy, with  $v_o$  in Fig. 2b) equal to 1V at 0Hz and  $i$  is 1A at  $\infty$ Hz, or infinite frequency. Equating  $\omega_0=1/CR$  then gives just 1rad/s, or 0.159Hz.

You can always denormalise to the frequency actually to be used, and adjust  $C$  or  $R$  as required, later on.

Using poles and zeros

In the vector diagram of Fig. 3,  $v_i-v_o$  of Fig. 2 was the thing that was kept constant, whilst in the circle diagram of Fig. 5, it was  $v_i$ . There

remains just one possibility – keeping  $v_o$  constant. This forms a useful introduction to pole zero diagrams.

Figure 6a) shows the vector diagram of Fig. 3 redrawn, with  $v_o$  as the horizontal reference vector. At zero hertz, the reactance of the capacitor is infinite, so the current  $i$  is zero. The volt-drop  $iR$  across the resistor is therefore zero, the angle  $\phi$  is 0°, and  $v_i$  is  $v_o$ .

As frequency rises, the reactance of  $C$  falls,  $i$  rises and so does the voltage drop  $iR$ . Thus  $\phi$  increases and so does  $v_i$ , the point B migrating ever upwards.  $v_o/v_i$  is the 'transfer function' of the CR low-pass circuit, the transfer function possessing both a magnitude and a phase,  $M \angle \phi$ .

Value  $v_i$  is a measure of just how much input voltage is required to produce an output voltage  $v_o$  of unity, at any given frequency. Thus  $M$  is inversely proportional to  $v_i$ , i.e. to length CB. Also,  $\phi$  is the angle by which the input leads the output, increasing to 90° at infinite frequency, by which time point B has disappeared way off the top of the page.

Figure 6b) shows a) redrawn, superimposed on a set of axes,  $\pm\sigma$  in the horizontal ('real') direction and  $\pm j\omega$  in the vertical ('imaginary') direction. These define the 'complex plane' or  $s$  plane. Any point upon it can be defined by the appropriate values of the  $x$  and  $y$  – or rather  $\sigma$  and  $j\omega$  – co-ordinates.

Together  $\sigma+j\omega$  are known as the complex frequency variable 's', and the transfer function is a function of  $s$ , written  $F(s)$ . In accordance with the policy of keeping things simple by normalising everything, assume that the point C is located at the point  $s=-1$  on the horizontal axis, i.e. at the point  $s=-1+j0$ .

From Equation 1, given  $R=1\Omega$  and  $C=1F$ , then when  $\omega=1$ ,  $v_o/v_i=1/(1+j)$ . This is shown in Fig. 6 c), for the radian frequency 1 on the  $j\omega$  axis, so  $v_o$  has magnitude  $M=1/\sqrt{2}$  and

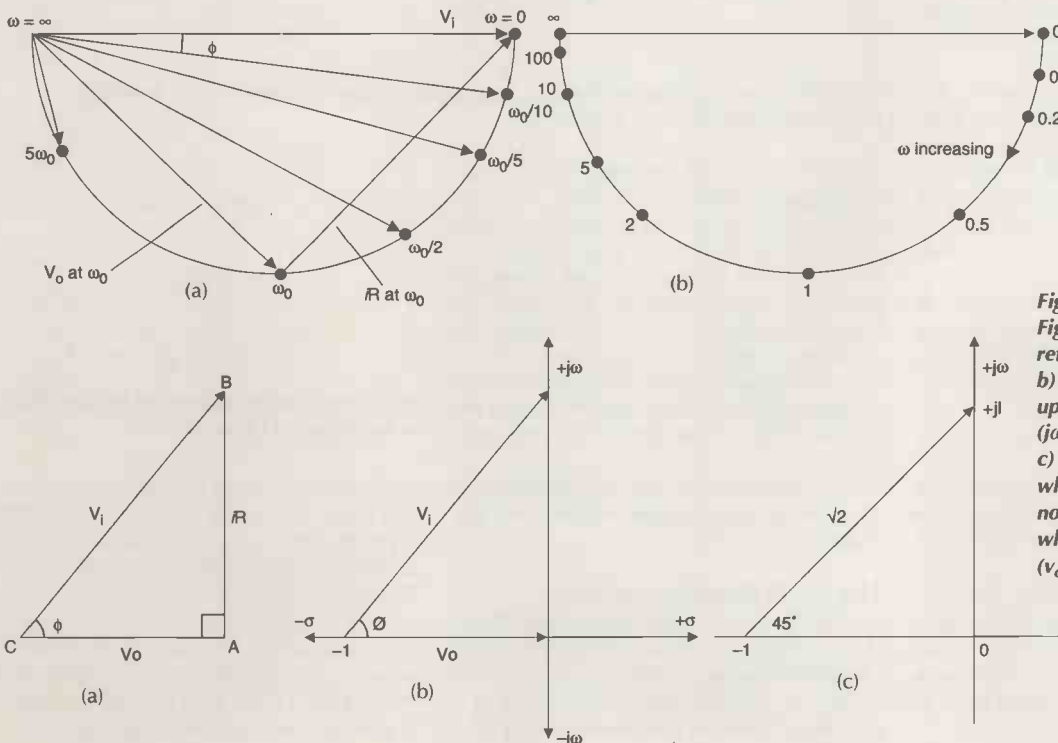


Fig. 5a) Circle diagram showing the behaviour of the circuit of Figure 2b).  
 b) As a), but with the frequencies normalised to  $\omega_0$ .

Fig. 6a) The vector diagram of Figure 3 redrawn taking  $v_o$  as the reference.  
 b) a) redrawn, superimposed upon 'real' ( $\sigma$ ) and 'imaginary' ( $j\omega$ ) axes.  
 c) b) drawn for the specific case where  $R=1/(\omega C)$ , i.e. a normalised frequency of unity, where the attenuation is 3dB ( $v_o=v_i/\sqrt{2}$ ) and the phase lags  $45^\circ$ .

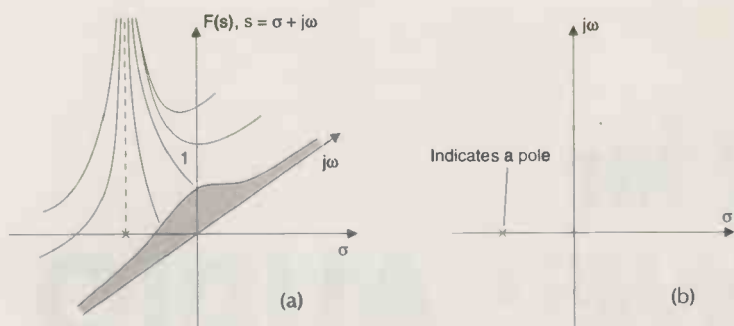


Fig. 7a) Three dimensional representation of the surface formed by the magnitude of  $F(s)$ , for negative values of  $\sigma$ , with a vertical slice along the  $j\omega$  axis. Note: the resultant curve for positive values of  $\omega$  is identical to Figure 4b). b) For simplicity, this two dimensional plan view of a) is often used. With practice, one can visualise the three dimensional surface, and the resultant section along the  $j\omega$  axis (representing the steady state frequency response) from such a two dimensional pole zero plot.

$\phi=45^\circ$ , lagging behind  $v_i$ .

To make Equation 1 into a true transfer function, one must substitute  $s$  for  $j\omega$ . Then, for the circuit of Fig. 2 b),  $F(s)$  becomes

Eqn 2:  $F(s)=1/(s+1)$ ,

assuming all values normalised, to keep things simple.

You can evaluate the magnitude  $M$  of  $F(s)$  for any value of  $s$ , and plot it as a point up in the air, above the corresponding point  $s$  in the complex plane. Taking the normalised expression  $1/(s+1)$ , when  $s=j1$  ( $\sigma=0$ ), the answer is 0.707, while when  $s=-1$  ( $j\omega=0$ ), the answer is infinity.

Plotting the magnitude of  $F(s)$  in this way for all possible values of  $s$ , gives a three dimensional surface above the  $s$  plane, which I have crudely sketched out in Fig. 7a). This shows only the part of the surface to the left of the  $j\omega$  axis (i.e. for negative values of  $\sigma$ ), with a vertical section through it, along the  $j\omega$  axis.

The surface can be imagined as an enormous rubber sheet, nailed down to the ground all the way round the edges. At  $s=-1+j0$ , the denominator of  $1/(s+1)$  becomes zero, so the expression explodes to an infinite value. This can be imagined as an infinitely high tent pole, propping up the rubber sheet at this point. There is said to be a pole at  $s=-1+j0$ .

The vertical section through the surface, along the  $+j\omega$  axis, gives the magnitude of the transfer function for sinewave inputs to the CR low-pass circuit. It is in fact identical to the plot of magnitude  $M$  in Fig. 4b).

Note that for this circuit there are no terms in  $s$  in the numerator, so there are no values of  $s$  for which the numerator could become zero. If there were any such zeros, they would be like thumb tacks, pinning the sheet to the floor at those points.

Figure 7b) shows a) in plan view, the pole being conventionally indicated as a cross. The

pure mathematicians tell us that for every pole, there must be a zero. The reason it does not appear on the diagram is that it is at infinity. Letting either  $\sigma$  or  $\omega$  go to plus or minus infinity sends  $F(s)$  to zero; a zero at infinity tacks the rubber sheet down all the way round.

While the section through the surface along the  $+j\omega$  axis gives the magnitude  $M$  of the transfer function, as noted earlier,  $\phi$  is given by the angle between the line from a point on the  $j\omega$  axis to the pole, and the  $\sigma$  axis, counting the angle as indicating  $v_o$  lagging  $v_i$  as you move anticlockwise relative to the pole.

This article has just scratched the surface of the subject. Where things really start to get interesting and illuminating is in considering vector, Bode, circle and pole-zero diagrams as applied to other circuit types, such as CR high-pass, transitional lag and all-pass circuits, not to mention circuits of second and higher order. But alas my space has run out.

# Interactive SPICE

Stop Waiting for your simulation results!  
Experience the power and Immediate Satisfaction of IsSPICE4!



ICAP/4, The Virtual Circuit Design Lab, is a completely integrated system with schematic entry, the IsSPICE4 native analog and mixed mode simulator, extensive SPICE model libraries and powerful graphics post-processing.



**Platform Support**

- Windows
- Windows 95
- Windows NT (x86, Alpha & MIPS)
- Macintosh
- Power Macintosh
- DOS, NEC



- Analyse and Simulate all types of designs with IsSPICE4, the First and Only Interactive Native Mixed Mode SPICE 3 Simulator
- System, Board, and IC level
- Analog, Digital, Sampled-Data, Mixed Mode, Behavioural elements
- Power, ASIC, RF, Mechanical, Physical, Thermal applications
- AC, DC, Transient, Distortion, Temperature, Monte Carlo, Noise, Sensitivity, Optimisation, and Fourier analyses
- Works with all popular schematic entry systems!
- Graphically Driven and Easy To Use
- Support & Service - FREE, EXPERT, UK BASED AFTER SALE SUPPORT, Web & CompuServe Forums
- Affordable, Prices from £450 to £2,300

Technology Sources Ltd  
Falmouth Avenue, NEWMARKET  
CB8 0LZ, UNITED KINGDOM  
Tel. 01638-561460  
Fax 01638-561721  
E-mail: aaj74@dial.pipex.com

Ask us for a  
**FREE Working  
SPICE  
Simulation Kit!**

**The Future Is Interactive!**

# New relay for POWER AUDIO

A new design of relay provides an ideal building block for speaker protection circuits by offering high power capability without the traditional adverse impact on tonal quality. Omron's **Barclay McKenna** discusses the relay design, and outlines a specific circuit implementation.

Perhaps it shouldn't happen – but it still does. Switch on the stereo and the first thing you hear is that habitual thump as the speakers flex in response to the inrush of current to or from the amplifier output.

Even in a thoroughly poor design, to be fair, it is not likely that the bemused music lover will be left with a pair of bass speaker coils dangling, terminally ripped from their mountings. But that still doesn't make the initial 'whumpf' a desirable system characteristic.

The sheer physical jolt of an amplifier's power circuits switching into life may not have an immediately visible effect on the life expectancy of a speaker but, on a cumulative basis, such physical shocks can lead to damaging displacement of the bass voice coil. The thermal shock of the inrush current can have an equally unwelcome effect on the integrity of the coil itself.

While it may be true that many low-frequency units owe their premature demise to excessive bass and volume settings – not to mention the owner's fondness for techno – the steady abuse of the coil and speaker cone by thumping amplifiers certainly speeds their demise.

Prevention of the damage is easily achieved by a variety of well tried means. Some involve the use of complex timing circuits in the power supply or output stages; the more successful, and more cost effective, interpose a relay or two between amplifier and speaker. The latter solution is often used, but it begs the question 'what sort of relay'?

## Choosing a suitable relay

Broadly speaking, relays come in two variations: power types and signal types. The former will

naturally handle high current surges associated with, say, industrial and some automotive applications. They are not, however, too concerned about the integrity of the signal waveform that passes through them.

If all you want is to switch power to a motor, then the odd alteration from input to output is hardly a consideration. Signal relays, on the other hand, will provide the sort of faithful transmission audio applications require. But signal relays tend to be limited in their power handling capabilities.

Omron's new *G5Z* relay however has been specially designed with power audio applications in mind, combining the desirable attributes of both power and signal relays.

## Crossbar integrity

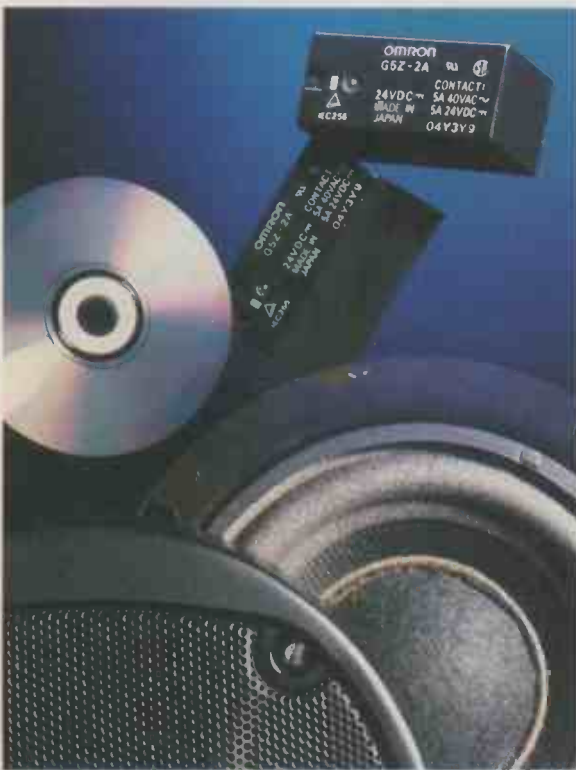
Central to the design of the *G5Z* is its use of a crossbar contact design. This crossbar is a solid conducting bar pulled across the contacts. Ordinary power relays with comparable current handling capability usually incorporate button contacts. The solid conducting bar ensures the high degree of signal integrity required for audio applications.

In the case of the standard *G5Z*, handling capability runs to 5A at 40V ac, or 200VA. Quoted at a power factor of one, a small measure of down-rating is necessary to deal with the vagaries of a musical signal, but that still amounts to enough late-night Bach organ toccata to make the neighbours suitably miffed. For really heavy use, a 750VA alternative is available.

The reworked crossbar design has allowed this capacity for music to be shrunk into a very small capacity for circuit board space. The relay occupies no more than an 11.5 × 25mm footprint, with a height of 16.5mm. Moreover, those dimensions are for a two-pole design, as required for today's compact audio applications. Contact resistance is a maximum 50mΩ to eliminate any untoward effects on the amplifier's damping factor.

## Building in relay

So how might a protection circuit built around the *G5Z* work in practice? The first thing to consider is the level of protection required. A simple RC network could form the basis of an on delay, but



dc isolation might also be important. A failure in the amplifier's output transistors for example would cause a dc flow directly into the speaker, so a circuit which provided the means to monitor this and employ the relay as a protection device is advantageous, Fig. 1.

At the same time, a short circuit on the speaker lines could damage the amplifier, and could even cause a fire. An additional circuit monitoring amplifier output current would be needed for this (not shown in the diagram).

The circuit shown addresses both the time delay on power up and the provision of dc isolation capability. Left and right outputs from the power amplifier connect to the speaker crossover networks via the G5Z relay.

Relay driving is provided by a Darlington pair transistor configuration,  $T_1$  and  $T_2$ , with diode,  $D_1$  inserted across the relay coil for back emf protection.

### On delay timing

The basis for the on delay timer is the resistor-capacitor network of  $R_1$ ,  $R_2$  and  $C_1$ . At power up, transistor  $T_2$  is off. As the capacitor charges, the potential at its positive terminal rises, eventually reaching the point where  $T_2$  switches on. Zener diode  $D_2$  increases the

degree of switching certainty and stability by ensuring minimal leakage current until its threshold voltage is reached, at which point its reverse current immediately rises. At this point,  $T_2$  is turned on, activating the relay.

The rate at which  $C_1$  charges – and hence the time delay before the zener's threshold voltage is reached and  $T_2$  switches on – is determined by the values of  $C_1$ ,  $R_1$  and  $R_2$ .

### Fault protection

As well as introducing delay in connecting the speakers to the amplifier output, the circuit shown also addresses disconnecting the speakers in the event of a problem.

Left and right outputs of the power amplifier are fed into a summing and ranging amplifier to provide a combined signal output, with a virtual earth configuration ensuring zero interaction between the two channels. Feeding this signal into a low pass active filter reveals the presence of any dc level. Cut-off frequency of this filter is typically less than 1Hz.

A zero-loss active rectifier enables detection of both  $-V_e$  and  $+V_e$  dc offsets, and the signal is then fed into a comparator circuit. Reference voltage for the comparator is set via the preset  $VR_1$  and resistor  $R_3$ . A typical trip

level of  $\pm 1V$  on the amplifier output would ensure safety of the system, and it should be borne in mind that a small offset, perhaps  $\pm 200mV$ , is normal.

In problem-free operation, there would be an off output from the voltage comparator. As a result, transistor  $T_3$  would be off, having no effect on the relay circuit. Should a dc level be sensed at the amplifier output however, the voltage comparator output would go high. This would switch  $T_3$  on, and effectively short circuiting  $R_2$  and  $C_1$ . Consequently,  $T_2$  is switched off, and the relay coil de-energised, so disconnecting the speakers from the amplifier output.

Switch  $SW_1$  could be incorporated in the circuit to provide a manual method of electrically isolating the speakers without powering down the amplifier.

Omron is so confident of the relay's capabilities that output from its factory has been boosted to nearly a million a month, with major audio manufacturers already designing-in the device as standard. ■

Further information can be obtained from Omron Electronics by ringing 0181-450 4646 or faxing 0181-450 8087.

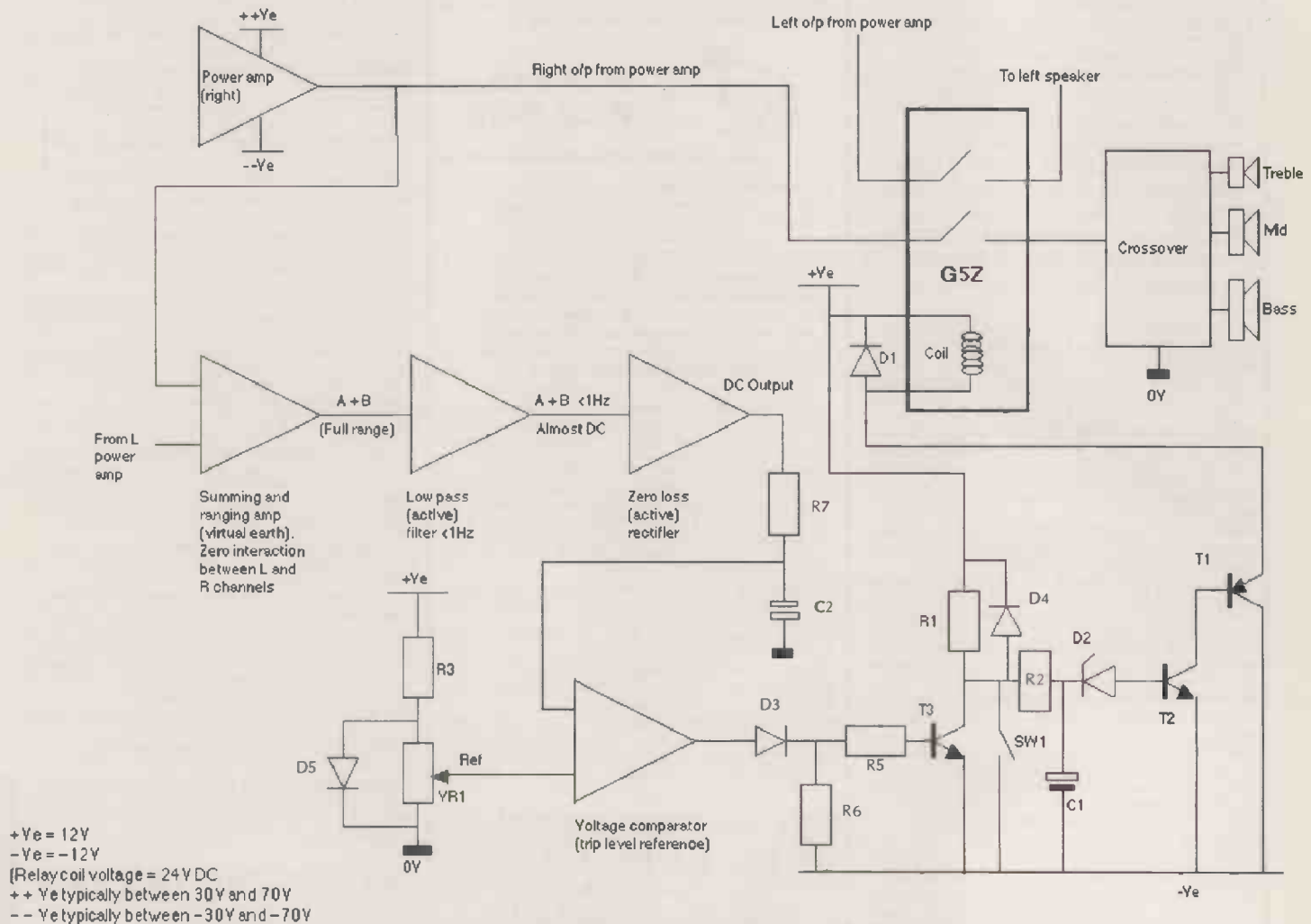


Fig. 1. Circuit for addressing time-delay-on-power-up and dc-fault-isolation problems. Heart of the circuit is the G5Z relay. It is designed specifically for audio applications, providing high power speaker protection capability without adverse impact on tonal quality.





# Virtually fast

**Paul Mapp has been looking at a new a-to-d converter module that turns your pc into a 25MHz spectrum analyser, a 50MHz dso, a multimeter or a data logger - all for around £500.**

**P**ico Technology produces several a-to-d converters that form the basis of 'virtual instrumentation'. These range from a low cost, 8-bit, single channel unit to a dual channel, 100kHz sampling, 12-bit module. The latest addition to the range, reviewed here, is a 50Msample/s, 8-bit a-to-d module, known as *ADC200*.

Windows software supplied with the *200* allows the stand-alone module to be used as a variety of instruments including an oscilloscope and spectrum analyser. Two variants, the *ADC200-20* and the *ADC200-50* provide sampling speeds of 20 and 50MHz respectively.

The unit supplied for review was a late prototype version, hand crafted, but otherwise fully functional.

## Hardware

Measuring 135 × 185 × 40mm, the *ADC200* is supplied with a single 3.5in high density disk, a 2m parallel port cable, power supply and two slim manuals. On the front panel are three BNC connectors, two for the A and B signal inputs, and one that doubles as an external trigger input or simple signal generator output.

Documentation consists of an eight page user manual plus the standard 40-page *PicoScope* for dos user manual. There appears to be no intention of supplying a manual for the Windows software, relying on the Windows help file to supply all relevant information.

The user manual is concise, clearly stating the operating conditions, specifications and connection details for the unit. Hooking up is simple; the parallel-port cable connects the converter module to a spare printer port on the pc - which must be dedicated to the *ADC200* - and the plug in power supply provides 12Vdc. As the unit has standard 1MΩ inputs, it will work with any standard oscilloscope probes.

The only slight worry on hooking up the unit was that the front panel led glowed dimly when the parallel cable was connected before the dc power was applied. But Pico says that this can safely be ignored.

Also, the power plug was prone to becoming disconnected on the review unit due to an over-thick rear panel. This has since been corrected by the manufacturer.

## Virtual instrument software

Two main programs are supplied with the *ADC200* - the familiar *PicoScope* for dos and the new, and welcome, *PicoScope* for

Windows. Drivers for C, Pascal, Basic and Windows, along with disk based documentation, are also provided for serious programmers.

Installation instructions are clear in the user manual and can be performed from the dos command line or Windows program manager. Both of these methods can install dos and Windows versions of the software.

Multi-lingual support is offered, but was not included with the review software. Installation under dos, Windows 3.1 and Windows 95 caused no problems.

Pico currently has no plans to release a printed manual for the Windows software. This can be easily overcome using one of the 'Help-to-Doc' programs available from many shareware libraries. I use *HLP2DOC* by Wolfgang Beyer, which converts Windows help files to Microsoft Word 2 format documents and is available as freeware.

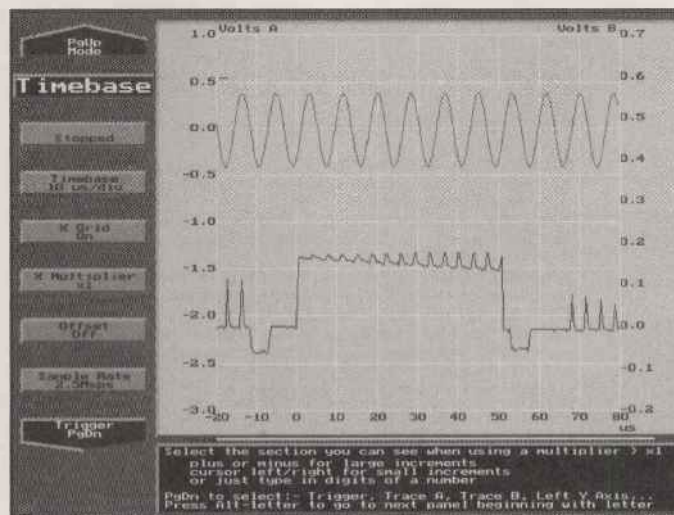
## Operating the module

The glossy information leaflet provided by Pico describes the *ADC200* as a '50Msample/s dual-channel storage oscilloscope, 25MHz spectrum analyser and multimeter' which runs via a parallel port on a standard IBM pc compatible computer. This is not strictly true but is the usual advertising format used by most manufacturers of this type of equipment.

There are actually two versions of the *ADC200* - the *ADC200-50* and the *ADC200-20*, as detailed in the panel. The former is a 50Msample/s unit which only provides a single channel at 50Msample/s, the dual channel mode operating at 25Msample/s. The *ADC200-20* that was supplied for review, providing a dual channel, 20Msample/s oscilloscope and 10MHz spectrum analyser.

The dos software has been supplied with Pico's a-to-d converter range for a while and is very easy to use. It operates well on a modest pc compatible. I have used the same software with an *ADC100* on a 25MHz 486SX lap-top computer, where it excels as a portable diagnostics and capture tool. Use with the *ADC200* appears to be identical, apart from the faster time-base, and it operates adequately on the SX25 lap-top.

The manual is clear and concise, explaining the use of the four modes of operation - meter, 'scope, XY 'scope and spectrum analyser - in detail, Fig. 1. Context sensitive help is available by default but may be hidden, providing a slightly larger display.



**Fig. 1. PicoScope for dos in oscilloscope mode. This is tried and tested software that works well even with modest pcs.**



Mouse pointing is not supported but is not really needed, plenty of keyboard shortcuts being available for access to the panel options. In most cases the space bar toggles or steps through the available values in the selected option, which is especially useful when used with the run/stop option which is available in all panels.

The top level panel, presented when the software is first run, is the mode menu, from which you can select one of the four operating modes. Below this, selected by the page-up and page-down keys, are mode specific panels. Oscilloscope mode panels offers timebase, trigger modes and channel gain options while the spectrum mode panels offers sampling, trigger type and display format options.

In meter mode up to six separate measurements can be selected and displayed on seven segment format digital displays.

### Common features simplify use

Common to all modes are panels allowing axes annotation to be set as required, notes to be added to the display, rules (markers) to be added for measurement and data to be filed or printed. In addition the converter provides a signal panel which allows a programmable logic level signal output to be provided on the external trigger connector when enabled. Frequencies in the range 1Hz to 250kHz can be set, which can be used as the external trigger if this is also selected.

The rules panel allows on-screen event markers to be placed, displaying event times and, with two rules, differential time. The display is fast and responsive, providing clear graphical data very close to that of a traditional oscilloscope or spectrum analyser. Oscilloscope mode provides inputs down to 10mV per division and timebase speeds to 1 $\mu$ s per division, axes magnification to  $\times 10$  and delayed trigger modes to examine data captured away from the trigger point.

In spectrum analyser mode, Fig. 2, sample rates to 20Msample/s are available, user selectable frequency, volts or decibel scales and a number of sampling window types. The default window is the Blackman type. Six other window types are available, as is signal averaging to reduce the effect of noise on the display.

Meter mode provides measurement of ac and dc volts, decibels relative to 1Vpk-pk and frequency. Six different measurements can be displayed simultaneously. Display updating slows dramatically when multiple meters are displayed, but this is to be expected.

A comprehensive range of printing and filing options are available. Printouts can be set for a variety of printer types and one of three formats – portrait, half portrait and landscape. Printouts are both clear and functional, the annotation options being used for titling and user text if required. Filing functions allow the saving and re-loading of both measurement settings and data in Pico's own format, or data to be exported in tabular text format for use in spreadsheets and the like.

When re-loading display data files can be quickly stepped through in sequential name order which makes searching saved data files for a particular feature very quick and simple.

Printing from the Windows software was disappointing, the only print options being the page orientation. A Lexmark ExecJet IIc printer, which worked fine with the dos software, printed the axes' labels and traces correctly but the graticule marks were printed so finely that they were almost invisible.

There were also problems using the edit menu, which simply has 'copy as text' and 'copy as graph' options. Copying as text produced the expected tabular format for importing into spreadsheets, etc. Copying as graphics produced a recognisable graphic with rather bold, overlapping text when viewed in the Windows clipboard.

Pasting into either Microsoft Word 6 or Works 3 showed very bold, overlapping text when viewed in a small window and no text at all when enlarged to half page size. When printed from either Word or

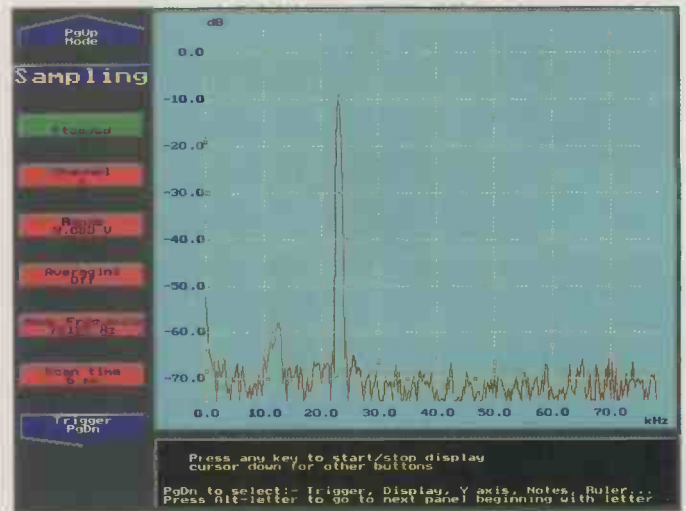


Fig. 2. PicoScope for dos operating in spectrum-analyser mode.

Works the traces and graticule printed beautifully but the text was printed in minute characters. This problem will obviously be addressed by Pico in time, some additional scaling and text font features would also add to the usability.

### Triggering options and delayed sweep

Triggering can be set to one of four modes; none allows the ADC200 to free run; auto triggers when the trigger condition is satisfied but runs at a user selectable slow rate when no trigger is present; repeat triggers only when the trigger condition is satisfied; single triggers once and stops. The remaining controls select the trigger source (signal channel A or B or external, E), trigger edge (rising or falling), trigger level and timebase delay.

Trigger level can be incremented and decremented, or manually entered if required. A marker on the appropriate channel axis indicates the set level. Timebase delay can also be incremented and decremented, or set manually. Trigger positions from -100% to +100% of the display period are available, moving the horizontal axis to suit.

One slight catch for the unwary when manually entering the delay is that the minus key is an illegal character if entered on its own. Delay must be entered and the minus added using the left cursor or home key.

One or two markers can be added to the display by simply placing the mouse cursor on the display, pressing a mouse button and dragging horizontally or vertically to produce horizontal or vertical lines.

### Blinking distraction

When using the mouse cursor over an active display, a few display cards cause the cursor to blink with the display update. Cirrus Logic

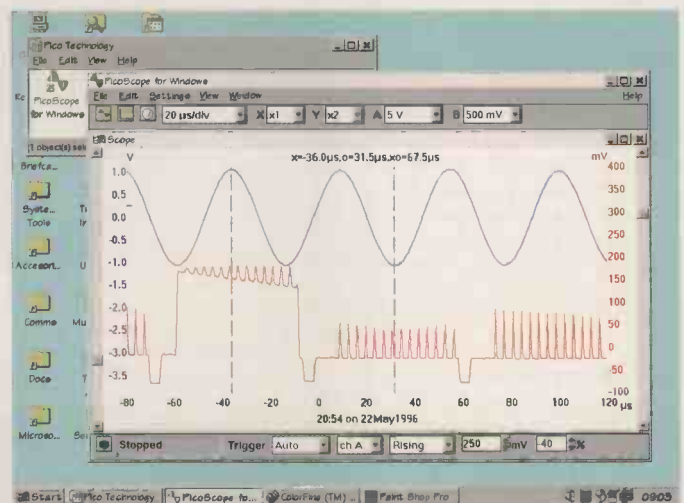


Fig. 3. PicoScope for Windows in oscilloscope mode.

### Running under Windows

The new Windows software is impressive as it manages to run real time displays at a decent speed in a scaleable window, Fig. 3. This has always been difficult to achieve due to the enormous graphics overhead of Windows, so congratulations to Pico.

I am running *PicoScope* under Windows 95 on an AMD 486DX4-100 processor with graphics acceleration disabled, which really should be considered a minimum specification for use with this software. While *PicoScope* for Windows will run quite happily under Windows 3.1 on the 486SX25 laptop mentioned earlier the performance is not really fast enough for anything other than very basic use, the dos software giving a superior performance in this type of environment.

The upper control bar has icon buttons for the three modes of operation, namely oscilloscope, spectrum analyser and meter. Clicking one of these buttons opens a new window in the mode requested, leaving any existing windows unchanged. The remainder of the upper bar has drop down menus specific to the current mode of operation, e.g. timebase, display multipliers and volts per division for scope mode.

chipsets cause this effect, which appears to be a function of the display hardware rather than *PicoScope*. Once positioned and a mouse button pressed, the actual rules themselves are perfectly stable so this does not detract from the usefulness of this facility.

Many other less frequently used options are provided on standard drop down menus at the top of the *PicoScope* window. These include all the facilities provided in the dos software plus a few new features unique to *PicoScope* for Windows, such as multiple operating windows. Many settings are also available via the function keys. There are also some interesting additions only possible in this sort of environment.

Traces can be saved after triggering, the *ADC200* automatically rearming for the next trigger. Data averaging can be performed and successive cycles overlaid. This is useful for capturing infrequent deviations from the norm. There is an option for redraw or roll (chart recorder) mode at low timebase speeds. This option was not properly functional in the software reviewed but no doubt Pico will correct it.

The preceding discussion has centred upon the oscilloscope mode, but applies equally to the spectrum and meter modes are also available in *PicoScope* for Windows. A unique feature in the Windows version is the ability to open multiple views of the same signal, Fig. 4. This ability provides the opportunity to replace multiple instruments operating simultaneously. Figure 4 shows an oscilloscope window, spectrum window, frequency meter and voltmeter all operating from the same input, each with their own independent parameters. The disadvantage of this mode of operation is slower operation.

### Overall performance

As the Pico dos software is tried and tested, the following comments concentrate on the *ADC200* with the new Windows software. Starting with dc measurements, e.g. a quick test of power supply

The full range of, for example timebase speeds, can be selected from a drop down menu by clicking on the item on the control bar and selecting the required setting from the menu. The display multiplier dialogue boxes are used to expand the horizontal and vertical displays up to  $\times 20$ .

When any expansion other than  $\times 1$  is selected scroll bars appear, Fig. 3, allowing the axes to be scrolled to show any part of the expanded axis in the display window. Under the default  $\times 1$  magnification the two traces for the *ADC200* are overlaid in different colours, the axes being coloured to suit. While fine for some measurements, many people including me prefer to separate the traces vertically. This can be achieved in *PicoScope* by expanding the vertical axis, shifting the zero point of each trace to the required location and reducing the input sensitivity to suit. Although a little clumsy and less than obvious – it took me a while to discover this – it works fine once mastered.

Display settings are easily saved as the default, once set to suit your preferences, although when the expanded axes are reloaded the scroll bars are omitted.

levels during debugging of a circuit. Applying a dc voltage to either input A or B with the switch set to dc, produces the expected level on the display. The *ADC200* has a  $\pm 20V$  input range and is protected to  $\pm 100V$ . Calibration appears to be good.

A couple of minor problems appear here. If trigger mode is set to auto, as will normally be the case, other than when only measuring dc levels, the update rate drops to the user specified repeat rate. In practice this occurs a couple of times a second even though it can be specified up to ten. This is due to the triggering scheme used in the hardware. You need to select a trigger mode of 'none' to get a rapid update. Also, a voltage level outside the display range, e.g. applying 9V on a 5V range, shows a horizontal line at the maximum level, i.e. 5V. This is unlike the dos software or a traditional oscilloscope, where the section of the trace out of range is not displayed. This could cause confusion.

Moving up the scale to audio measurements, operation appears smooth and reliable. Triggering is easy and relatively stable although there appears to be a tendency to trigger on the wrong edge every now and again, especially in dual trace mode. This has now been fixed says Pico. Comparing the traces captured in *PicoScope* with those seen on a traditional oscilloscope

shows no noticeable deviations. All the facilities provided work as expected, giving a useful and easy to use replacement for the traditional oscilloscope. In practice this applies throughout the range to several megahertz.

By the time video signals are reached, the 20MHz *ADC200* is beginning to show its limitations and the 50 would be useful. The lower trace shown in Fig. 3 is from a cheap video signal generator producing a white crosshatch pattern on a black background. Effects of aliasing, due to the digital sampling, can be clearly seen on the amplitude of the sharp vertical 'spikes' which form the fine white lines of the crosshatch pattern on the video signal. These are uniform in amplitude.

### What are virtual instruments?

'Virtual instruments' are becoming more common in the electronics industry due to the availability of fast cheap computers like the IBM pc. These instruments have front ends like traditional instruments but dispense with the bulky and expensive displays and controls in favour of a standard interface to a computer. As well as providing the control and display for several instruments in one unit the computer provides the ability to capture, manipulate and store the measurement data. This captured data can then be used in circuit simulators and other design packages to ensure CAD based designs react as expected to real, rather than simulated, data.

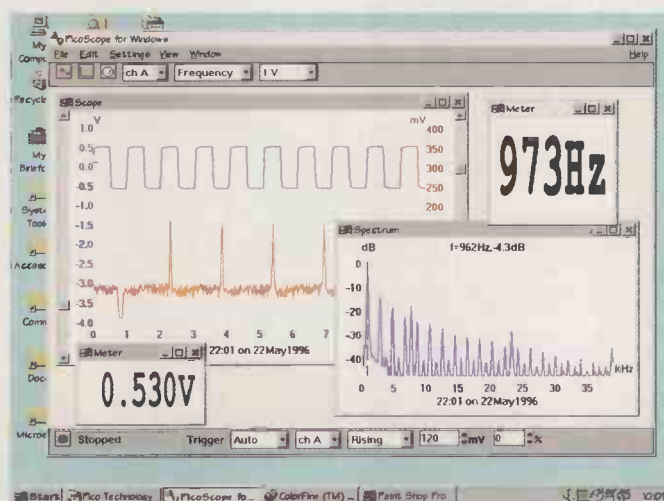


Fig. 4. A unique feature in the Windows version is the ability to open multiple views of the same signal.

Increasing the timebase to 1µs/div, Fig. 5, showed limitations of the converter in the form of switching noise and distortion due to the digital sampling. However, Pico says it is sourcing a new converter that eliminates the problem.

Shorting the input to the ADC200 reduces this noise to approximately the level of the noise seen on the upper trace in Fig. 5. For a unit of this type this performance is quite acceptable so long as the user is aware of the limitations and their effect on displayed traces.

### In summary

Overall performance of the ADC200 package is impressive, with only a handful of minor problems which do not, on the whole, reduce the usability of the unit. As long as the limitations of the hardware are understood it forms an extremely useful addition to the workbench, really coming into its own when used as a data capture tool.

The new Windows software performs well on a higher spec. pc. The 486DX4-100 used for the majority of the review should be considered a minimum specification for this type of software. PicoScope for Windows appears, on the whole, to be a competent package, providing a good range of well thought out features which are both clear and easy to use. As with many newly introduced software packages there are still a few rough edges which need to be ironed out and Pico are working hard to make sure this is done.

On the down side, the signal generator facility provided on the ADC200 did not function properly on the review unit. With both dos and Windows software it failed to produce the programmed frequency and was interrupted continuously by the a-to-d conversion process, which slowed noticeably when the signal generator was enabled.

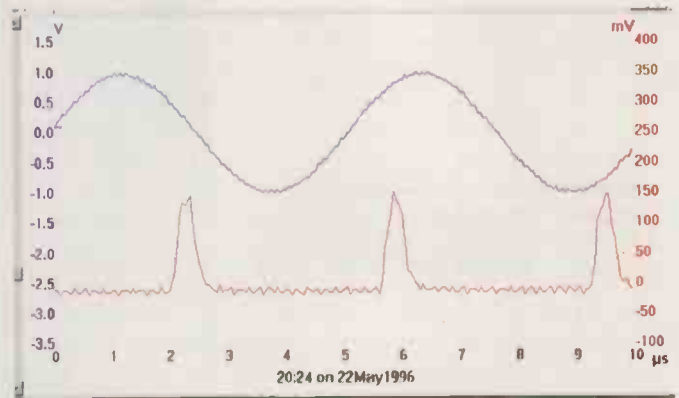


Fig. 5. Windows PicoScope – performance limits of the 20MHz a-to-d.

While performing well on its own with a single display window, PicoScope for Windows slows dramatically when multiple display windows are opened. If you have multiple applications open, with PicoScope running in one window, there is a very marked reduction in the pc's response time. The many online help screens in PicoScope also seemed to take a long time to appear when selected – several seconds on occasions.

In conclusion, the advantages of the ADC200 far outweigh the few minor problems observed by the author. No doubt Pico will address and correct these and provide us with a really useful Windows based virtual instrument. In the mean time, if the few Windows problems are just too much then the dos software works just fine. ■

# ADC200 virtual instrumentation

## 20% reader discount

Pico Technology's ADC200 is a high-speed virtual instrument designed for use with a pc. Connecting via a printer port, the ADC200 includes both Windows and DOS PicoScope software, turning your PC into a 50Msamples/s dual-channel storage oscilloscope, a spectrum analyser, a frequency meter or a voltmeter. The ADC200 breaks the price/performance barrier for digital storage oscilloscopes. For less than half the price of the cheapest benchtop instrument, you get a fully-features oscilloscope with options such as FFT analysis and waveform storage/printing, which are features normally found only on the most expensive DSOs. Normally, the ADC200-50 sells at £499 and the ADC200-20 is £359 excluding VAT and postage. But *Electronics World*



Plugging into the PC's printer port, the ADC200 is very easy to install.

readers can obtain the units at the 20% discount prices of £399.20 and £287.20 respectively.

### Specifications of the ADC200 a-to-d converters

Parameter	ADC200-20	ADC200-50
Sampling	1 ch. 20Msamples/s 2 ch. 20Msamples/s	50Msamples/s 25Msamples/s
Buffer size	2x8k	1x16k, 2x8k
Resolution	8-bit	8-bit
Analog connections	2 channel x 1MΩ impedance AC/DC coupling via switch	
Digital connections	External trigger/signal generator >100kΩ input impedance	
Voltage ranges	±20, 10, 5, 1V ±500, 200, 100, 50mV	
Error	Voltage ±3%, time ±100ppm	
Trigger modes	Event: None, rising, falling Source: ChA, ChB, digital Timing: pre/post 1% increments	

### Photocopy or use this coupon to order

ADC200-50 is £399.20+17.5% VAT, i.e. £469

ADC200-20 is £287.20+17.5% VAT, i.e. £337

Add £10 courier delivery to each order.

Please send me

.....ADC200-50(s) at £.....

.....ADC200-20(s) at £.....

Postage and packing £10.00

Total £.....

Name.....

Company (if any).....

Address.....

.....

.....

.....

.....Post code.....

Phone number/fax.....

Signature.....

.....

Make cheques payable to Reed Business Publishing Group Ltd. Or, please debit my Master, Visa or Access card.

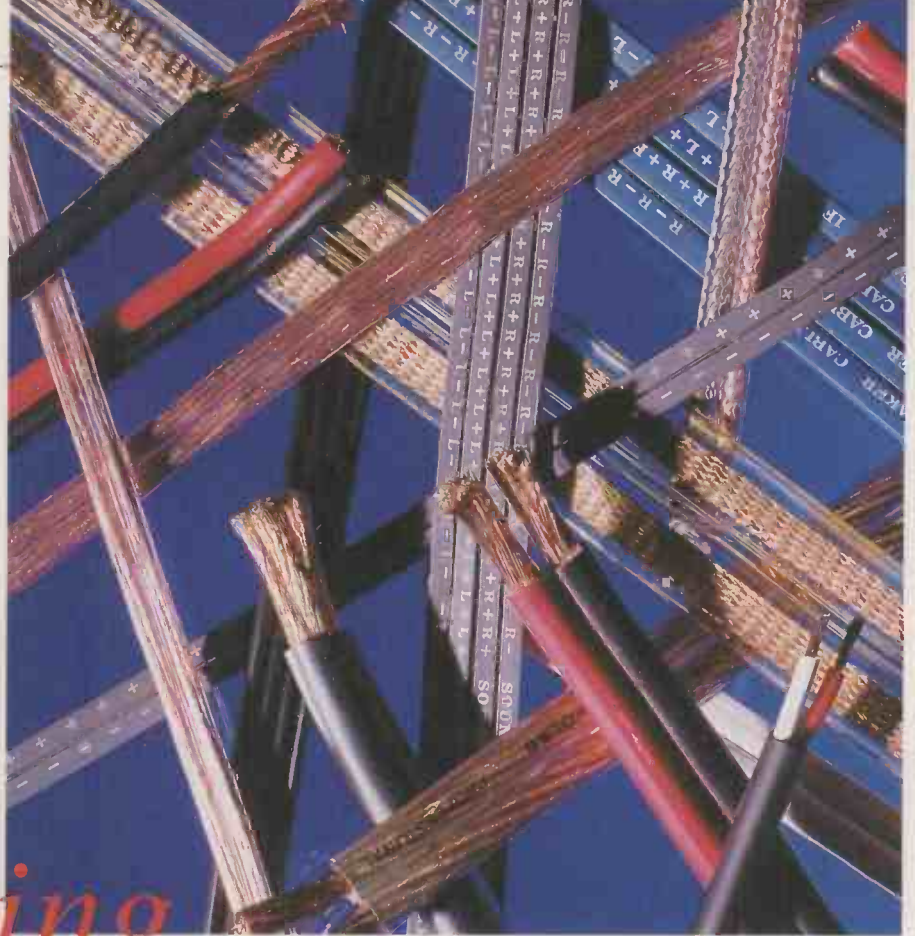
Card type (Access/Visa).....

Card No.....

Expiry date.....

Please mail this coupon to *Electronics World*, together with payment. Alternatively fax credit card details with order on 0181 652 8956 or telephone on 0181 652 3614. Address your order to Electronics World Editorial, ADC, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS or e-mail jackie.love@rbp.co.uk with credit card details. Please allow 28 days for delivery.

Selection of speaker cables specifically for automotive applications – some with 210A capability. Picture courtesy Semiconductor Supplies International, Sutton.



# Measuring SPEAKER CABLE differences

**Ben Duncan explains how cable differences had been measured before they were modelled in his article in the February issue, and describes the technique and results.**

Cable differences were possibly first publicly demonstrated at the Institute of Acoustics' Reproduced Sound conference in 1990<sup>1,2</sup>. Here, my friends Dr. Keith Holland and Phillip Newell used a dual-subtractor amplifier to make cable losses and errors audible in realtime on music program, as well as with complex test signals. In 1991, Davis<sup>3</sup> demonstrated that cable resistance, the only parameter that hard line objectivists appear to acknowledge, was not the most critical parameter for audio. Even for bass frequencies, the cable's series inductance was of importance. Moreover, he argued that

shunt capacitance across the cable had no malign influence, i.e. that contrary to popular opinion heightened values would not cause high-frequency loss.

## Test procedure

In 1995, I devised a simple but quite realistic test for speaker cables that would show what is going on in a graphic sense, applicable to real music signals, with their perpetual discontinuity. The Dual-Domain version of the Audio Precision (AP) test set has a DSP-based FFT-test routine called 'FFT-80k' with 192kHz sample rate, which allows audio burst sinewaves to be graphed over time, Fig. 1 – analogous to a transient analysis simulation. A similar test but using a squarewave has been subsequently drawn to my attention in a less rigorous report by the high-fidelity accessories maker, QED<sup>4</sup>.

A 0.9Vrms test signal was used, enough to develop 100dB<sub>SPL</sub> at 1kHz and 0.4m, while representing only an 1/8th watt into the nominal 8Ω load, Fig. 2. The load included the associated, conventional two-way passive crossover. Inductors are air-cored, and capacitors are polypropylene types, expressly chosen by ex-Tannoy speaker designer, Mark Dodd, for low-hysteresis energy storage. My

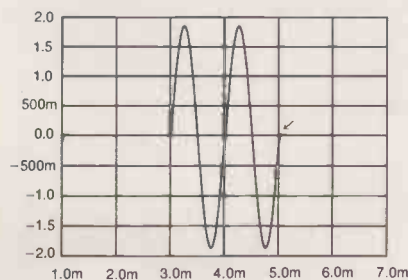


Fig. 1. The 1kHz test-tone burst employed to test speaker cables. In Figs. 3 and 4, the arrowed area is magnified.

laboratory test amplifier, rated at a modest 150W/8Ω, has a conventional dual-pair mosfet output stage with high global negative feedback, followed by an air-core output inductor of less than 1μH. Steady-state output impedance at the output terminals and at the 1V output level is nominally quite low, nominally below 10mΩ, at least at 1kHz. To reduce the worst-case test contact resistance below this and the conductors' own resistance, XLR connectors were soldered to both ends of the tested cables. Connections were also made with the test signal muted, to avoid degradation by arcing.

**Measurement results**

The 30 results of this test procedure for 10 cable types at three test frequencies are pictured in the test reports published internationally in both *Studio Sound* and in *Stereophile*, that were cited in the February article. Here, just the two cables modelled in the simulation (Feb '96) have been abstracted: a fairly conventional mains cable, cable C, that has been widely used for wiring professional speakers, is compared with the low inductance *SupraPly* type, cable J. Although the conductors are similar in csa, the L and C parameters are quite different:

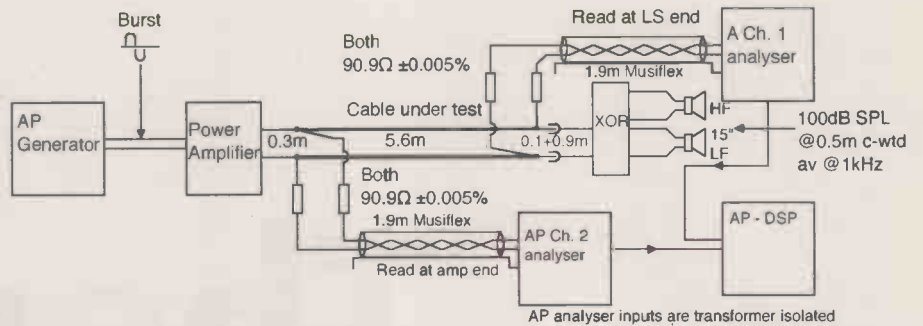
	Cable C	Cable J	Approx diff.
Series resistance	59mΩ	50mΩ	x0.84
Loop inductance	3.5μH	2.05μH	x0.58
Shunt capacitance	551pF	146pF	x2.65

In other ways the two cables are similar. They are thin-stranded, and have PVC insulation and sheathing. But cable J has lowered skin effect, and includes a metal other than copper.

Each of the graphs, Figs. 3 & 4, is a magnification of the point immediately after the sine-burst stops, as arrowed in Fig. 1. In each graph, one response is almost flat. This is the more tightly controlled response at the amplifier output, i.e. the stimulus end, as shown in red, in my Feb '96 simulation plots. Deviations here reveal transient feedback control deficiencies. The outermost, wilder response is that at the speaker end. The differerent magnitudes directly show the degree by which cables impede the amplifier's feedback damping control at the speaker terminals.

**In summary**

My measurements of August last year do corroborate with my simulations of reasonable equivalent circuits for stranded speaker cables, as published in February. The exact forward and reverse voltage of the diodes is relatively unimportant, but the diodic inter-strand contacts certainly exist, and the non-linearity they cause is measurable if one uses the right equipment. Ordinary %thd tests are quite



**Fig. 2.** The test setup uses a standard DSP aided test using de facto standard equipment from Audio Precision. The signal is read at both ends of the cable by the AP's high common-mode rejecting receivers. The cables were hung uniformly in a widely spaced 'U' away from obvious E and H fields and ferro-metal objects. The drive-unit chosen for testing was a Tannoy 15in dual concentric in a medium sized vented cabinet – a half-way house if there is one, between the extremes of professional and domestic speaker designs.

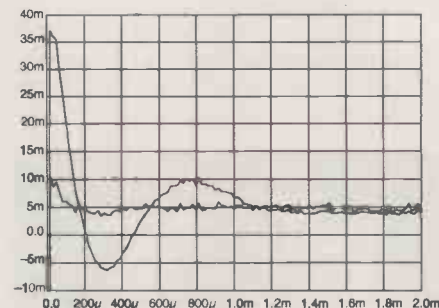
unsuited as the data is lost in noise.

My tests moreover show how some of the cables expressly designed for speakers including, as it happens, one made by Graham Nalty, can significantly improve damping or settling time on music program. The results also illustrate the logic of making special cables for mains in emi sensitive environments, such as listening rooms, considering that current into all 50/60Hz conventional capacitor-smoothed ac-to-dc power supplies without pfc is a mid-frequency burst waveform, much as simulated here.

Jenving technology is on 0046 522 234 60, fax, 0046 522 23460.

**References**

1. Newell, P & Holland, Dr K, Esoteric loudspeaker cables, do they really deliver their promises?, Proc. IOA. Vol.12, part 8, 1990.
2. Butler, T, Cable Controversy, *Hi-Fi News*,



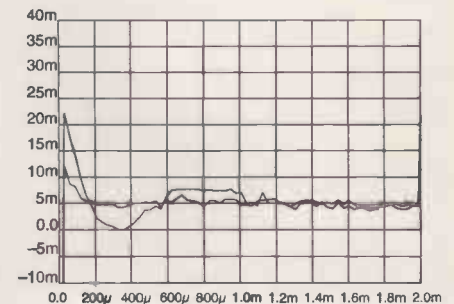
**Fig. 3.** Damping of ordinary pvc insulated mains flex, comprises 50/0.25 plain copper conductors of circa 99.7% purity, with high or non-specific oxygen content, leading to early onset of chloride poisoning and oxide complexing. Circular conductors in a sheath of circular OD. Compare to Fig. 11 in Feb '96 EW.

Jan '91 – report on the demonstration associated with the above paper.

3. Davis, FE, Effects of cable, loudspeaker and amplifier interactions, *JAES*, June '91.
4. The Genesis Report, A technical appraisal of loudspeaker cable technology, *QED*, 1995.

**Further reading**

- Hawksford, MJ, The Essex Echo, *Hi-Fi News*, Aug '85; Aug & Oct '86; and Feb '87. An in-depth Maxwellian mathematical treatment of audio cables, predicting the behaviour shown here.
- Farley, BS, Loudspeaker cables as transmission lines (letter), *Hi-Fi News*, Oct '77. An early suggestion that it is valuable to increase the capacitance of speaker cable.
- Pass, N, Speaker cables; Science or snake oil?, *The Audio Amateur*, 2/80 USA.



**Fig. 4.** Damping of Jenving's Supra Ply 2.0, which comprises 240 high purity copper (99.99% purity, oxygen free) strands specially impregnated with tin, with csa totalling 2.0mm<sup>2</sup>, in a rectangular, high mutual inductance profile. The quite thin, special PVC insulation has low emission of chloride ions. Outer sheath is ordinary PVC. Compare the rapid damping behaviour to that predicted by my model in Fig. 13 in Feb '96 EW.

# Thermal *issues*

**Ray Morris\* explores the issue of thermal management versus thermal engineering.**

The operation of nearly every electronic device generates heat. If left unaddressed, it can cause problems at all stages of a product's life-cycle.

Thermal issues are at the core of a major challenge facing the electronics industry. The intersection of two conflicting trends. One is end-user demand for faster and therefore hotter semiconductors and circuitry to power the next generation of consumer electronics and personal computers. The other is the demand for smaller packaging, which is creating a thermal situation that threatens manufacturers of electronic components, original equipment manufacturers, and ultimately the end-user.

#### Turn up the heat

Heat is a major problem that if left unaddressed can cause problems at all stages of a product's life-cycle.

The operation of nearly every electronic device generates heat, from the microprocessors used to run today's computers, to the mobile phones that have become common-

place on city streets across the world. The laws of physics dictate that the performance and reliability of electronics and other integrated circuit devices are absolutely constrained by device temperatures. Mathematicians have worked out formulas that indicate that for every 10°C rise in junction temperature the failure rate doubles. Performance and reliability are jointly constrained by the manner in which electronic components are cooled and how the overall system attributes are handled.

There are many means by which a temperature-related equipment failure can occur: thermal runaway, gate dielectric, junction fatigue, electromigration diffusion, an electrical parameter shift, a package related failure, and more. In simple terms, heat can wreak havoc on electronic devices in many different fashions.

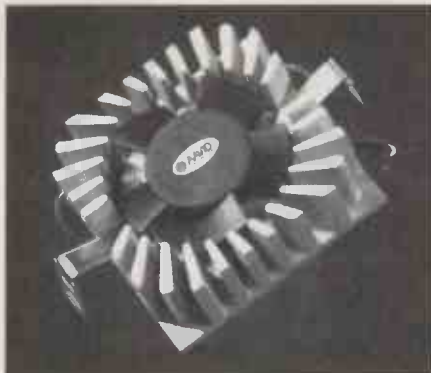
Unless we find innovative ways to disseminate substantially more heat, there will be many more instances of equipment failure — all of them temperature-related.

#### Thermal management: yesterday's tool

Traditionally, the solution in the electronics world has been to slap a heat sink, fan or combination heat sink onto an application or into the enclosure as an after-the-fact way of dealing with a thermal problem. The resulting products tend to be bigger. They also tend to offer fewer reliability and cost/performance advantages to the customer, especially if their performance must be scaled back to manage thermal issues.

While these kinds of 'thermal management techniques,' as they can be called, have been adequate in the low-power arena, they no

*Processor cooling systems need to be not only compact and efficient, but also reliable.*



\*Ray Morris is with Aavid Thermal Technologies.

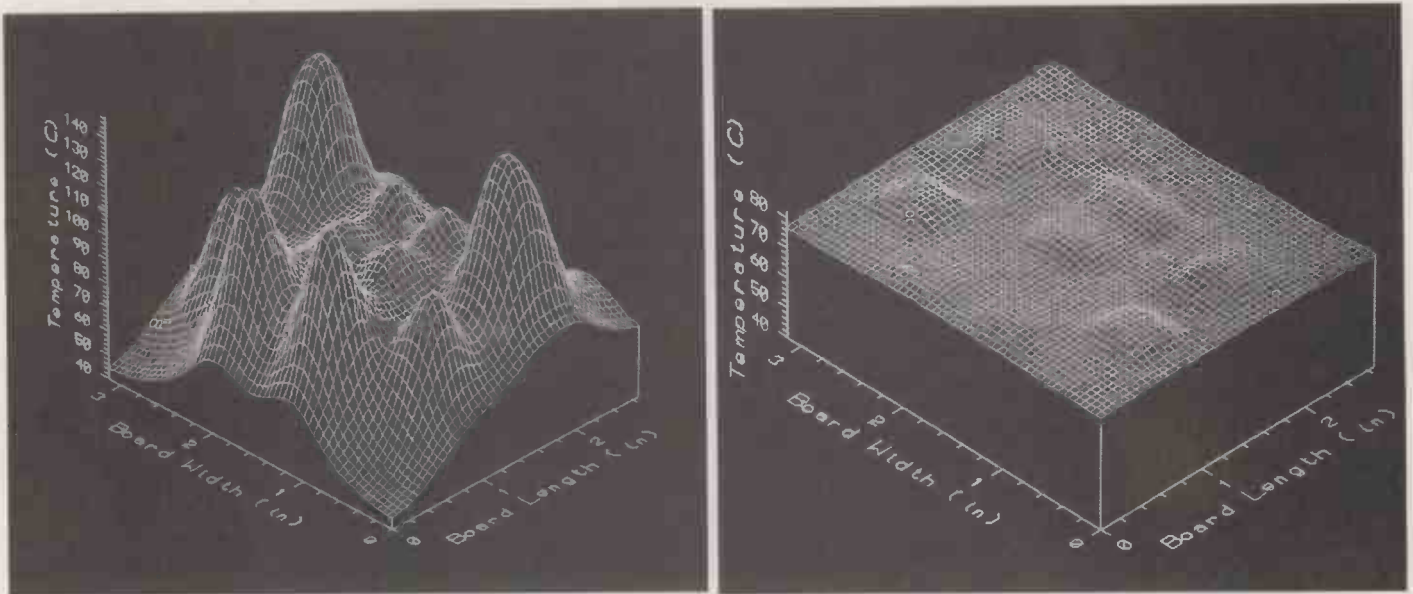


Fig. 2. Aavid's proprietary thermal and fluid flow simulation programs – shown here modelling an electronic assembly without thermal management, top, and the same electronic assembly after Aavid's optimised thermal solution, bottom – predict local surface temperatures and heat transfer coefficients. Graphic and tabular outputs from these programs allow engineers to optimise heatsink design and thermal solution sizing.

longer represent a valid option with next-generation electronics devices.

As you can imagine, thermal management techniques, while adequate in some situations, are more than likely to have a negative impact on overall design budget. This is because engineers are forced to go back to the drawing board to contend with thermal constraints discovered at the last minute.

### Thermal engineering – an enabling technology

By identifying and 'engineering out' thermal issues early in the design process, engineers have much greater control over product build costs.

In fact, it is physics that permits the development of innovative solutions – but these solutions must be evaluated during the electronic design process to eliminate thermal problems before a prototype is developed.

This is called 'thermal engineering' – addressing system-wide thermal issues from the earliest stages of product design using a broad array of technologies and disciplines. In this way, manufacturers avoid the frantic scramble to address thermal problems that surface suddenly during product testing, just before the prototype is due at the customer site.

But thermal engineering is more than a way of eliminating heat. Thermal engineering is an enabling technology that offers manufacturers a strategic edge in systems design.

For example, suppose your goal is to run a Pentium in a notebook computer. By implementing a thermal design that permits the dis-

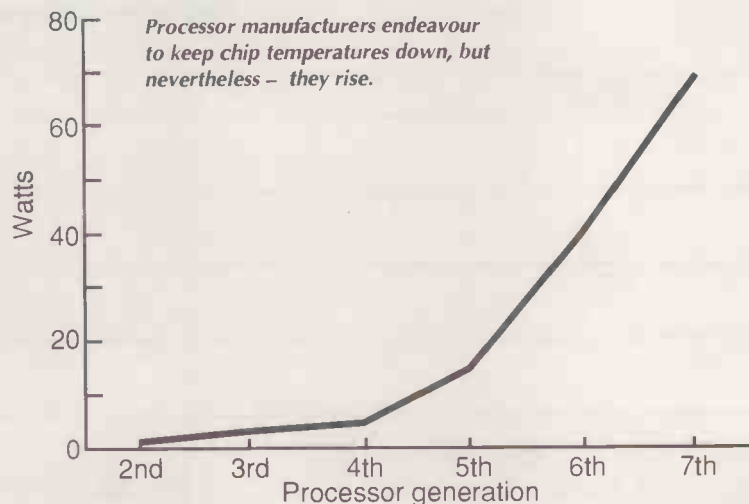
sipation of 50 watts of heat – a small amount by high-power standards – you not only can have the Pentium operational, but you also have the additional capability for heat dissipation. You can run the Pentium at full speed along with the entire supporting ASIC chip set and throw in a video driver for an active matrix display. While this example assumes a top-notch electrical team, the advantages are clear.

Thermal engineering involves modelling of the device in the system – a process known as temperature prediction capability. In the thermal engineering process, designers look at the analysis of the device on the board or in the system. After a particular thermal solution is modelled,

it must be subjected to what is known as either design or temperature verification.

After this, the designer considers the mechanical design aspects of thermal engineering, where the designer has to apply the correct manufacturing technology, or integrate the right manufacturing technology in to the system and its available airflow to create the most economically and thermally optimum design.

Having the leeway to rely on a single thermal solution for multiple generations of product not only provides manufacturers with time savings and increased electrical design productivity, it also offers significant benefits



in the design of additional features that may help a manufacturer get out in front of the competition.

**Today's thermal toolbox**

Thermal engineers are exploring a number of technology avenues that they expect will accommodate the electronics equipment of the future. Some of the solutions include heat pipe technology, fluid cooling, cutting edge air flow techniques such as focused flow and boundary layer optimisation. Also, new alloys that spread heat more effectively are being investigated.

As size and power issues collide to impose thermal limits on product development, thermal engineering promises to emerge as one of the fastest growing markets in the computer industry in the 1990s and beyond.

International Interconnection Intelligence – a Monterey, California-based research firm specialising in packaging issues – estimates the average annual compounded growth rate for thermal engineering products at 13 to 14% worldwide for the 10-year period from 1990 to 2000. This represents a jump from \$2 billion to \$6 billion.

**Who will provide the solution?**

Thermal problems affect every party in the manufacturing and supply chain. Most vulnerable is the consumer, who depends on the

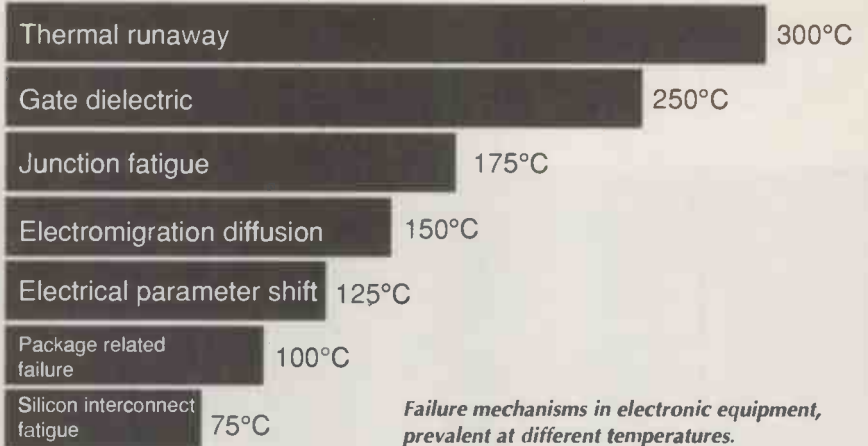
device's performance. To have a piece of equipment fail to the extent where it is unsalvageable undermines the working premise between customer, retailer and manufacturer.

Businesses assume that the equipment on which they must rely every day will continue to function without catastrophic failure.

Equipment failure at the consumer level carries serious repercussions for the entire industry. Not only does the failure cast doubt upon the judgment of the retailer in offering such products to its customers, but it calls into

question the role of the manufacturers in selecting components for its equipment.

Smaller, faster, feature-rich and literally hotter electronics emphasise the critical need for good thermal design to maximise product reliability and performance for the end user. However, the issues are not insurmountable — building tomorrow's electronics begins at the product concept stage — and will become a reality only by fully taking advantage of cooling solutions available through thermal engineering. ■



*Failure mechanisms in electronic equipment, prevalent at different temperatures.*

**FREE TO SUBSCRIBERS**

**Electronics World offers you the chance to advertise ABSOLUTELY FREE OF CHARGE!**

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words (remember to include your telephone number as one word). You must include your latest mailing label with your form, as this **free** offer applies to private subscribers only. Your ad will be placed in the first available issue.

This offer applies to private sales of electrical and electronic equipment only.

Trade advertisers should call **Malcolm Wells on 0181-652 3620**

All adverts will be placed as soon as possible. However, we are unable to guarantee insertion dates. We regret that we are unable to enter into correspondence with readers using this service, we also reserve the right to reject adverts which do not fulfil the terms of this offer.


*Please send your completed forms to:*  
**Free Classified Offer: Electronics World, L329, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS**



Please quote "Electronics World" when seeking further information

## ACTIVE

### Discrete active devices

**400A mosfet switch.** A fast mosfet switch module for power application at up to 100V battery voltage by Ixys exhibits a forward resistance of  $4.2\text{m}\Omega$ , which allows a continuous current of 418A at 200V reverse voltage. Inductance is low and overvoltages are therefore not troublesome; in a three-phase circuit, forward voltage is less than 1.8V at 350A peak current. Module dimensions are 110 by 62 by 30mm. GD Rectifiers Ltd. Tel., 01444 243452; fax, 01444 879722.

**1.7kV damper diode.** Philips introduces the *BY479X-1700*, claimed to be the first 1.7kV diode for use in television displays and multi-sync monitors horizontal deflection circuits, in which it is the only damper diode needed. Forward recovery voltage is 12V and recovery time 200ns to 5V, the device coping with power dissipation in circuits operating at up to 64kHz. Electrical isolation between the *SOT186A* pins and tab is 2.5kV. Philips Semiconductors (Eindhoven). Tel., 00 31 40 2722091; fax, 00 31 40 2724825.

### Linear integrated circuits

**Switches and mux/demux.** Quality Semiconductor has a family of analogue switch and multiplex/demultiplex ics, intended for multimedia and forthcoming PC-tv use. The analogue switches have an on resistance of  $5\Omega$ , 700MHz bandwidth,  $-110\text{dB}$  crosstalk at 50kHz ( $-30\text{dB}$  at 30MHz) and isolation of  $-90\text{dB}$  at 50kHz ( $-50\text{dB}$  at 30MHz). Three analogue mux/demux devices are available. *QS4A205/210/215*. *205* is quad, 2:1 device with a 830MHz bandwidth; *210* a dual 4:1 unit having a 700MHz bandwidth; and the *215* a 24:6 model with tri-state outputs, also with a 700MHz bandwidth. Quality Semiconductor, Inc. Tel., 01420 563333; fax, 01420 561142.

**400MHz op-amps.** *MAX4108/9* are 400MHz,  $\pm 5\text{V}$  op-amps providing very low distortion. The *4108* has a 400MHz,  $-3\text{dB}$  bandwidth, is unity-gain compensated and offers a spurious-free dynamic range of 93dBc at 5MHz. *4109* is compensated for 2V/V, has an sfd of 90dBc and a 225MHz  $-3\text{dB}$  bandwidth. Both have differential phase and gain of 0.002%.

Output current drive is 70mA. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

**Current-to-voltage converter.** A quad converter by Linear, the *LT1311* is designed for the amplification of photo-diode outputs in optical disk drives that use multiple diodes for tracking and focus as well as data. There are four 12MHz current-feedback amplifiers with internal feedback, the only external component being a bypass capacitor. Since the current-feedback technique is, to some extent, independent of input capacitance up to about 50pF, the device can be remote from the reading head while still giving a 145ns settling time for a 2V step. Gain accuracy is  $\pm 4\%$  at 20mV/ $\mu\text{A}$  and offset error/drift are 250nA/2.5nA per  $^\circ\text{C}$ . Micro Call Ltd. Tel., 01844 261939; fax, 01844 261678.

### Motors and drivers

**Induction motor controller.** Micro Linear's *ML4421* is claimed to be the first single-chip speed controller for ac induction motors, running in forward or reverse and maintaining a selected speed to within  $\pm 5\%$ . Speed is set by setting up a drive waveform at the required frequency at an amplitude to

give optimum torque, a feedback circuit monitoring the phase of voltage and current drives and adjusting drive frequency and amplitude to maintain the set speed. *ML4421* works at any frequency, including 400Hz. Ambar Components Ltd. Tel., 01844 261144; fax, 01844 261789.

### Oscillators

**Variable crystal oscillators.** ACT announces the *ACT7000* series of crystal oscillators with a pulling range of up to  $\pm 100\text{ppm}$  for 0.5-5V control input, depending on the model. Frequencies covered are in the 10-35MHz range and transient times are under 10ns. Stability is  $\pm 30\text{ppm}$ . The oscillators are hermetically sealed in a metal can with a profile of 8.5mm or less. Advanced Crystal Technology. Tel., 01635 528520; fax, 01635 528443.

## PASSIVE

### Passive components

**Aluminium electrolytics.** From Philips comes the *PSM-SI 056/057* series of miniature, snap-in, non-solid electrolytics, which have a life rating of 12000h at  $85^\circ\text{C}$  (210000h at  $40^\circ\text{C}$ ), for operation the  $-40$  to  $85^\circ\text{C}$  area. Capacitance range is 470pF-68nF for the *056* series and 47pF-1.5nF in the *057*; tolerance is  $\pm 20\%$  and working voltage either 10-100V or 200-450V. They are charge and discharge proof and have a pressure relief on the casing. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

### Connectors and cabling

**Test cables/connectors.** Multi-Contact, represented by Electrospeed, has several new ranges of test cables, connectors and accessories. Among the connectors is the Multilam, fully shrouded, 4mm plug, which has a turned brass pin surrounded by a spring-loaded Multilam of hard-drawn copper alloy. This is for high-current use and meets IEC 1010-1, having a 1kV voltage rating, 32A current and test voltage of 4kV. Leads include the HK2.5-D flexible, double-insulated test lead cable for 4mm plugs, made from multi-strand wire and double pvc insulation and rated at 1kV, 32A. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

**Pcb terminal blocks.** Camden Electronics offers the *CTB0305* 3.5mm rising-clamp terminal block range, which stands only 9.1mm



**Chip capacitors.** Murata's Emifil *NFM39R* range of surface-mounted three-terminal capacitors are available in values from 22pF to 22nF and measure 2 by 1.25 by 0.5mm. Rated voltage is 50Vdc, current 300mAdc, insulation resistance 1G $\Omega$  and operating temperature  $-55^\circ\text{C}$  to  $125^\circ\text{C}$ . Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

above the board. Two or three pole interlocking units, which are also available assembled into a 24 pole block, take 1mm wire and are rated at 6A, 125Vac. Insulation resistance is over 40M $\Omega$  and dielectric strength more than 2.5kV. Camden Electronics Ltd. Tel., 01727 864437; fax, 01727 855400.

### Filters

**Sm filters.** 20A surface-mounted filters from Steatite have values up to 10000pF in C and pi form. They avoid the need for through-hole filters and screening bulkheads and, being square in section, are suitable for pick-and-place equipment. Steatite Insulations Ltd. Tel., 0121 6436888; fax, 0121 643 2011.

### Hardware

**Handheld cases.** Briticent's handheld and DIN cases are of ABS plastic and are meant to house equipment such

### Optical devices

**1.40 $\mu\text{m}$  laser diode module.** Mitsubishi offers the *FU-622SLD-2M4* module, which is for the 1.48 $\mu\text{m}$  band and is designed for pump working. It is contained in a butterfly package with a pigtail and sealed diodes on a silicon substrate with a PNP layer for current blocking and reduced leakage current. The laser diode is rated at 200mA at 2V reverse and the monitor diode at 2mA and 20V reverse. Spectral width is 10nm and tracking error 0.3dB. Cooling circuitry is incorporated. Mitsubishi Electric UK Ltd. Tel., 01707 276100; fax, 01707 278692.



Please quote "Electronics World" when seeking further information

as remote-control handsets. They come in sizes from 56 by 36 by 16mm to 170 by 93 by 52mm, some of them being made from Noryl auto-extinguishing material and others having a Plexiglas cover; those destined to contain remote controls have one or two coloured buttons and a battery compartment. Depending on the model, there are options, including ventilation, an aluminium top or a black anodised front panel; standard colours are black, red, grey, ivory and beige and others can be provided. The company offers a Buyers' Guide. Briticent International. Tel., 01425 474617; fax, 01425 471595.

**Emc enclosures.** Weidmuller EMC has a range of glass-reinforced polyester enclosures based on the standard models by Weidmuller Klippon. The Kestrel enclosures are internally coated with nickel or

**Am function generator.** TTI's TG230 2MHz function generator includes an internal amplitude modulator, also accommodating external am input to give 0-100% modulation depth. An internal sweep generator gives linear and log. frequency sweeps with sweep ratios of more than 1000:1, start and stop frequencies being digitally set and indicated. Again, an external input is accepted and will provide frequency modulation. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

coppered silver for electrical protection, a conductive silicone rubber seal maintaining the electrical characteristic and excluding moisture. Cases come in 17 sizes, from 80 by 75 by 60mm to 600 by 250 by 125mm, and in grey, red or blue finish. A carbon-loaded version increases electrostatic protection and is black. The company offers a drilling and assembly service. Weidmuller EMC Ltd. Tel., 01734 811571; fax, 01734 811570.

**Servo chassis.** Copley can supply the Model PST 'six-pack' chassis to take a mix of up to six of its servo amplifiers, complete with power, cooling, electrical protection and interconnection. It is supplied with an isolation transformer, rectifier and filter capacitor and rated at 750W for either 75Vdc or 150Vdc output. Up to three ac fans can be used and the chassis itself forms a heat sink. Cable harnesses are available to match any number of amplifiers and a resettable circuit breaker protects the whole chassis, individual amplifiers having their own internal protection. Copley Controls. Tel., 001 617 329 8200; fax, 001 617 329 4055.

**Industrial PC enclosures.** Arcom has APC-CE/1 and APC-CE/2, two new CE-compliant enclosures for PCs to be used in light industry or domestically, or in heavy industrial applications. The racks take up to 12 boards and give a clean, filtered ac/dc supply carrying no noise and causing no emissions. A screened, fan-cooled housing prevents radiation and there is provision for floppy and hard drives. A range of PC/PC-AT boards is available, including 486 processors,

i/o and utilities. Arcom Control Systems Ltd. Tel., 01223 411200; fax, 01223 410457.

**Test and measurement**

**Differential amplifier.** A differential amplifier by Preamble Instruments, the Preamble 1855, is intended for signal conditioning for oscilloscopes or digitisers, providing differential measurement capability to instruments with single-ended input. Gain is steerable to 10 or 1 and there is 10:1 input attenuator. Bandwidth is 100MHz which can be filtered internally to 10MHz, 1MHz or 100kHz by 3-pole limit filters, gain is automatically displayed. Its built-in voltage generator can be set to any voltage in the  $\pm 15V$  range to within 100 $\mu V$ , being connected to the inverting input of the amplifier to form a comparator amplifier or applied internally to provide true differential offset. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

**Pcb troubleshooter.** Huntron's ProTrack 1 is the first in a new series of programmable printed board troubleshooting instruments, combining signature analysis with some new hardware and software. Model 20 is a bench-top instrument which is used with the Scanner 1 to scan up to 128 pins at a time, making real-time comparisons between boards. It can also be interfaced with a PC running the company's Workstations for windows auto test software to create custom test routines and the Prober enables complicated boards to be tested without using expensive fixtures. Results are shown immediately.

Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

**Budget-priced oscilloscope.** OS9020P from Feedback is possibly the lowest-cost oscilloscope available in the UK; it is meant for maintenance, education and enthusiasts. Bandwidth of the two identical channels is 20MHz and the usual chopped, alternate and inverted modes are available, as is an XY display. The screen is 6in diagonal. Maximum sensitivity is 5mV/div, with the 10 times magnification. Feedback Test and Measurement. Tel., 01892 653322; fax, 01892 663719.

**Digital, real-time oscilloscopes.** The Tektronix TDS range of oscilloscopes samples signals at five times analogue bandwidth on two channels simultaneously to reduce the possibility of aliasing or other effects. There are three models to give bandwidth/sampling rates of 100MHz/500Msamples/s (TDS340); 200MHz/1Gsamples/s (TDS360); and 400MHz/2Gsamples/s (TDS380). Each has two input channels with a dedicated oversampling digitiser and an FFT button to convert the normal time-domain display to a spectrum. The 360 and 380 have a 3.5in disc drive to allow the saving and recall of waveforms, which can then be passed to a PC for further work. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

**500Msamples/s dso.** DataSYS 944 by Gould is a 400MHz bandwidth digital storage oscilloscope sampling a 500Msamples/s to capture signals down to 2ns wide. Bandwidth is guaranteed over the whole sensitivity range of 2mV/div to 5V/div. Noise levels are 'significantly lower' than that of earlier instruments. Each of four channels has a 50K memory. An optional internal plotter provides hard copy and IEEE-488 and RS-423 interfaces allow transfer to a PC, where the company's Transition 2 software helped to compile reports and to carry out analysis. Gould Instrument Systems Ltd. Tel., 0181 500 1000; fax, 0181 501 0116.

**Video signal generator.** TG2000 by Tektronix is a signal generator for television equipment, with positions for eight independent analogue and digital generators to provide simultaneous multiple signals and formats. There is a library of test signals and Windows-based software affords a simple method of making new ones. It will give moving patterns for dat-compression testing and has a programmed system clock for non-standard scanning rates. Tektronix UK Ltd. Tel., 01628 403300; fax, 01628 403301.

**Wide-band preamplifier.** EG&G Instruments has introduced the Model 5185 wide-band 200MHz amplifier for



Please quote "Electronics World" when seeking further information

Instrumentation use. Frequency response is 0-200MHz, with switched gain of 10 and 100 and selectable 50Ω or 1MΩ input impedance. There is also an adjustable voltage offset to remove dc levels before the output. There is an external, remote power supply or the unit will accept ±15Vdc supplies. EG&G Instruments Ltd. Tel., 01734 773003; fax, 01734 773493.

## Literature

**Ac Ivdts.** Macrosensors has a 4-page bulletin on its range of ac linear variable differential transformers for oem and end-user application. Three ranges are available: two of them are drop-in replacements for units by other makers and the other units are 0.375in diameter types for use where small size is needed together with the performance of a larger unit. Eurosensor.

**16-bit micros.** A short brochure from Toshiba describes the *TLCS-900* family of 16-bit microcontrollers, which allow designs to be optimised for cost, power consumption, low-voltage operation or processing power for the particular application. The brochure gives details of the cpu core and describes all the options, a chart helping to identify the most appropriate type for a given task. Development tools are also described. Toshiba Electronics UK Ltd. Tel., 01276 694600; fax, 01276 694800.

**Satellite communications.** California Microwave has a set of brochures to publicise its services and hardware and software products in this field, ranging from complete earth stations and networks to remote control and monitoring software. California Microwave. Tel., 001 516 272 5600; fax, 001 516 272 5500.

## Power supplies

**Ups for poorer mains.** Fiskars' new PowerRite Max uninterruptible power supply uses the company's DoubleBoost voltage regulation to cope with mains fluctuations of 35% without switching to battery operation, a feature that possesses advantages in server availability, in particular when the mains supply is not of the best quality. The Ups also has Fiskars' advanced battery management system which is claimed to prolong battery life by 50%, periodically tests the battery and recharges it 20% faster than is usual, so that the battery is ready for the next catastrophe. The Ups is supplied with Lansafe III network power management software which shuts down all networked devices in the order determined by the user. It is available in output power from 450VA to 1500VA. Fiskars Electronics Ltd. Tel., 01734 306600; fax, 01734 305868.

**500kHz switching regulator.** Linear

has introduced the *LT1376*, which is a constant-frequency pwm type switching at 500kHz and having a 1.5A output at nearly 90% efficiency. The high frequency allows the use of 4.7μH inductors and capacitors can be used to produce a complete surface-mounted regulator. Input range is 6V-25V and there is a logic-operated shutdown mode to 20μA. Another version, the *LT1375*, can be frequency-synchronised over the range 580-900kHz by a logic-level clock. Micro Call Ltd. Tel., 01844 261939; fax, 01844 261678.

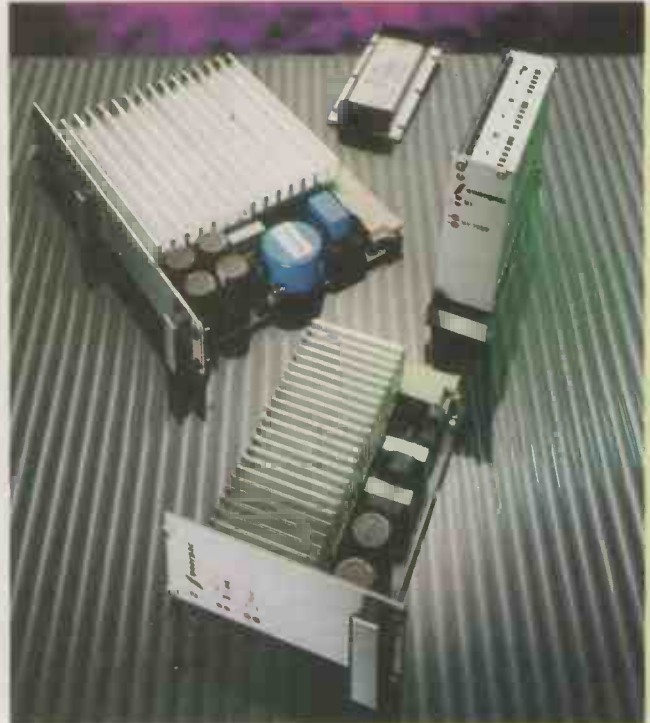
**'Smallest' split power supply.** From Maxim, the *MAX865*, a cmos charge-pump dc-to-dc converter producing both positive and negative rails from one input and contained in a μMAX package, which is 1.1mm high and takes up half the board space of an 8-pin SOIC. Input voltage is 1.5-6.2V to produce two rails of twice the input voltage, each putting out up to 10mA from 75Ω. Another version, the *MAX864*, has pin-selectable oscillator frequency and logic-controlled, 1μA shut-down. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

**Ac/dc power supplies.** Coutant-Lambda has a new series of ac/dc supplies, the SWT range, that incorporates universal and auto-selectable models giving 30-100W of power. The series is pcb mounted and handles inputs of 85-265Vac, conforming to EN55022 Class B for conducted emission noise. All conform to UL1950, CSA22.2-234 and EN60950 and the European low-voltage directive. Coutant Lambda Ltd. Tel., 01271 865656; fax, 01271 864894.

**30mV dropout regulator.** Zetex's ZLDO linear regulator has a dropout voltage of 30mV, which is claimed to be 10 times less than competitive devices. Currently, there are 3.3V, 4.85V and 5V models available, with other models offering up to 18V to come later. ZLDO has a sensing circuit to warn when the input drops to within 300mV of the output. In normal working, the regulator takes 600μA for a 300mA load and, in sleep mode, 11μA. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

**1A voltage regulators.** *EZ1117/1117A* are 0.8A and 1A positive voltage regulators for use in active SCSI terminations and low-voltage microcontrollers and as smps post regulators. They give a 1.2V maximum dropout voltage and ±0.2% regulation with any line, load or temperature variation. Adjust pin current is 90μA or less, output voltage 2.85-3.3V and input voltage 7V. Semtech Ltd. Tel., 01592 773520; fax, 01592 774781.

**0.05% voltage references.** Precision



references in the Linear Technology *LT1236* family offer 5ppm/°C drift (worst case), less than 1ppm pk-pk noise, and 0.05% output accuracy. Two devices are available to provide 5V and 10V, both sourcing and sinking up to 10mA and settling quickly on transient loads. Line and load regulation are 0.5ppm/V and 12ppm/mA. Linear Technology (UK) Ltd. Tel., 01276 677676; fax, 01276 64851.

**DC-to-DC converter with filtering.** Analog Devices' new hybrid *ADDC02805S* power converter provides 5V, 20A from 28V and has its own internal filtering circuitry and many other protection and system functions, all in a 2.5 by 1.5in package. It gives 100W continuously from a 16-50Vdc input range. Facilities offered include thermal monitoring and shutdown, input transient protection, an output status pin, inhibit and sync, current sharing and an input-referred auxiliary voltage for external circuits. Analog Devices Ltd. Tel., 01932 266000; fax, 01932 247401.

## Radio communications products

**Data transceiver.** Needing no licence, a uhf data transceiver from A&R Electronic Developments operates on 458MHz, allowing 32-channel, 9600baud transmission over several miles. Two versions provide 12.5kHz or 25kHz channels. Output

**Eurocard supplies.** Enetron's EN and ED series of Eurocard switched-mode power supplies deliver 25W to 400W with many combinations of single, dual, triple and quadruple output, all LVD-compliant and meeting EN55022 for emi. Input to the EN range is 88-127Vac or 184-256Vac or, optionally, universal. All are provided with a led status indicator and voltage adjustment and a range of optional facilities such as power fail, remote on/off and safety covers. EN supplies provide the same output facilities, but accept 10-400Vdc input. XP plc. Tel., 01734 845515; fax, 01734 843423.

power and channel are programmable over two digital lines and standby current is under 5mA from a 9-13V supply. Joseph Electronics Ltd. Tel., 0121 643 6999; fax, 0121 643 2011.

## Switches and relays

**Binary rotary switches.** Grayhill Series 94 binary-coded rotary dip switches are now available in the UK. The switches are completely sealed and are in either surface-mount form or for through-hole mounting, with both perpendicular and right-angle mounts. All are available with octal, binary-coded decimal or hex. codes, output standard or complement. Initial contact resistance of the gold-plated

## NEW PRODUCTS CLASSIFIED

Please quote "Electronics World" when seeking further information

contacts is 50mΩ at 10mA, 50mVdc and the contacts are rated at 30mA at 30Vdc for 2500 cycles make and break; carrying current is 100mA at 50Vdc. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

**Flat-pack relays.** Meisei L1 Series 4-pole flat-pack relays are only 11.5mm high, consume 210mW and will switch 240Vac. They are fully sealed and have four Form C, four Form D or two Form C and two Form D contacts in the one package. The contacts is gold-clad silver palladium alloy to give a contact rating of 1A at 30Vdc, coil-to-contact isolation being 1.5kV. The relays are available in 5V to 48Vdc form. Inelco Ltd. Tel., 01734 810799; fax, 01734 810844.

**Flash disk software.** Arcom offers AFFS, which is flash disk filing software for PC bus boards to allow the emulation of conventional read/write disks by solid-state flash eeprom in a system then capable of running dos or Windows on diskless systems. It is compatible with the Flash Translation Layer specification for PCMCIA cards and can be used in systems made from STEbus, ISA (PC/PCATbus) or VMEbus boards. Silicon disks of any capacity can be formed and up to 23 disks can be installed on an embedded system. Arcom Control Systems Ltd. Tel., 01223 411200; fax, 01223 410457.

**Push-button switch.** Bulgin's MP0037 sealed, push-button switch is meant for use where the public can get at it or in food industries. It is made in stainless steel with single-screw fixing and screw terminal connections. Front panel sealing is by barrier and panel seals. Action is single-pole momentary push-to-make and the silver contacts are rated at 1A, 50Vac/dc. Gothic Crellon Ltd. Tel., 01734 788878; fax, 01734 776095.

**Dip switches.** Aries has announced more dip switches of three types: rotary, tri-state and piano-style. The rotary type come in 10-position and 16-position versions, both in six-pin dips with 7.62mm row spacing and flush actuators. They have moulded-in leads and are sealed, with gold-plated contacts. Tri-state switches have 4, 5, 7, 8, 9 and 10 poles, gold-plated contacts and +, 0 and - positions in gull-wing or through-hole packages. The piano-style type is for mounting on a pcb edge and have between two and ten poles in silver-plated contacts. Aries Electronics (Europe). Tel., 01908 260007; fax, 01908 260008.

**COMPUTER**

**Industrial PC.** The MIC-2000 series of industrial PCs from IMS is based on a standard ISA bus passive backplane, taking front-loading, plug-in cards with fixing screws and handles. The plug-in modules give PLC-style front access, having plug-in terminal blocks for i/o. It comes with a 486 cpu module that has all standard

PC i/o, and crt and flat-panel interfaces. Standard PC cards for the PC bus up to 2/3 length can be accommodated. Integrated Measurement Systems Ltd. Tel., 01703 771143; fax, 01703 704301.

**486 cpu card.** Iosis announces a companion to its 455 half-size single-board computer -- the 410 -- which takes a selection of processors, including the Pentium Overdrive, and provides flat-panel and svga drive on board. An internal PCI bus is used for the IDE and VGA and a PC104 expansion bus and ISA for peripherals. Memory in 72-pin simms can be 1-64Mbyte of dram. Iosis. Tel., 0117 9730435; fax, 0117 9237295.

### Data acquisition

**I/o boards.** Amplicon Liveline has five new 200 Series data acquisition boards for Windows DLL and dos, all being mountable on DIN rails and supplied with screened cables. PC214E is a low-cost, 48-line i/o board with three independent 16-bit counter timers; PC218E/2E/5E have between 6 and 18 programmable counter timers with digital i/o; and the PC272E is a ttl-compatible digital i/o type giving 72 lines. Example libraries and code in Delphi, Borland and Visual C++ are given for Windows DLL; in Borland and Microsoft C++ for dos. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

### Data communications

**Data transceiver.** Maxim's MAX3221 1-drive/1-receiver RS-232 transceiver uses the company's AutoShutdown technique to reduce supply current to 1µA when it does not sense a valid signal level at the input, turning on when a valid signal is present at any input. A dual charge pump power supply and low-dropout transmitter deliver true RS-232 performance with supplies of 3-5.5V at a 120kb/s data rate. Four 0.1µF capacitors are needed externally. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

### Development and evaluation

**PCI fpga design kit.** Actel announces the ACT3, which is a set of software and hardware for the design of zero-wait-state PCI interfaces using field-programmable arrays. There is a full suite of design tools, including Actel Designer Series 3.0, a VHDL or Verilog test bench for verification, the first zero-wait-state VHDL or Verilog-HDL CorePCI master, slave and bridge models and the the new ACT3 family of fpgas. Actel Europe Ltd. Tel., 01256 29209; fax, 01256 55420.

### Data logging

**Em field logger.** In view of a possible link between exposure to elf electromagnetic fields and certain illnesses, it is necessary to gather data on the strength of fields. Delta-T Devices has produced the ELF Logger, which measures both electric and magnetic fields, having large diameter magnetic field sensing coils. Frequency response is 45-300Hz and



**A new RDS decoder, the T960, from Miaoogen Electronics, provides comprehensive monitoring of RDS data via Windows. Aimed at Radio broadcasters and RDS developers, the software decodes and prints out PI, PTY, PS, RT, CT, PIN, AF, TA, TP and EON. Interfacing with a PC serial port, the high quality tuner/decoder, covers 87.6 to 108.8 MHz. Special features of the T960 are RDS quality, frequency scan, RT history, digitally controlled audio and integral AC/DC PSU. Tel/Fax 0181 647 8238**

sensitivity 0.1-1000nT for magnetic fields and 2.5-5000V/m for electric fields. Logging rate is programmable from 1/s to 1/day and the memory handles 16000 readings, expandable. Delta-T Devices Ltd. Tel., 01638 742922; fax, 01638 743155.

### Mass storage systems

**Hard disks for mobiles.** From Integral Peripherals come the Viper 8510PA 510Mb. 1.8in PCMCIA type III drive and the Platinum/1200 1.3Gb, 2.5in type, both intended for use in portable computers. Both drives use the company's dynamic head-loading technique, which holds the heads away from the disk surface when not in operation to prevent 'head slap'. Both also use the MicroGlide technique, in which the heads fly very close to a non-textured, polished disk. Integral Peripherals. Tel., 001 303 449 8009; fax, 001 303 449 8089.

### Programming hardware

**Updates from Data I/O.** Data I/O has introduced new versions of its programmers, which now handle new devices from Altera, AMD, Lattice, Motorola, NEC, QuickLogic, WSI and Xilinx. The 2900 v3.8 takes devices with up to 44 pins and the 3900 v2.8 88-pin devices, taking 200-pin types with interface adaptors. UniSite v5.0, the top-end instrument, will handle virtually every available device, regardless of technology or package. Data I/O Ltd. Tel., 01734 440011; fax, 01734 448700.





## IFs go

## digital

**Encoding the IF signal in a heterodyne receiver can improve discrimination, reduce spurious carrier component and remove flicker noise from the demodulated signal. Andy Thurston\* describes an encoding method using sigma-delta conversion.**

The availability of powerful digital processing engines at acceptable prices has allowed the inclusion of various new features in modern radios. Many communicate with digital modulation schemes, such as GSM or TETRA. These radios have many features uniquely implemented by dsp or microprocessor techniques: channel coding and decoding; dealing with time-division, multiple-access, tdma, frame structures; processing of protocol for call set up and maintenance; and correlation techniques to detect training sequences.

Additionally, many features formerly implemented by analogue circuitry can be handled in the digital domain, such as demodulation, channel filtering, both carrier and timing recovery, and finally equalisation.

Clearly an analogue to digital converter is required, but at which point in the architecture? One option is to encode the baseband *I* and *Q* signals separately using a suitable pair of a-to-d converters and appropriate IF and RF circuitry, Fig. 1.

#### Converting at a low IF

Alternatively you may choose to perform the a-to-d conversion at a low IF, Fig. 2, and thus gain several benefits. Firstly, the final mix to baseband *I* and *Q* signals may be performed digitally, which is particularly simple if the sample rate is four times the intermediate frequency since the orthogonal local oscillators required for this mix become the repeated dig-

ital sequences (1, 0, -1, 0) and (0, 1, 0, -1), or  $\cos \Pi n/2$  and  $\sin \Pi n/2$ . Generation of these local oscillators is extremely simple, and the mixing process can be performed with addition and subtraction only.

Secondly, since the orthogonal baseband paths are now of a digital rather than analogue nature, perfect matching of the phase and amplitude characteristics of these paths becomes a matter of course. In contrast, in an analogue implementation of these paths, to achieve, say, a 40dB discrimination between upper and lower sidebands, it is necessary to match the gains to better than 0.1dB and to match the phase to better than 0.01rad, or 0.57°.

Finally, the issue of dc offsets arising from the mix to baseband or from the baseband a-to-d conversion process does not arise, and similarly the problem of local oscillator breakthrough in the final mixing stages does not occur. Both the dc offsets and local oscillator breakthrough on mixing to baseband have the effect of masking any signals at the carrier frequency. Bandpass conversion effectively prevents this problem.

#### The final IF

The choice of the final IF at which the a-to-d conversion will take place must be considered. If the chosen IF is too low then the filtering requirements at the preceding IF are made more demanding, whereas if the IF is too high then the cost of the a-to-d converter may become prohibitive. This is especially true if a standard multi-bit converter is used.

However, consideration of the nature of the IF signal reveals that a conventional multi-bit converter is perhaps not the best means of performing this conversion. After all, the actual signal bandwidth will typically be fairly narrow band in comparison to the IF itself, and the full Nyquist bandwidth of the converter is not really required. It is seen that the ratio of the sampling frequency to the channel bandwidth is very high, and that a great deal of oversampling has been employed.

This fact may be exploited by using a bandpass sigma delta a-to-d converter, which is an

\*Dr AM Thurston is with GEC Marconi Research.

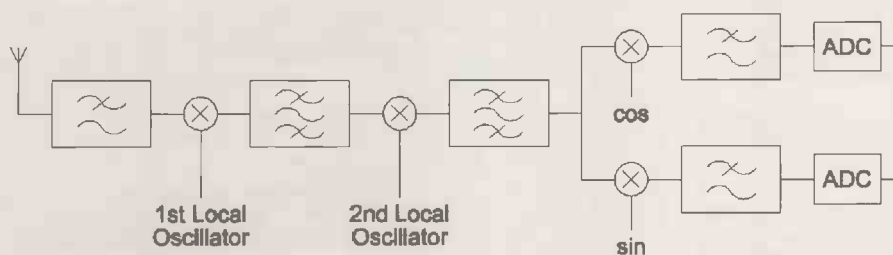


Fig. 1. Baseband a-to-d converters in a heterodyne receiver. These converters suffer from dc offsets at their inputs. Any gain or phase mismatch in the preceding analogue circuitry will impair the discrimination between upper and lower sidebands.

adaptation of the more familiar baseband sigma delta d-to-a converters found in bit-stream compact-disc players (see panel).

### Oversampling for performance

The basic principle of a sigma delta converter is the closed loop suppression of quantising noise. A simple model of such a converter is shown in Fig. 3. Bandpass filter A is designed to have high gain at the IF. Closed loop analysis then shows that noise added by the quantiser is heavily suppressed at the output, typically by a magnitude similar to the open loop gain.

The spectrum of a typical output of such a converter is shown in Fig. 4. Quantising noise is heavily attenuated around the IF, giving far improved resolution of the encoded signal. Provided that a multi-bit quantiser is employed then the system is easily analysed, modelling the quantiser as a linear gain with the addition of quantising noise.

The situation is far more difficult when a single bit quantiser, or comparator, is used, since the open-loop gain is not defined in any meaningful sense. The open-loop responses of such converters are highly non-linear and conventional control theory is of limited or no use. The basic principle of suppression of the noise at those frequencies of high open-loop gain still applies, but keeping the closed loop stable becomes more of a challenge.

The design of stable single bit converters may be approached in a number of ways, such as search algorithms which aim to minimise the measured inband noise, or by use of empirical rules regarding the filter design. The filter A would typically consist of a chain of high-Q resonators, the outputs of which are summed in the required ratio at the input to the quantiser. Neglecting the contribution of the earlier filter stages to this summed total

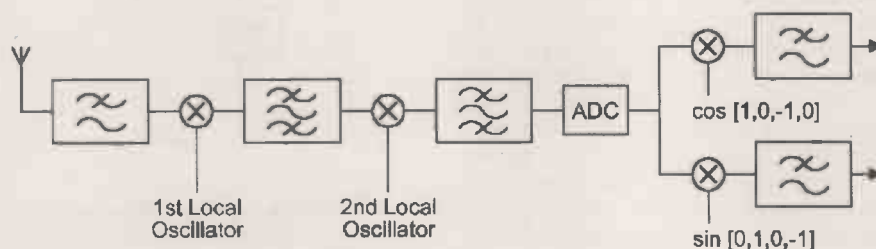


Fig. 2. Low IF a-to-d conversion in a heterodyne receiver. The converter is now resilient to dc offsets since they are removed by the subsequent mixing and filtering stages, and the match between the I and Q paths may be made arbitrarily accurate since they are processed purely in the digital domain.

would simply result in instability.

Also, to more evenly suppress the quantising noise across the passband, the individual resonators would typically be tuned to separate frequencies across the passband rather than together at the centre, giving an equi-ripple response to the passband. Finally, note that since the quantiser also samples the output of the loop filter at the main sampling frequency, it is the sampled pulse response of the filter. This is important, and the response of the filter between sampling instants has no effect on the noise shaping or stability.

### Second-order conversion

A second-order bandpass sigma-delta converter is shown in Fig. 5. This converter is implemented using continuous time LC resonators, two current-steering d-to-a converters, a sampled comparator and some digital delay. Sampled pulse response of the filter measured at the input to the comparator is designed to be  $(2+n/2) \times \cos(\pi n/2)$ , which is standard for use in a second-order bandpass converter.

The  $2 \times \cos(\pi n/2)$  component is synthesised in the first resonator as the simple ringing of

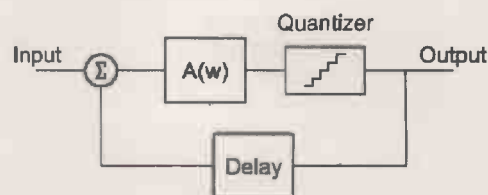


Fig. 3. Simplified model of sigma delta a-to-d converter. Here the sigma delta converter is depicted as a simple negative feedback loop, where the in-band quantising noise is suppressed at the output by the action of the gain stage  $A(\omega)$  in the feedback loop. The quantiser can be reduced to a sampled comparator, provided  $A(\omega)$  is properly selected.

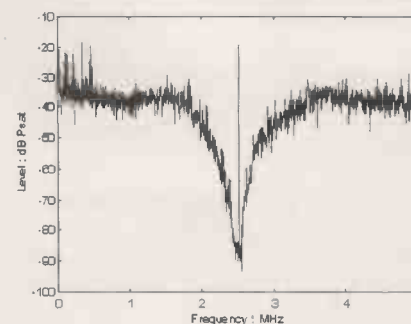


Fig. 4. Output spectrum of second-order single-bit bandpass sigma delta a-to-d converter. Developed at the Marconi Research Centre, the a-to-d converter generated a 10MHz single-bit output. 16384 samples were captured, windowed and FFT'd on a pc to show the spectral content, with a large signal in the notch and the quantising noise shaped away from the passband. The output would normally be mixed to baseband, low-pass filtered and then re-sampled at a lower sampling frequency.

## Sigma-delta conversion

Sigma delta conversion is intrinsically a narrow-band technique employing a high degree of oversampling with a closed loop quantisation-noise shaping circuit to give enhanced performance over a small fraction of the Nyquist bandwidth. The technique is generally used with a single bit quantiser, since the resulting circuit is very simple and may be made extremely linear. The linearity stems from this use of a single bit d-to-a converter.

In a multi-bit d-to-a converter, each level must be replicated accurately with respect to the other levels, and also consistently, without variation. In a single-bit d-to-a converter, each level must be replicated consistently, but the absolute level of the signal has no effect on the linearity, just on the overall gain, since two repeatable points, however positioned, always lie in a straight line.

Although originally developed as a baseband conversion technique, several institutions have developed bandpass variants over the last few years which are now finding application in various radio products. The design of such bandpass a-to-d converters is considered in this article.

the filter in response to the pulse from the d-to-a converter. The  $(n/2) \times \cos(\pi n/2)$  component is synthesised in the second resonator as the growing response to its sinusoidal input; the output of the first resonator. The two components are then added, the first as the voltage across  $R_1$ , and the second component as the voltage across the second resonator.

The composite signal is then reproduced across  $R_2$ , where the corrective pulse from a second d-to-a converter is added to give the composite pulse response shown in Fig. 6. The correction d-to-a converter is required to supplement the main response for the sample at  $n=0$ , since the main converter is still active at this stage and has only imparted one half-unit of charge into the filter, leaving it deficient in amplitude and requiring correction.

The overall result is a continuous-time filter response with the required sampled pulse response. The output spectrum of this converter is shown in Fig. 4.

Delay around the loop is set to be two sample periods, measured from the initial sampling of a pulse, through the digital delays in the feedback path, to the centre of the d-to-a converter pulse and consequently to the  $n=0$  position in the synthesised filters pulse response. This delay corresponds to exactly one half of a wavelength at the IF, since the IF is one quarter of the sampling frequency.

Half-wavelength phase inversion around the loop is used to constitute the negative feedback, rather than the use of the inversion usually found at the input summing node of a baseband negative feedback loop. Correct maintenance of this loop-delay is required to ensure best performance.

An incorrect delay would give the converter an unwanted natural resonance, degrading the inband performance and amplifying the quantising noise at the resonant frequency. If the loop delay is too far out, instability can result.

**Frequency and bandwidth**

The performance of such second-order a-to-d converters is a function of the sampling frequency and of the bandwidth of the converter. Simulation results show that the inband noise power density at overload is approximately given by

$$NPD = -30 - 50 \log(F_s) + 40 \log(Bw) \text{ dBO/Hz,}$$

where  $F_s$  and  $Bw$  are the sampling frequency and bandwidth in megahertz, and the overload point of the converter is 0dBO. Performance at lower signal levels is some 2dB better.

This equation is slightly subjective in that the overload point is not well defined, as it is for a conventional multi-bit a-to-d converter, and the actual choice of the overload point may be made differently for different applications. Also, the equation assumes that the Q-factors of the filters are extremely high, and in practice some loss of performance will always result from the use of damped resonators.

One method to enhance the performance for a given sampling frequency and bandwidth is to raise the order of the converter. However,

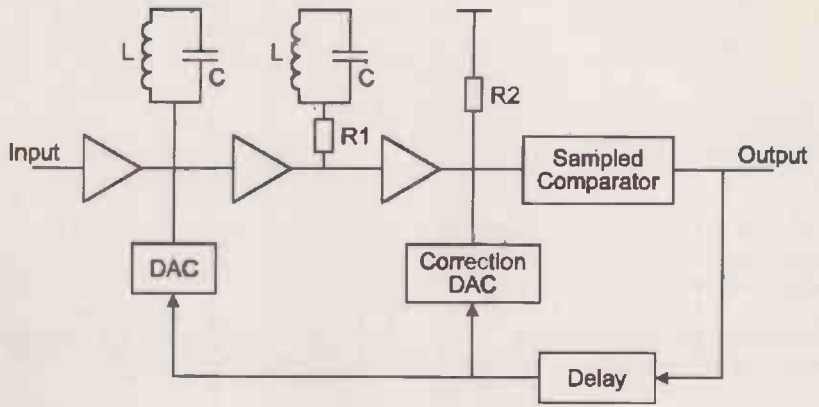


Fig. 5. Second order bandpass sigma delta a-to-d converter. Resonant characteristic of the pulse response is synthesised in the tuned circuits and across  $R_1$  in response to current pulses from the d-to-a converter. The correction d-to-a converter is necessary to supplement the pulse response at the first subsequent sampling instant, as shown in Fig. 6.

this cannot be achieved without providing additional protection against overload, since converters of order three or above cannot be guaranteed to automatically recover from an overload condition. Enhanced suppression of noise derived from the extra filter stages is obtained at the expense of lowering the overload point of the converter, until eventually the converter is unconditionally unstable.

One method of providing the overload protection is to include overload detect and reset circuitry, and this method is often used in audio converters. The audio signal is arranged to naturally limit before reaching the overloading amplitude. If the a-to-d were allowed to overload then the result would be an audible click as the converter is reset.

A more elegant means of protection is shown fitted to a third order bandpass converter in Fig. 7. In this arrangement two discrete signal paths are provided through from the main d-to-a converter to the input of the comparator. One unlimited path for first and second-order filtered components which cor-

responds exactly to the total filter path of the previous second order converter, and one limited third order path where the signal is passed through a limiting amplifier before being recombined with the first and second order components.

Behaviour of the second-order unlimited modulation process is to naturally suppress the signal which has built up in the third resonator, until the converter is no longer in an overloaded condition. Performance of the converter during this process lies somewhere between that of a pure second and pure third order converter, and so initially would seem to compromise the performance that can be achieved with an unlimited third order configuration. This is not in fact the case.

Behaviour of the second-order unlimited modulation process is to naturally suppress the signal which has built up in the third resonator, until the converter is no longer in an overloaded condition. Performance of the converter during this process lies somewhere between that of a pure second and pure third order converter, and so initially would seem to compromise the performance that can be achieved with an unlimited third order configuration. This is not in fact the case.

**Exceptional overload performance**

The performance obtainable exceeds that of an overload detect/reset converter because of the position of the limiter within the architecture.

Output of the limiter is applied directly to the input of the comparator, and hence any noise generated by the limiting process is shaped by exactly the same sigma delta process that shapes the quantising noise. Consequently, even if the limiter is frequently activated, the initial rise in the inband noise level is trivial. For this reason the level of the third order component in the filtered signal can be raised to such an extent that the basic third order sigma delta process would be unstable, and the limiter is relied upon completely to retain stable behaviour.

The additional noise suppression achievable

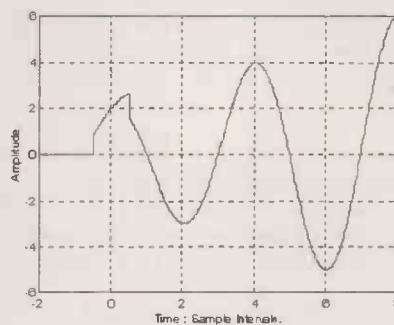


Fig. 6. Synthesised pulse response in second order sigma delta. Desired impulse response is [2, 0, -3, 0, 4, 0, -5, 0, ...]. This is successfully synthesised in the resonators of the converter shown in Fig. 5. Discontinuity seen around  $t=0$  is caused by the correction d-to-a converter switching on and off, necessary to boost the first sample to its required value of 2.0.



by raising the third order filtered component this high outweighs the additional noise generated by the limiting action. Hence, a net improvement in the performance is obtained.

Simulations have shown that an extra 3dB of noise suppression can be achieved using this technique compared to overload detect/reset circuits, though the latter retain their performance for longer as the input signal is raised to overload.

The in-band noise level of the converter shown in Fig. 7 is given approximately by,

$$NPD = -70 \log(F_s) + 60 \log(BW) \text{ dB/Hz}$$

at overload, and approximately 6dB lower at lower signal levels. The advantage over a second-order system thus depends on the bandwidth and sampling frequency used. Note also that the penalty for using damped resonators is greater in the third-order case, and thus the full advantage will seldom be achieved. However, the benefits of the higher order architecture are generally found to be worth the extra circuitry.

A second way to enhance performance is to perform noise cancellation, Fig. 8. The filtered error signal of a first a-to-d converter is encoded in a second converter. Subsequently, the second signal is filtered with the inverse of the error filter then added to the output of the first converter. The net effect is to cancel the error present in the output of the first converter, leaving only the error introduced by the second converter.

By placing gain in the error filter it is ensured that the errors of the second converter are at a lower level than those of the first, and an improvement of typically 30dB can be obtained in a practical system. This method can be used to obtain extremely high performance from a converter, but there is a significant processing overhead required to implement and sustain the digital inverse of the error filter.

If a fixed equalising filter is used then the degree of cancellation which can be obtained is limited, whereas to achieve the figure of 30dB requires that the characteristics of the error filter are measured. This is done by applying a calibration signal to the main d-to-a converter of the first converter, and the inverse filter derived from the calibration measurements.

All of the above converters have single-bit outputs requiring decimation filters and digital mix to baseband to obtain a more useful signal. Typically, after mixing to baseband, the signals would require decimation by between 32 and 128 to reduce the sampling rate to the Nyquist rate of the baseband signal. Such filters are not considered here.

### Discretely biased

The techniques described are biased towards discrete implementation, which may not be the best approach for all applications. It does however yield performances which may be difficult to achieve in an integrated circuit, and at intermediate frequencies certainly as

high as 70MHz and possibly higher still.

Integrated versions of these can be made using switched capacitor circuits, or by implementing the resonators with state variable filters based on op-amps. Switched capacitor circuits and op-amps tend to have relatively high noise figures. As a result, additional gain may be required when dealing with low level signals, requiring more power. The gain may additionally cause distortion and degrade the blocking specification of the receiver.

An example of a commercial application of a bandpass sigma-delta converter is the GEC-Marconi Communications H2550 digital hf receiver, which employs two third-order bandpass sigma delta converters in a noise cancellation configuration. The sam-

pling frequency is 10MHz and the converters operate on an intermediate frequency of 2.5MHz. The overload point of the converters is -13dBm, and they achieve a noise figure better than 16dB and a third order intercept point better than 28dBm.

The converters are implemented with discrete components and achieve their performance with high-linearity low-noise rf circuitry. In a fully integrated form, though, there are many available baseband sigma-delta a-to-d converters.

I am not aware of any bandpass equivalents currently on the market. Several IC design companies are, however, known to be engaged in their design, and we look forward with interest to their release. ■

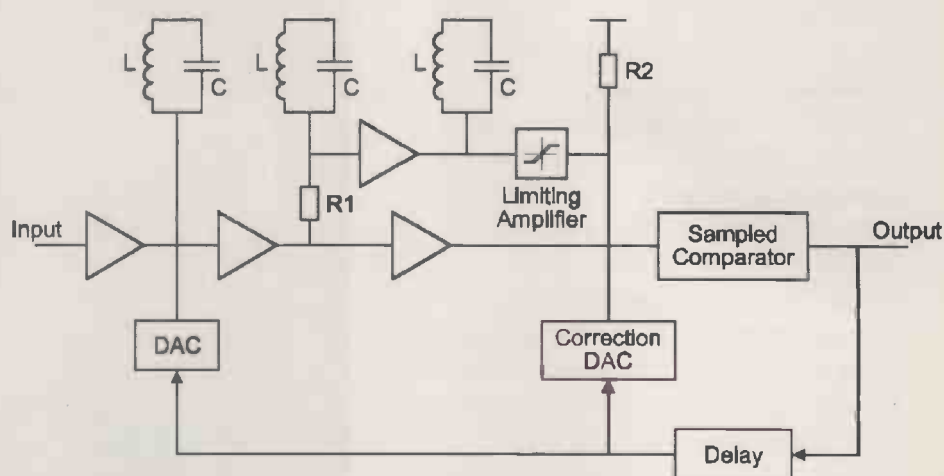


Fig. 7. Third order bandpass sigma delta a-to-d converter. This is similar to the second order converter of Fig. 5, but with the addition of a limited third order resonant path. The limiter prevents the converter from locking into an unstable mode during an overload. This is just one means of stabilising higher order converters, but a particularly quiet one since any noise generated by the clipping action of the limiter is shaped out-of-band by the sigma-delta action.

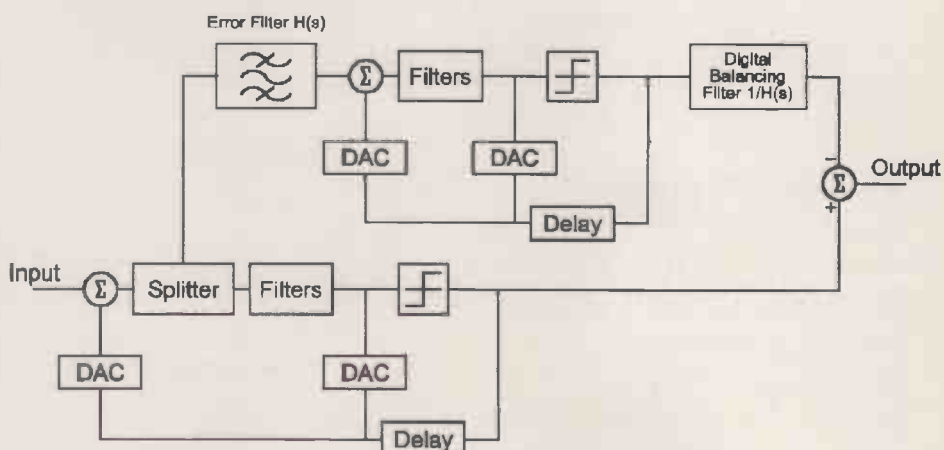


Fig. 8. Twin loop sigma delta converter with noise cancellation. Error produced by the first a-to-d converter is subsequently encoded by a second converter, and then the two signals are subtracted digitally to give enhanced performance. The penalty is the need to reciprocate the phase and amplitude response of the analogue error filter in the digital balancing filter. Consequently either a calibration routine or a high tolerance filter must be used.

# READER OFFER

## Temperature controlled soldering station – over 20% EW reader discount

SL-20 is a temperature-controllable soldering station with bar-graph temperature display and a control range of 150 to 420°C.

As a limited offer, Vann Draper is offering this CE approved unit to *Electronics World* readers at the special price of £55 – fully inclusive of VAT and delivery – representing a discount of over 20%. Normally, the SL-20 sells at £59, excluding VAT and delivery.

Featuring an iron-coated 1.6mm interchangeable tip, the SL-20 has a 48W element providing rapid warm up and fast thermal response. Temperature feedback is via a sensor within the iron's body.

The SL-20's electronic control/display system allows temperature accuracy to be obtained to within  $\pm 10^{\circ}\text{F}$  of the selected setting.

Mains requirements for the SL-20 are 220/240V and 50/60Hz. Operating at 24V, the iron itself has a groundable tip for safe soldering of esd-sensitive components. Each SL-20 is supplied with 1.6mm tip, mains lead, operating instructions and a 12 month guarantee.

### Key specifications

Control range	150-420°C (300-790°F)
Accuracy	$\pm 10^{\circ}\text{F}$ of setting
Heating power	48W
Iron voltage	24V
Display	12 point LED bar
Size	170 by 120 by 90mm
Weight	2kg
Enclosure	Light grey ABS
Mains supply	220/240V, 50/60Hz
Guarantee	12 months



## Use this coupon to order your SL-20

Please send me:

- |                                    |                       |
|------------------------------------|-----------------------|
| .... SL-20 soldering station(s) at | £55 fully inclusive   |
| .... extra 1.6mm bit(s) at         | £1.53 fully inclusive |
| .... 0.8mm bit(s) at               | £1.53 fully inclusive |
| .... 3.2mm bit(s) at               | £1.53 fully inclusive |

Name

Company (if any)

Address

Phone number/fax

**Total amount**

£.....

Make cheques payable to Vann Draper Electronics Ltd Or, please debit my  
Master, Visa or Access card.

Card type (Access/Visa)

Card No

Expiry date

Signature

Please mail this coupon to Vann Draper Electronics, together with payment. Alternatively fax credit card details with order on 0116 2773945 or telephone on 0116 2771400. Address orders and all correspondence relating to this order to Vann Draper Electronics at Unit 5, Premier Works, Canal Street, South Wigston, Leicester LE18 2PL.

\*Overseas readers can also obtain this discount but details vary according to country. Please ring, write or fax to Vann Draper Electronics.

# SUBSCRIBE TODAY

And Electronics World will help you keep the leading edge

**EVERY MONTH**  
- the best writing on  
*Electronics design applications*

**ELECTRONICS WORLD**  
INCORPORATING WIRELESS WORLD



**1 Year £30 UK, £43 Europe, £52 Row**

**2 Years SAVE 25% £45 UK, £65 Europe, £75 Row**

**Phone: +44 01444 445566, Fax (+44) 01444 445447**

## SUBSCRIPTION FORM

**YES, I WOULD LIKE TO SUBSCRIBE TO ELECTRONICS WORLD**

Name \_\_\_\_\_  
 Job Title \_\_\_\_\_  
 Company Name \_\_\_\_\_  
 Address \_\_\_\_\_  
 \_\_\_\_\_  
 Postcode \_\_\_\_\_ Country \_\_\_\_\_  
 Telephone \_\_\_\_\_ Fax \_\_\_\_\_

### PAYMENT DETAILS

1 year £30 UK     £43 Europe     £52 Rest of World  
 2 years £45 UK     £65 Europe     £75 Rest of World  
 Please invoice me/my company. Purchase Order N° \_\_\_\_\_  
 I enclose cheque made payable to Electronics World \_\_\_\_\_  
 Please charge my Visa/Access/Amex/Mastercard

Expiry date \_\_\_\_\_

Signature \_\_\_\_\_

Please tick box if you do not wish to receive promotions from other companies.

UK RETURN ADDRESS: Electronics World, Freepost CN 2619, Reed Business Publishing, 9th Floor, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5BR.  
 REST OF WORLD: ELECTRONICS WORLD, Reed Business Publishing, 9th Floor, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS, UK.

SBS

022

# Improving power-factor

Dedicated ICs can correct power factor to 98% but since they output dc, they are not much use for improving existing supplies. Irving Gottlieb describes the passive alternative.

The power-factor concept involves the phase relationship between two waveforms. Normally, these are the sinusoidal-voltage wave from the ac power line and the resultant sinusoidal-current wave consumed by the load, Figs 1a, b.

Figure 1a shows the relationship with a purely resistive load. Voltage and current waves are in phase and there is no angular displacement between them.

In this ideal mode of operation, unity power-factor is realised. This derives from the definition of power-factor which is cosine  $\theta$ , where  $\theta$  is simply the angular displacement – i.e. phase – of the zero-crossings of the waves in the manner illustrated in Fig. 1b. Note that in Fig. 1a,  $\theta$  is zero, so cosine  $\theta$  is 1.

In Fig. 1b, the current wave lags the referenced voltage wave by the angle  $\theta$ , which now is appreciable, at around  $60^\circ$ . Power-factor, that is the cosine of  $60^\circ$ , is 0.50. Such a low power-factor would be caused by an inductive load, such as a lightly-loaded induction motor.

Because of the motor's reactance and attendant poor power-factor, utility companies are obliged to supply about twice the line current that would be needed for unity power-factor operation. This decreases the efficiency of power transmission, increases costs and plays havoc with voltage regulation. It also causes temperature rise in transformers, and can upset

the performance of circuit breakers and fuses. In addition, the customer finds that the amount of power obtainable from the wall socket is reduced relative to that available at unity power-factor operation.

Although this information is old-hat to most electronics designers, confusion often sets in when one or both of the waves are non-sinusoidal. This is not surprising, for the consequences are easily misinterpreted. Consider the following situations.

## Non-sinusoidal waveform problems

In Fig. 2a, it would be natural enough to see a unity power-factor by virtue of the simultaneous zero-axis crossing of the voltage and current waveforms. However, the many odd-harmonics comprising the square current-wave only partially satisfy this criterion. As a result, the ac line would see a lower than unity power-factor and extra current would have to be supplied in order to accommodate the harmonic energy.

As far as power-factor is concerned, it is as if physical reactance were present in the load. Having digested the nature of the waveform combination in Fig. 2a, confusion may still occur. Consider Fig. 2b, involving triac waveforms with a resistive load. It turns out that the power-factor at the load is always unity because the waveforms of load voltage and load current – although non-sinusoidal –

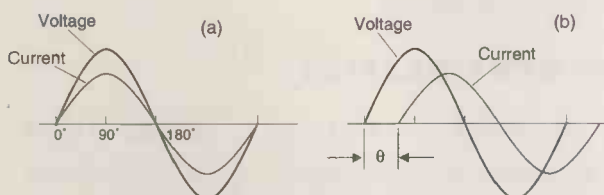


Fig. 1. Power-factor traditionally dealt with sinewave relationships. a) Unity power-factor exists when the sine waves representing impressed line voltage and the resultant line current are coincident. b) When one of the sinewaves leads or lags the other, the power-factor is defined as the cosine of angle  $\theta$ .

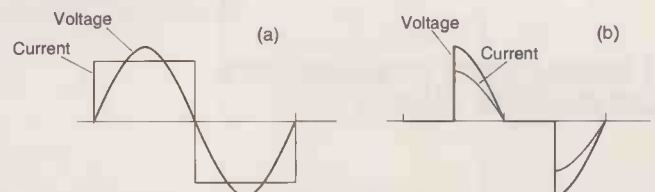


Fig. 2. Power-factor evaluations with non-sinusoids can be deceptive. a) The sinewave and the squarewave cross the zero-axis at the same times. But unity power-factor does not exist. The unseen harmonics in the squarewave are generally out of step with the sinewave, thereby lowering the effective power-factor. b) Voltage and current waves in the resistive load of a thyristor are identical. Even though these chopped waves are non-sinusoids, the load power-factor is unity.

always have the same shape. As a result, they also have identical percentages and phases of harmonic content.

This is not so from the ac line's point of view. Here, the comparison is between the sinusoidal line-voltage and the non-sinusoidal line-current. When adjusted for fractional load power, the line power-factor of triacs can be painfully low. And the situation is even worse for single scr control circuits, where even-harmonics are present in the line-current.

**Power factor in psus**

In Fig. 3, waveforms 1 and 2 are characteristic of the full-wave or bridge rectifier circuits generally found in power supplies. Note the narrow and peaked haversine current-wave. This corresponds to a low power-factor, usually about 0.63, or 63%.

Considerable third-harmonic energy is injected back into the ac line and various equipments can malfunction from the electromagnetic interference. The peak current can cause excessive errors in certain measuring instruments too.

If the excessive third-harmonic current in the peaked wave can be prevented from flowing, trapezoidal waveform, no. 3 in Fig. 3 results. This is not an ideal modification, but it can yield a power-factor in the vicinity of 85% – a significant improvement over the 'natural' 63% power-factor of power supplies.

The advantage of the trapezoid stems largely from the reduction of the dead-angles clearly evident with the narrow haversine wave. This waveshape modification is brought about by insertion of a parallel-resonant tank-circuit in one of the leads between the ac voltage-source and the rectifier bridge, Fig. 4. Note that this tank must resonate at the third-harmonic of the line-frequency.

**Implementing the technique**

Optimisation of this technique will probably require empirical effort. Certain inherent contradictions must be balanced. For example, the tank circuit should have both, high resonant-impedance and high Q. These parameters are mutually antagonistic.

I have determined that a good start is to target the resonant impedance for 300Ω. This works well for off-line supplies in the 20-40W range. Use is made of the relationship,

$$Z_o = \sqrt{L/C}$$

where  $Z_o$  is the resonant impedance in ohms,  $L$  is the inductance in henries, and  $C$  is the capacitance in farads. The trick is to simulta-

neously satisfy the resonance equation,

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

where  $f_o$  is 150Hz for 50Hz lines, and 180Hz for 60Hz lines. Doing this is not difficult if you start with an inductance of approximately 300mH. Note that  $f_o$  must be exactly the third-harmonic of the power-line frequency.

With  $L$  at about 300mH, choose  $C$  arbitrarily. Thereafter, the value of  $C$  can be adjusted to obtain best results. More about adapting for different power-supply ratings later.

The inductor's Q is governed by the  $C/L$  ratio and by ohmic, eddy-current and hysteresis losses. In light of this, best performance may not be obtained from ordinary 50/60Hz silicon-steel cores with E-I laminations. Tape and powdered cores – especially toroids – tend to be better prospects.

Admittedly, this simple technique falls short of the performance attainable from active harmonic-suppression. The active alternative causes the current wave to follow the sinusoidal voltage-wave much more closely, improving power-factor to 98% or more. However, dedicated power-factor correction ICs usually deliver several hundred volts of dc. As a result, they are not applicable for improving the power factor performance of most existing power supplies.

**An alternative correction scheme**

Another comparison can be made with the scheme shown in Fig. 5 which has been suggested in other literature. In principle, the energy storage of a large, high-Q shunt connected tank circuit can present an essentially resistive load to the ac line, producing a good power-factor. In practice, such a resonant circuit must operate at line frequency and certainly must store much more than the consumed energy of the power supply. As a result, unreasonable demands are imposed on the size of the core, and on the resonating capacitor. Besides, such a scheme could be vulnerable to damage from third-harmonic energy already on the power line.

So, all things considered, the simple passive harmonic-suppression technique described here can fill the niche where substantial improvement – rather than near perfection – is acceptable. Whereas the approximate LC values depicted in Fig. 4 apply to a nominally 30W supply operating from 120V, appropriate scaling factors can be used for other arrangements. If, for example, the supply operates from 12V, a 30mH inductor would be resonated by a capacitance of around 30μF. ■

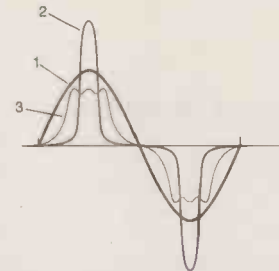


Fig. 3. Power supply waveshapes. 1) Line voltage sine wave. 2) Typical line current due to full-wave rectifier. 3) Line current after attenuation of the third harmonic by resonant tank. The near trapezoidal current results in a higher power-factor than the peaked wave of 2).

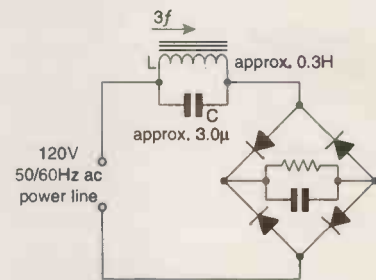


Fig. 4. Basic technique for power-factor improvement of a 30W supply. Passive method makes use of a third-harmonic wavetrap. Approximate LC values are shown. Exact third-harmonic resonance is required for optimum effectiveness. This will be 150Hz for 50Hz power lines and 180Hz for 60Hz lines. For a 30W supply, the resonant impedance,  $\sqrt{L/C}$  is about 300Ω. Scaling factors may be used for supplies of other ratings.

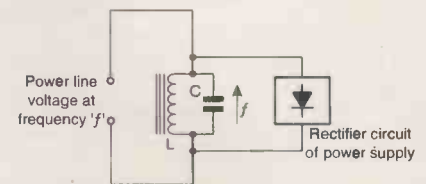


Fig. 5. Theoretically valid, but impractical method for power-factor improvement. This technique also makes use of the frequency selective energy storage of a resonant tank. However, in this case, the LC circuit must be tuned to 'f', the frequency of the power line. Moreover, energy storage must be great enough so that the resonant Q is not appreciably depleted by the rectifier load. Because of these requirements, oversized core dimensions and capacitor values are needed for all but the smallest of power supplies.

# LETTERS

Letters to "Electronics World"  
Quadrant House, The Quadrant,  
Sutton, Surrey, SM2 5AS

## Golden ear tarnished

Some people may observe that in the past I have been harsh in my criticisms of 'Golden Ear' persons, who claim that they can hear magical differences between different types of speaker cables and audio interconnect cables.\* However, I am prepared to criticise equally sharply, those who unfairly criticise 'high-end-audio' enthusiasts.

In the *EW+WW* of December 1995, pp. 1012-1013, the Reg Williamson states that "...exotic components – whether passive or active – are a waste of money," in his simple audio preamplifier circuit. (In this case, one simple preamp/one control circuit was constructed with inexpensive components, and another preamp was built with the same nominal circuit, but with 'exotic' or 'highly expensive' components.)

In 224 out of 248 listening tests, the listeners said they could not hear any difference. The writer said, therefore, that "... exotic components... are a waste of money".

Firstly, let me state that I have tin ear, and while I am accused of having bad hearing primarily by my wife, I can still hear everything I need to. Yet I cannot easily distinguish between different audio processes, by listening. I probably did too much lawn-mowing when young. But I am still capable of thinking.

It may be true that for most people, it is a generally poor investment to buy audio equipment built with 'exotic components'. But it is quite unfair to argue that nobody should ever spend money on the best quality components.

Of the 24 listeners who could tell the difference between the fancy-parts preamp and the cheap-parts preamp, there might be eight people who could hear a difference, but could not tell any preference. There might be eight others who could hear a little difference, but did not think the cost worthwhile. But there might be eight others with sophisticated tastes in audio equipment, and really good ears –

\*"What's all this Speaker Cable Stuff, Anyhow?", Robert A. Pease, *Electronic Design*, 15 May 1996.

and they might consider it an extremely wise investment to buy a piece of audio equipment that sounds better. I can't say they are wrong, and Mr. Williamson is wrong to say that they are wrong, to prefer a more costly preamp.

It may be true that for most people, costly components are a waste. But for the author to assert that it is wrong for everybody or for any thinking person – and especially by readers of your pretty-good magazine. First point made.

Second point: the author indicates that he made two preamps, one with inexpensive parts and one with fancy parts, and a few people could discriminate between the two. But the author does not indicate what differences were made in the parts list. He implies that some active components were different, and some passive components were different. He implies that blind or double-blind tests were made. And some listeners could hear a difference.

But the original circuit used inexpensive *TL071* and *TL072* operational amplifiers. I have no doubt that a trained ear might be able to hear some small but significant difference between a good, low-noise audio op-amp and the inexpensive ones as specified in the original circuit.

I am willing to believe that some components may make a real difference in the audio quality. I believe, for example, that the active components – the op-amps – may make a discernable difference – maybe not by me – and maybe not by 90% of the people – but by some people. For example, two different op-amps might have the same amount of harmonic distortion, but completely different transient intermodulation distortion performance. It's not reasonable to expect different op-amps to sound the same. Point two made.

Point 3: I am also prepared to argue that when other expensive passive components were substituted, probably nobody could tell the difference. Let's say that if you change one capacitor from Mylar to polypropylene or to Teflon,

nobody can tell the difference.

Let's say there is a possibility that if all the capacitors were changed from Mylar to Teflon, nobody could tell the difference, in double-blind testing. If the resistors were all changed from cheap carbon resistors to fancy metal films, in most circuits, nobody can hear a whit's worth of difference. But if the op-amps are changed, perhaps 9% of listeners could tell a difference. So, maybe some exotic components are a waste of money. And maybe some are not.

If the op-amps are installed in sockets, it might get really interesting to take the cheaply-built preamp, and substitute high-quality op-amps. And it might be interesting to take the 'exotic' preamp and swap in the *TL072s*. Now which one sounds good, which one sounds like the straight-through wire, and which one sounds odd?

So I argue that it was quite unfair for the author to condemn the use of 'exotic components' on a blanket basis. It is just as unfair to condemn ultra-hi-fi audio equipment, with no scientific or subjective evidence, and without any critical thinking, as it is for the 'Golden Ear types' to praise some components with no scientific or subjective evidence and without any critical thinking.

Robert Pease  
California

## Funny you should mention it

Your Update page headline 'EMC all over again', p. 444, June '96, brought a wry smile to my face.

Yes, I took notice of the DTI during the EMC Awareness Campaign, heeding the warnings like 'If your product is not compliant, you will be out of business'; yes, I approached my MD and explained what we would have to do; yes, my MD allocated me an extra budget with which to purchase test equipment. And, after all that I worked my butt off in order to make 501 products compliant in four years.

Now, can someone tell me, when will all of these non-compliant companies be out of business? Many of my colleagues have laughed themselves silly at me, telling me that nothing will ever come of it all.

Who is laughing now, six months on? Certainly not me. Yes, I know that the Directive is complaint driven. I am sick of telling TSO's about non-compliant products.

CE marking for the LVD becomes mandatory on 1 January 1997. I see a lot of products coming into our service department – even products from big name manufacturers – which would not stand a chance of meeting the requirements of the LVD. Indeed, I was present at the main trade show for my particular trade this year at Frankfurt. I saw many thousands of none CE marked products there, and I saw a lot which should not have been marked, but were. Not once in the seven days I was present did I see a Bundesamt für Post und Telekommunikation (BAPT) official (the German equivalent of a Trading Standards Officer), or a Customs official, checking product compliance.

One product which sticks in my mind – a high powered stereo audio amplifier made by a well respected manufacturer – was emblazoned with the CE mark letting the world know it was compliant. On the rear panel, next to the CE mark were a pair of gold-plated, uninsulated 4mm binding posts – a direct contravention of Clause 15.1.2: EN60065: 1994. There is no way that such a unit could be compliant with the existing electrical safety regulations, or the LVD.

So, will I worry about the LVD for 1997? No. All of my products have been compliant for years. Will my competitors worry about it? Very unlikely.

K. C. Aston  
Leeds

## Agree to disagree about valve sound

Referring to Letters in the April issue, I hope that Nick Wheeler and I can agree to disagree about 'valve sound'. But if he happens to have a vintage Bentley, then perhaps I should offer to swap him a Ford Mondeo.

McFadden's intuitive explanation of the operation of the concertina phase splitter is elegant, but I was unable to immediately reconcile it with the Thévenin model. Rather than theorising, the conflict seemed to be most easily resolved by

experiment. If the equation he quotes is correct, then  $r_{out}$  should tend towards  $1/g_m$ , resulting in extremely wide bandwidth into a representative load of 100pF. I therefore deliberately selected a valve with low  $g_m$  (Mullard ECC83) in order to make the measurement more manageable.

The first test was to determine whether the bandwidth at cathode was equal to that at the anode, so a 500kHz square wave was applied, and both outputs monitored. As you see from the diagram, the outputs are virtually identical, proving that the output resistances are equal. Channel 2 was inverted to make comparison easier. The slight noise on the anode (lower) trace is a consequence of power supply hum which was incompletely removed by the averaging function of the oscilloscope.

The next test was to determine the output resistance by measuring the bandwidth, so a 1Vpk-pk 1kHz sine wave was set at the cathode output, whose frequency was increased until the level fell to 707mV. The -3dB cut-off was at 2.23MHz as measured by an external frequency counter.

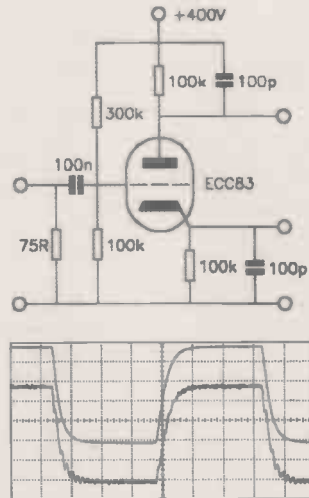
A load line was then drawn, and values of  $\mu$  and  $r_a$  at the operating point were predicted from the anode characteristics given in the Mullard Technical Handbook.

The value of  $r_a$  is around 67k $\Omega$  and  $\mu$  is about 100. Inserting these values into the Langford-Smith equation,  $R_{out}$  equals  $r_a R_L / (R_L(\mu+2) + r_a)$ , predicted an output resistance of around 650 $\Omega$ . Input capacitance of the oscilloscope probes was 12pF, so the total shunt capacitance was 112pF. Predicted bandwidth was therefore 2.19MHz, agreeing very well with measurement.

Mr McFadden is therefore correct. My understanding of the operation of the concertina phase splitter into equal loads was wrong, and I thank him for spurring this investigation. Unfortunately, I like to know where my equations came from, and why, but found that even Langford-Smith did not offer a derivation. As a result, I offer the following line of thought for comment.

The concertina operates with negative feedback, which we would normally consider to increase  $r_{out}$  at the anode, but experiment shows that it is actually reduced. The general feedback equation is  $A$  equals  $A_o / (1 + \beta A_o)$ , and the gain of a triode is  $A$  equals  $\mu R_L / (R_L + r_a)$ .

The denominator of the feedback equation is the factor by which



Morgan Jones' phase splitter with 100ns/div output curves for a square wave. Curves show minimal difference between the two outputs. Channel 2 is inverted to help comparison.

resistances are changed. Letting  $\beta=1$  ( $R_k=R_a=R_L$ ), and substituting in the triode gain equation gives a feedback factor of  $R_L(\mu+1) + r_a / (R_L + r_a)$ .

Output resistance,  $r_{out}$ , of a common cathode triode amplifier with no feedback is  $R_L r_a / (R_L + r_a)$ . If the feedback is actually working to reduce the output resistance at the anode, then this value must be divided by the feedback factor:

$$r_{out} = R_L r_a / (R_L + r_a) \times R_L + r_a / (R_L(\mu+1) + r_a)$$

The  $(R_L + r_a)$  terms cancel, leaving:

$$r_{out} = R_L r_a / (R_L(\mu+1) + r_a)$$

This is almost identical to the Langford-Smith equation, but for a factor of  $\mu+1$  rather than  $\mu+2$ ...

A can of worms has been opened here, since we now have a phase splitter whose output resistance changes with loading. If the concertina is loaded with a Class B stage, then at any instant only one valve will be switched on, and since the input capacitance is made up largely of Miller capacitance, only one output of the concertina will be loaded capacitively at a time, the output resistances revert to those I gave previously (Letters, Mar '96), and the build-out resistor is required.

Although the 'Bevois Valley amplifier' operates substantially in Class A, and should therefore be degraded by a build-out resistor, once output transformer losses at high frequencies are taken into account, feedback will drive the

output stage into Class B at high frequencies, thus explaining the improvement in square wave performance seen in the prototype.

If a concertina is driven into a low level driver stage, then a build-out resistor is undesirable, but if driven into a higher level stage (which may enter Class B, and whose gain, and Miller capacitance change with level), then a build-out resistor may be required. The value of this resistor might need to be tailored for a specific output transformer, but the theoretical value offers an upper limit.

As to the question of balancing signal currents, the mistake is entirely mine, and although I will not be modifying the amplifier shown in the illustrations (because it sounds so good), a fourth version currently under construction will be modified. To round off, the (somewhat extensive) component changes would be as shown in the table below.

Morgan Jones  
Southampton

### Testing, testing 123

There has been a very large response to my article on a high-performance microphone preamplifier and, as many of us know by now, the SSM2016 has made an untimely exit from the market. I must apologise for not ensuring continuing supplies of the device; I obtained some without difficulty quite recently and didn't imagine there would be this level of demand, or lack of supply.

So, the only sensible option seems to be redesigning for the 2017. The noise and distortion performance is not very much worse than the 2016, I was not making use of the 2016's output capabilities, and the other aspects of the circuit - input circuitry, protection, metering, filtering and power supply - remain valid.

I have therefore redesigned the preamplifier board for the 2017, attending to the vital details of keeping input and outputs separated

and ensuring separation of signal and power grounds, and it seems to work very well.

I have also tried out the INA103 which was most helpfully pointed out as an available alternative. It has extremely low distortion - far lower than any available microphone - but it is slightly noisier and unfortunately, like the 2017 and unlike the 2016, it does not give direct access to the input transistors. As a result, they cannot be exactly trimmed for dc balance. This means that with both the 103 and the 2017 you either have to use an electrolytic in series with the gain-setting resistors, upset the input impedances with an external bias circuit or put up with a slight click as the gain is changed.

I have opted to place a very large 1000 $\mu$ F electrolytic bypassed with polyester in the gain-setting section and have to confess I can't reliably hear a difference between this and direct coupling. It would be interesting to know if anyone else can. Offset voltage across the capacitor is less than a millivolt so we would expect 'shelf life' from it.

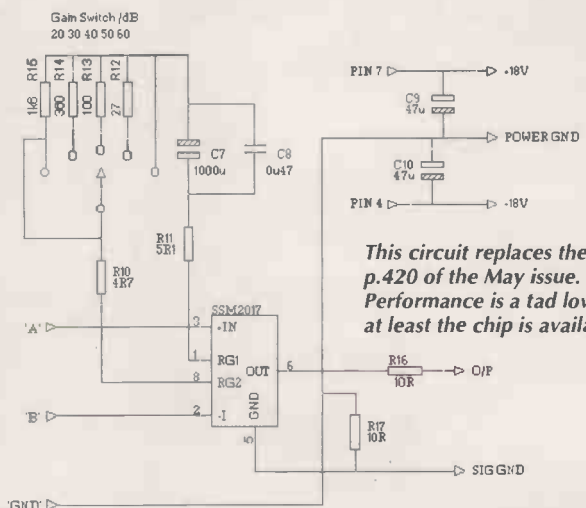
I am having the boards made, single-sided, drilled and tinned. If you would like a set, please send a cheque or money order for £28 (all inclusive) payable to MicroPower Measurements at 4, Elwick Terrace, Hutton Ruddy, North Yorkshire TS15 0DH.

For interest I append the diagram of the preamplifier section incorporating the 2017; all the other parts of the project remain unchanged.

Simon Bateson  
Hutton Ruddy  
North Yorkshire

### Better windows

In the April issue, Phil Dennis makes the mistake of confusing the multitasking WIMP based paradigm of computing, with Microsoft's rather poor implementation of it in the form of Windows. The British company Acorn has produced a far



This circuit replaces the one on p.420 of the May issue. Performance is a tad lower, but at least the chip is available.

New component values for Morgan Jones' phase splitter							
$V_{HT} = V_1$ ( $I_a = 5.74mA$ )		$V_2$ ( $I_b = 3.22mA$ )					
$R_a$	$R_k$	$R_{fbk}$	$C_{fbk}$	$R_a$	$R_k$	$R_{build-out}$	$C_{shunt}$
4 $\Omega$	33k $\Omega$	678 $\Omega$	1218 $\Omega$	1.8nF	31.88k $\Omega$	31.88k $\Omega$	30k $\Omega$
8 $\Omega$	33k $\Omega$	583 $\Omega$	1722 $\Omega$	1.3nF	31.88k $\Omega$	31.88k $\Omega$	30k $\Omega$
16 $\Omega$	33k $\Omega$	530 $\Omega$	2434 $\Omega$	910pF	31.88k $\Omega$	31.88k $\Omega$	30k $\Omega$

more successful implementation of this method of interacting with computers.

As a user the real test is how much work I can get through in a session, not how fast the clock speed of my machine is, and compatibility means being able to transfer my data between different machines using different processors, not dancing to the tune of Microsoft's cash register.

Les May  
Rochdale  
Lancs

### Mistaken identity

Mr Hopwood (Letters, May '96) has jumped to the conclusion that I was accusing him of belief in anti-gravity and perpetual motion (free energy). As far as I know, Mr Hopwood's only connection with the latter is his suggestion that 'cold fusion' might need to be primed by sunlight (*EW+WW Letters*, Dec. '93). I was, in fact, thinking of Dr Aspden who, readers will recall, believes in this nonsense and has also proposed a 'cyclotron' theory in order to 'explain' the so-called link between electromagnetic fields and disease.

Dr David Fisher  
Cardiff

### Cancer and power

Mr Brown's letter in the May issue of *EW* raises a fair question.

Dealing with Denver first, the surveys I quoted were based on a relationship between power line routing and so-called radiation cancers. Over the past 90 years it has been established that these are different to those induced by uranium mining. The markers for uranium ingestion are lung cancer and other disorders caused by internal alpha particle irradiation

from dust and radon, and are separately classified in the ICD statistics I quoted.

On the matter of statistical quantities, I entirely agree with Mr Brown. The numbers are so small, that like CJD, the only certainty will be a buildup of evidence from focussed research. What is interesting is that areas of the country with high background radiation levels like those on 'young' granite do not have high levels of radiation induced cancers of the types noted in power line surveys. They do have appreciable radon induced cancer levels – hence the Department of Health's ongoing campaign to ventilate those dwellings at risk.

My work and that of other researchers has thrown up the probability that natural ground gamma radiation is not implicated in the apparent link between electric power systems and radiation cancers. The culprit is short range fission products caused by the electrodynamic field round power systems reacting with downcoming high energy solar particles.

Unfortunately the sun has gone off the boil, so we must wait a few years to prove the effect with new and better equipment.

Anthony Hopwood  
Upton-on-Severn  
Worcestershire

### Play nice

Dr Fisher clearly does not like Mr Hopwood. From his reply Hopwood shows that he couldn't care less about that, so good for him. I might not believe his views but I go along with Voltaire.

In my 71 years on this earth I have long ago learned that if one side in a debate or discussion resorts to personal abuse then it is clear that

that person cannot make a case for his views especially when he resorts to lies as well. We see it every day in Parliament.

Who does Dr Fisher think he is to set himself up as superior to Prof. Eric Laithwaite (anti-gravity)? Why doesn't he become an MP? He appears more suited to that occupation.

There is too much 'thought policing' in the scientific community already – not least in *Nature* – and to some extent, I am sorry to say, in *Electronics World*.

Finally, no physicist nor engineer should use the words 'never' or 'impossible' in a predictive sense as it is an open invitation to Murphy's Laws to slap egg on your face in the future.

G.E. Miller  
Hastings  
East Sussex

### On autopilot

Almost exactly three years ago I was one of about twenty-five subjects in an investigation to examine the effects of magnetic fields on human navigation. To be more precise it was an experiment to test what is known to biologists as 'compass' ability.

The researcher has been publishing peer reviewed papers on the subject since 1987 and has written at least one book on it. His work is not universally accepted, but he can be certain that his fellow scientists will not descend upon his laboratory and insist that he repeat the effects he claims forthwith.

That appears to be exactly what happened to Anthony Hopwood, and Dr Fisher wants to use the outcome to discredit any further effects that Mr Hopwood claims to have detected.

Les May  
Rochdale, Lancashire

### Down the garden path

The discussion in *EW* about transistor linearity is – to my mind – somewhat misleading. Douglas Self has repeatedly claimed that the bjt is at least ten times more linear than a mosfet.

But the fact is that the bipolar transistor has the highest non-linearity possible in a silicon device. The current change is  $2.72 (=e)$  times for any 25mV base voltage change, which is so high that it can hardly be seen in a linear scale. The bjt is anything but linear.

What Self is referring to is the linear characteristic of the complementary stage. This is an effect of its large negative feedback. This invisible feedback is nearly 60dB in Class A, an effect of the high gain. Had it been open loop, the gain would be  $100 \times 8$ , which is 800. Now the gain is one. The rest is feedback. Small wonder that the stage is linear. But that is not the merit of the bjt. The linearity is borrowed plumes!

"So what?", you may remark. The linearity is there, at least in Class A. However, one has to be clear, because there is a tremendous difference between bjt and mosfet stages.

Bengt Olsson  
Saltsjö-Boo  
Sweden

### Historical units

I was interested to read the 'Gems and Oddities' described by Ian Hickman in his article 'Circuit Reflections' in the May 1996 issue. It refers to the Jar as the unit of capacitance once used by the Navy and described in the 1925 edition of the *Admiralty Handbook*. Apparently 1 Jar was equal to 1.1 InF.

I came across a similar oddity when working in the laboratories of Standard Telephones & Cables Ltd in the early 1930s. The company made repeater valves for the Post Office Telephone Network and the network had its own unit of attenuation. It was the 'msc'. All the valve test sets, decade attenuator boxes and similar equipment that I used were calibrated in units of msc.

The msc, I discovered, was the attenuation produced by one mile of standard cable. Here was a very practical unit, since an amplifier with a gain of 20msc would send the conversation a further 20 miles down the line.

If I remember correctly, 1msc was equal to 0.88dB.

OH Davie  
Reading  
Berkshire

Continued on page 603

### Too noisy

I'm surprised that recent correspondence on the Sallen & Key filter topology has not mentioned another drawback namely its poor noise performance.

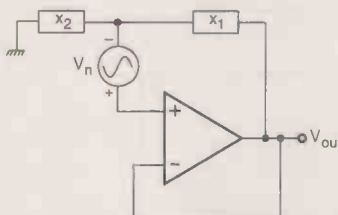
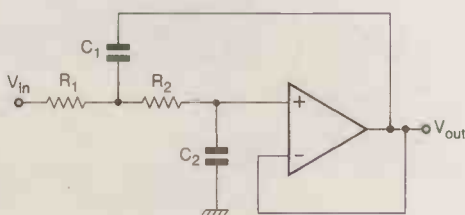
Although the topology is often chosen for its design simplicity and operating stability it possesses a high gain to internally generated noise.

In the low-pass form pictured, where typically  $R_1=R_2$  and  $C_1>C_2$ ,  $C_1/R_2/C_2$  form an attenuator which near the cut-off frequency passes a high proportion of the output signal back to the positive input. This results in a noise output much higher than the amplifier's input-referred internally generated noise  $V_n$ , and may surprise those who take the maximum

circuit gain to be unity. It is of course only the gain to ground-referenced signals that is unity - the amplifier still has a very high gain to differential inputs!

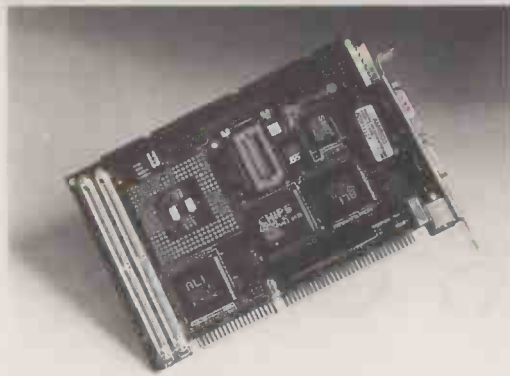
The problem is worst in the final stage of high-order filters where the ratio of  $C_1$  to  $C_2$  is generally highest, but can be significant also in second or third order designs with general-purpose op-amps, as I found when building a low-noise photodiode amplifier. The problem can be reduced by replacing the op-amp with a single transistor (in common collector mode) having a much lower noise figure, or by using a different filter topology.

Anthony New  
Bristol





## COMPONENTS & SYSTEMS FROM IOSIS



System Components from ISO9001 Source  
 Half Size Single Board Computers  
 386SX-40 to 486 Pentium Overdrive with ISA and PC/104 Bus  
 2 Serial Ports, IDE & FDD & Printer Port  
 with a variety of on-board functionalities:  
 Flash/ROM Disc, Cache, SVGA CRT/Flat Panel Controller  
 PC/104 Modules:-  
 386 & 486 CPUs, Solid State Disc, Isolated RS232/485  
 VGA CRT/Flat Panel Display & SVGA Controllers  
 PCMCIA types I, II & III  
 System Enclosures with Passive Backplanes  
 Colour & Mono Flat Panel LCD Displays  
 System Integration and Support

2c Chandos Road, Redland  
 Bristol, BS6 6PE  
 Tel: 0117 973 0435  
 Fax: 0117 923 7295



CIRCLE NO. 117 ON REPLY CARD

## The Universal Programmer that stands-alone



with everything you need. Don't buy your next programmer until you see the 'Eclipse'

- Windows and DOS user interface
  - Unparalleled in speed & sophistication ideal for R&D and volume production
  - 96 to 256 pin drivers
  - Programms PLDs, EPLDs, FPGAs, PROMS, EPROMS, E/EPROMs, FLASH & Micros
  - Universal DIP, PLCC, PGA and QFP modules - no more socket adaptors
  - Stand-alone or remote operation
- Europe's largest programmer manufacturer**



call today on +44 (0)1707 332148  
 or fax +44 (0)1707 371503 for further information

All trade marks are acknowledged and respected

CIRCLE NO. 118 ON REPLY CARD

## COMPONENTS FOR MODEMS

Telecom Design Communications - the one-stop shop for all your modem needs.

### Modem Chipsets

Rockwell's range of market-leading modem devices provides high-speed 28.8 kbps, through single-chip 14.4 kbps with data/fax/voice, to low power, low cost 2400 bps data only. Call TDC for superb solutions for fast Internet access. Write in number **108**



### SocketModems™

Rockwell SocketModems™ make integration of voice, data, and fax functionality a breeze. Connect with one of our BAPT line interfaces for fastest time to market. Write in number **244**

### Digital Simultaneous Voice & Data

Operating at 28.8 kbps, DSVD is ideal for new and expanding markets like business presentations and interactive games - play and talk simultaneously on a single standard phone line! Write in number **245**



### Line Interfaces

Carrying a BAPT Certificate of Recognition to ease the path to full UK approval, Xecom Inc. line interfaces are the compact solution to PSTN connection. Other country versions are also available. Write in number **246**

### Modem Manufacturing Packages

Aimed at OEMs and System Integrators wishing to incorporate modem functionality into their products, TDC have introduced an evaluation board based on Rockwell's single-chip V.32bis data/fax/voice device. Write in number **247**



If you need communications facilities, our team of applications engineers can assist you at every stage from design and integration through to BAPT approval.



Telecom Design Communications;  
 Connect House, Stroudley Road,  
 Basingstoke, RG24 0UG.  
 Tel: 01256 332800.  
 Fax: 01256 332810.  
 BBS: 01256 57900.

51° 16. 16' N, 0° 1.04' W: SU 653535.46531535

CIRCLE NO. 119 ON REPLY CARD

# Hands-on Internet

**Cyril Bateman** discusses the benefits and limitations of new applications on the World Wide Web.

The World Wide Web has recently become more commercialised with the introduction of many glossy corporate Web pages and several new professional search tools. One of these well worth trying is located at Netscape.com.

While the last article featured Java – a staple source of sustenance to programmers and designers alike – this month I suggest a bite of the ‘chilli’ pepper, being the logo adopted by Netscape for their Infoseek information system.

If you use Windows ‘95, you can download iSeek for use on your local machine. If not, you can log on to ‘http://cgi.netscape.com’ to run their searches. This site provides easy access using the Infoseek program or one of the twenty alternatives offered. Infoseek was the search tool used exclusively in preparing this article, Fig. 1.

A commercial aspect of Infoseek is the ‘ISN Internet Shopping Network’, which by UK standards offers some keen prices. It is

Fig. 2. The Infoseek Internet Shopping Network home page. This has been accessed via the Infoseek Computers and Internet ‘other’ topic sub-menu. This on-line shopping mall has much to offer, but check prices, currency and taxes first.

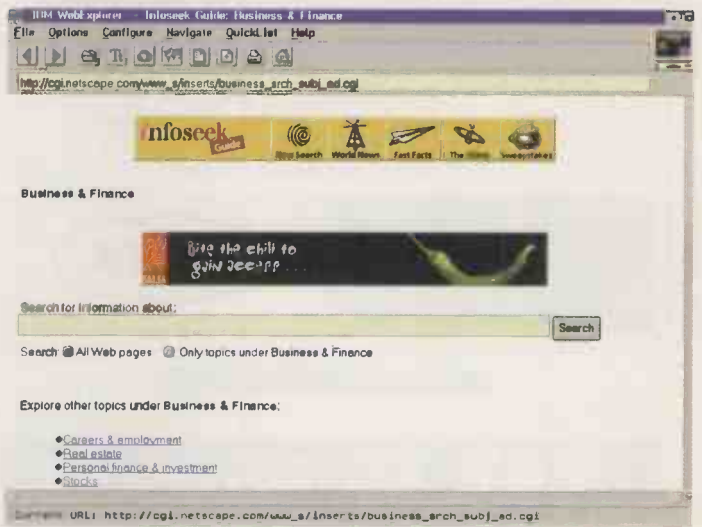


Fig. 1. The Infoseek Web Search home page from http://cgi.netscape.com. Windows 95 users can download the iSeek Beta client, for local use. Others can use Infoseek or choose from twenty alternative search tools on this page. You get the most relevant matches, related topics and a brief resume with each response.

accessed via the ‘Computers and Internet’ sub-topic at this site, Fig. 2.

Fundamental elements of Internet, namely the ‘Archie’ and ‘Gopher’ search engines, were covered in the April ‘96 issue. However, as outlined in June ‘95, other cataloguing systems have slowly developed.

The original site at ‘Cern’ and the well established ‘Yahoo’, ‘Lycos’ and ‘Web Crawler’ searchers, have now been supplemented. The ‘Alta Vista’ system claims to have indexed 16 million Web pages, the ‘Electric Library’ database of 1000 full text newspapers, magazines and journals, and the infoseek guide. Infoseek, recently rated number one search service by *PC Computing*, provides stock quotations and company profiles in addition to access of the

Internet databases, Fig. 1.

For surfers outside North America, one aspect of this commercialisation, while resulting in very pretty presentations, is less user friendly. Many recent Web pages have begun using graphics intensive pages resulting in very slow updates and costly downloads by modem. Previously this could be overcome by turning off graphics, relying on the text page menu selections only. But some new pages incorporate menu selections within the graphic to encourage one to view their effort.

The more established page designers however still manage to produce equally attractive pages, and, by using smaller GIFs or JPEGs, ensure much faster access, Fig. 3.

In addition to the Web browser applications discussed in the May

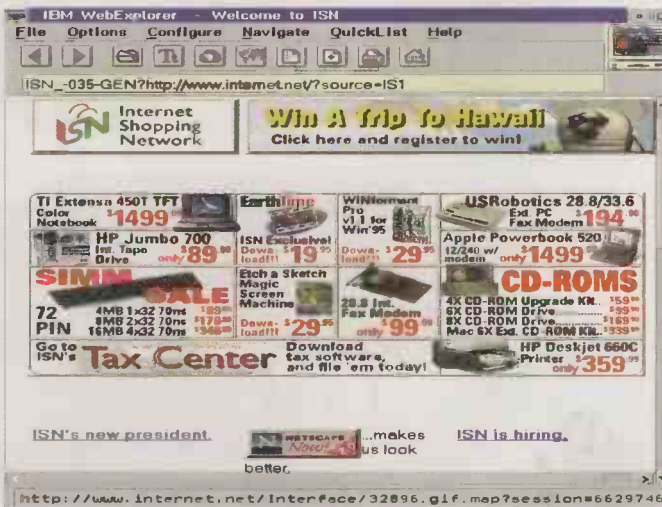




Fig. 3. The IBM home page at <http://www01.ny.us.ibm.net>. This page is intuitive in use yet downloads quickly due to careful design. It works well with or without graphics, which in total amount to only 12Kbytes.

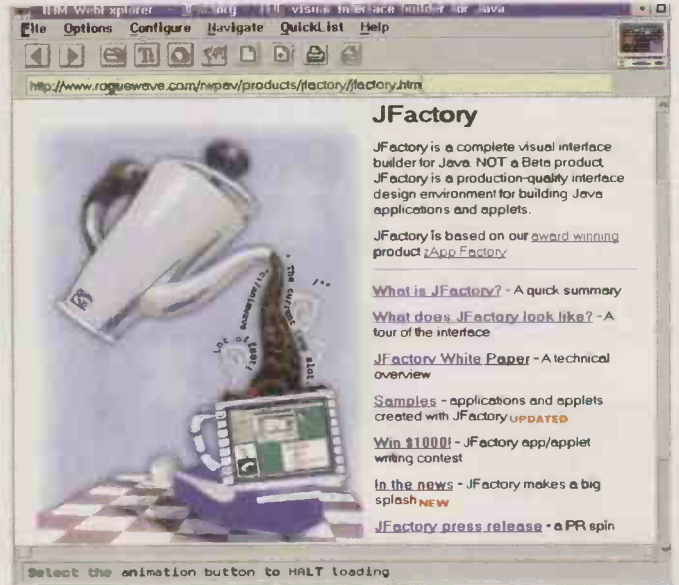


Fig. 4. The JFactory Java Home Page at <http://www.roguewave.com>. This has been accessed following the results of an Infoseek search on Java. While interesting, this graphic occupies some 62Kbytes and downloads very slowly.

issue, Java as a development language is proceeding apace for all hardware and operating systems. 'JFactory' already offer a production quality interface design environment for building Java applications, but they too are guilty of using large and slow loading graphics. The sample shown is a GIF file of some 62K in size, Fig. 4.

Some have claimed that 'Java' could develop to supplant Visual Basic, Visual C++ and Delphi, as the leading Windows development package. Licences have now been taken by almost all major software houses including Microsoft. While most development is taking place in North America, IBM is developing Java support for OS/2 and AIX at their UK Hursley Park site near Winchester, Fig. 5.

A brief explanation of Java, together with IBM's view of the importance of 'Java', can be downloaded from the company in an 80 page technical overview of the Java language and the HotJava browser.

Continuing with the 'Spice' macromodel and Semiconductor houses topic, the Maxim Integrated Products home page is a model of simplicity and rapid download. This company offers Spice macromodels, regularly issued design guides and product samples on request to registered users, Fig. 6.

A visit to Philips Semiconductors on two recent occasions resulted in some pretty pictures but at the slowest down-

load rate ever. I hope that feedback to their web manager will soon correct this. Until then this site is best accessed with graphics turned off.

Unfortunately it is not possible to judge the size of a graphics file until after it has been downloaded. Some of the better web pages, for large graphics, show a box stating the file size, giving one the choice to download the graphic. But this desirable option has not been made available on the Philips site, Fig. 7.

When accessing Texas Instruments, remember the address is TI.com. Using the address Texas reveals some interesting pages not relevant to electronic design. The TI home page at <http://www.ti.com> also has a pretty, but painfully slow loading, graphic. Corporations approving these pages might be less happy if forced to view using a modem. Perhaps this should be *de rigueur*, until we can all enjoy better bandwidth access, Fig. 8.

On the topic of bandwidth I am still using my original 14.4kbaud Zoom modem running under



Fig. 5. The IBM Hursley, Winchester 'java' home page at <http://ncc.hursley.ibm.com/javainfo>. This is a small part of the page but the whole page downloads quite quickly since JPEG graphics are used. The design works well with or without graphics download. Java is US speak for black coffee. Register here to download the OS/2 or AIX java software developers kit, or the Web browser.



Fig. 6. Maxim Integrated Products' Home Page at <http://www.maxim-integrated.com>. This is a totally intuitive page which downloads very quickly, giving all desired information. Access the company's Spice model libraries or request data or samples, before leaving.

**Fig. 8. The Texas Instruments Home Page at <http://www.TI.com>. Another site with a slow downloading image, again best visited with graphics turned off. While TI does have macromodels available, this was unclear when the page was visited. Ask for the 'Linear Info-Access Selection Disk with Macromodels'.**



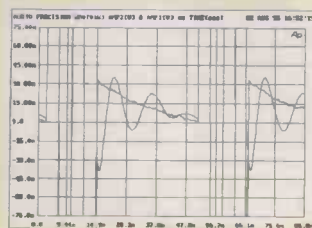
**Fig. 7. The Philips Semiconductors home page at <http://www.semiconductors.philips.com>. This is a small part of this page showing the 50kbyte GIF graphic – which downloaded very slowly. Unless the Internet or your system is working very quickly, turn off graphics first. Perhaps if sufficient viewers feedback their download times, this page will be changed.**

OS/2 Warp with ibm.net as provider. If starting from scratch, I would now purchase a 28.8kbaud modem. Recently ibm.net and many others have moved to the fastest currently available modems at 28.8bps. The increased speed of downloads on a good day is noticeable even when using a local 14.4k modem. Previously the best typical speed achieved was around 100Kbyte per minute. Since my providers' upgrade, on occasion transmissions have peaked around 3140bps, or around 170Kbyte a minute. Perhaps my upgrade costs to 28.8 bps are now justifiable. ■

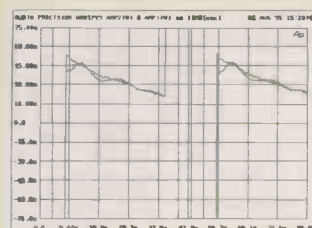
**References**

1. Netscape 'infoseek' <http://cgi.netscape.com/home/internet-search>
2. Internet Shopping Network <http://guide.infoseek.com>
3. Hands-on Internet. *EW&WW* April '96 p 304/395.
4. Surfing with intent *EW&WW* June '95 p 488/492.
5. JFactory <http://www.roguewave.com>
6. IBM Hursley Park UK <http://ncc.hursley.ibm.com/javainfo>
7. IBM New York <http://www.ibm.co./News/explain.html>
8. Maxim Integrated Products <http://www.maxim-ic.com>
9. Philips Semiconductors <http://www.semiconductors.philips.com>
10. Texas Instruments <http://www.TI.com>

# SUPRA Ply<sup>®</sup> speaker cable



**Other brand 125Hz**  
Wavy trace shows poor damping after a transient



**SUPRA Ply 125Hz**  
Superior damping - similar results at all audio frequencies

## The test winner!

Stereophile USA December 1995  
 Studio Sound UK December 1995  
 Reproduced Sound Conference Nov 1995  
 "Speaker cable differences: CASE PROVEN"  
 by Ben Duncan Research.

Low inductance concept, low, benign oxidation  
 Much faster, tighter damping gives you higher definition and more control. Result: less blur, less listening fatigue. Transient error in a spaced wire or a zip-wire is as much as 1/28th of the immediately preceding signal; our cable design reduces this at least ten times.

The low, benign oxidation is discussed in Ben Duncan's article in *Electronics World*, February 1996: Modelling cable

Please send for our catalog to see our complete range of cables and connectors, for pro and HiFi!

## Jenving Technology AB

Backamo 12800 • S-459 91 Ljungskile • Sweden  
 Fax: +46 522 23131 Tel: +46 522 23460

Supra Ply has got a big brother, Ply 3.4 £8.00/m for superior bass sonics  
 We are cable specialists since 1976 with distribution established in 24 countries

# ANCHOR SURPLUS Ltd

The Cattle Market Depot  
Nottingham NG2 3GY. UK  
Telephone: +44 (0115) 986 4902/  
+44 (0115) 986 4041 24hr answerphone  
Fax: +44 (0115) 986 4667



## Special Offers for One Month Only

Marconi TF2610 rms LCD DVM 2mV-700V  
DC & 5Hz to 25MHz **£195**

Racal Dana 9300B rms Voltmeter 100uV-300V 5Hz to 60MHz **£125**

Farnell TM8 Sampling RF Voltmeter 1mV-3V 10KHz to 1.5GHz **£150**

Marconi TF2603 RF Millivoltmeter 1mV to 3V...50KHz to 1.5GHz  
300uV sensitivity...incl Accessory Kit **£60**

Racal Dana 9301 True rms Voltmeter 1mV to 3V...10KHz to 2GHz **£125**

RS QM358 8 channel Oscilloscope Multiplexer. 35MHz Bandwidth  
4 or 8 channels...20Hz-1.2MHz rate **£50**

RS/Thurlby 1905a Intelligent Digital Multi Meters 5½ digit LED  
0.015% accuracy...Data Log...Prog filters...Math functions **£175**

Thandar TC200 LCD LCR Meters 0-200uF...0-2H...0-20MΩ **£50**

Time Electronics 404N/1021 Voltage+Current Calibrators  
to 0.001mV and 0.0001mA...0.05% accuracy **£325**

Clare A217 Earth Bond Testers 0-30A 0-250mΩ **£75**

Cole T1007 Mains Check Set...Voltage...frequency and Spike count **£50**

Franklin Wavetek 3600 Power Line Disturbance Monitor/Recorder  
1-3 phase...50-800V...40-800Hz...Incl Printer+LED's **£475**

Hioki 8832 Mem Hi-Corder...640x200 pixel LCD display...4 analog or  
32 digital channels. Printer. Complete as New **£750**

Eaton 2075 Noise Gain Analysers + 7618 Noise Source  
10MHz-18GHz...0-30db...-20db-50db gain

NEW Stock Just Arrived...NOW ONLY **£1750**

## Micro Video Cameras

You may have noticed that we have teamed up with the publishers of Electronics World to give you a Readers Offer for this Month. Please realise that we do stock many items for Home and Business Surveillance and will be pleased to FAX you a data sheet or, if you send us an SAE we will send you our brochure listing Cameras and Associated equipment. But, PLEASE do not delay...The Offers are for One Month only...and only while present stocks last...We do have 1000's available, but they do sell fast at these prices that CANNOT be beaten!!  
*Guaranteed...after all we do Import them DIRECT from the Manufacturer!!*

## OPEN SEVEN DAYS A WEEK

Mon-Fri 9am-6pm Sat 8am-4pm Sun 10am-4pm

NO APPOINTMENTS NEEDED. CALLERS ALWAYS WELCOME

All Prices are Ex VAT & Carriage

All items are Fully Tested with Verified Calibration  
and carry our Unique 30 Day Un-Conditional Warranty



CIRCLE NO. 121 ON REPLY CARD

# Listening for clues

Although simple, the squawk box can be invaluable – especially when looking for a signal buried in noise. Ian Hickman has taken the squawk box to its ultimate, combining a fully protected laboratory audio power amplifier with an af millivoltmeter.

Every electronics laboratory in which I have ever worked has had a general-purpose laboratory amplifier. Such a device is invaluable for 'listening to' a wide variety of circuit types.

You might think that the more obvious option is to see what is going on with the aid of an oscilloscope. But if there is a mixture of noise, hum and possibly other signals as well, it may be difficult or impossible to interpret the display, or even to trigger the oscilloscope so as to obtain a coherent picture.

With a mixture of signals present in a signal, an audio-frequency spectrum analyser might be more appropriate. Few laboratories possess such an instrument. Luckily though, most electronic engineers have not one but two af spectrum analysers – one on each side of their heads. All that is needed to make use of these is the universal labamp.

Labamps are usually knocked up in a hurry to help solve a particular problem. Typically, they consist of an amplifier and a small loudspeaker, housed in a die-cast box and powered by an internal dry battery. With its tinny low-fidelity reproduction, such a device is generally known as a 'squawk-box' – and very useful it can be too. In

fact, its advantages are as numerous as its disadvantages.

For example, running from an internal battery means that the amplifier is immune to the hum problems which might, in a mains-powered version, be caused by earth loops. But unfortunately, just when you need the amplifier in a hurry, it usually transpires that the batteries are flat because the last user left the unit switched on. Then again, it would be useful to be able to hear whether the signals in the circuit under observation are corrupted by hum not caused by an earth loop, but with its small loudspeaker, the typical squawk-box remains silent on this topic.

## A new squawk-box approach

A while ago, I resolved to replace my squawk-box – the last in a long line, mostly converted from superannuated radios – with a version having a decent frequency response and a generous output of a few watts. This indicated mains operation, but with precautions to avoid the possibility of hum due to earth loops.

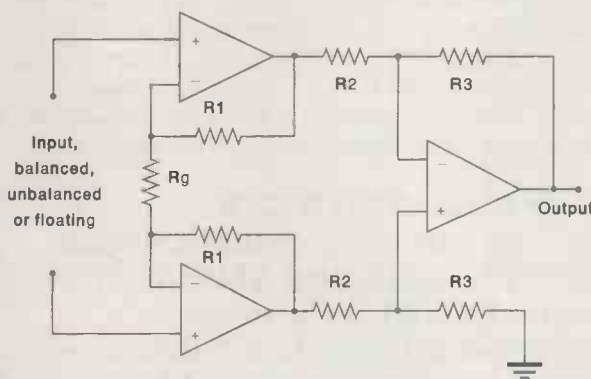
For building audio amplifier systems, a calibrated input step attenuator and meter circuit are incorporated, making the unit double as an af millivoltmeter. In addition, a 600Ω unbalanced signal output is provided, permitting use as a hum-loop free, general-purpose pre-amplifier.

For good measure, access is provided to the loudspeaker's voice coil, to permit the unit to be used also as an extension speaker. Optionally, the amplifier's output can be made available to drive an external speaker.

## The input stage

While the unit is provided only with an unbalanced high impedance input, the actual input stage is balanced. This permits the rejection of any hum present on the 'earthy' input low line, on which

Fig. 1. Basic three op-amp instrumentation amplifier. Overall effective common-mode rejection depends on the ratio of  $R_1$  to  $R_g$  – among other things.



the wanted signal may be riding. The input stage therefore uses a conventional three op-amp instrumentation amplifier configuration, as shown in Fig. 1, using three quarters of a TL081 quad op-amp. Gain of the input pair to balanced or 'push-pull' signals is equal to  $(2R_1+R_g)/R_g$ , while their gain to common-mode or 'push-push' signals is unity, i.e. these appear unaltered at the output of the input pair.

While the input pair provides no common-mode rejection as such, the balanced-to-unbalanced signal ratio is improved by the ratio  $(2R_1+R_g)/R_g:1$ , which could be large. Output of the input pair is applied to the input of the third amplifier, whose gain to balanced signals is the ratio  $R_3/R_2$ .

However, assuming the two  $R_2$ s and two  $R_3$ s are exactly matched, they form a bridge circuit, so that the common mode component appearing at the inverting input of the third op-amp exactly equals that appearing at the non-inverting input. Thus the overall common mode rejection ratio, or cmrr, is that provided by the third op-amp, multiplies by the additional ratio  $(2R_1+R_g)/R_g:1$  mentioned earlier.

In the present application, the wanted signal appears between the input terminals in unbalanced form, but the circuit still responds to the difference voltage between the two terminals. However, any hum due to an earth loop on the input low terminal, i.e. the outer of the BNC input socket, will appear also on the input high lead or centre pin of the socket. In this way, a common-mode component will be rejected as described above.

**Measuring millivolts**

The af millivoltmeter stage is a simple one, using a full-wave rectifier circuit. It is scaled to read rms when the input is a sinewave. Obtaining a linear scale was at one time difficult, due to the forward volt drop of the necessary diodes.

Various schemes were formerly used. These ranged from individually calibrating the meter scale to allow for the diode nonlinearity, to using a high impedance, such as the collector output of a transistor to approximate a constant current source. The circuit chosen appeared in *Wireless World* many years ago. It encloses the meter and a bridge rectifier in the feedback loop of an op-amp, Fig. 2.

Assuming the open-loop gain of the op-amp remains high up to the highest frequency of interest - 20kHz in this case - it will force the voltage at the inverting terminal of the op-amp to follow that at the non-inverting input. In the process it will force a current defined by the lower resistor through the meter. This will happen regardless of the volt-drop across the diodes, which will in any case vary slightly with temperature.

As the input voltage passes through zero, the op-amp becomes momentarily open loop. Just

a small voltage difference between its input terminals forces it to slew as rapidly as it is able until the other side of the diode bridge turns on, restoring closed-loop operation.

**The complete instrument**

This is shown in Figs 3 and 4. Figure 3 shows the input at a BNC socket applied via a dc blocking capacitor and a 4.7kΩ safety resistor to a range switch  $S_2$ . This, in conjunction with the gain of the following stages, provides nine input ranges giving full-scale deflection, fsd, factors for the millivoltmeter function of 3mV fsd to 30V fsd.

The input of the op-amp connected to the wiper of  $S_2$  is protected by back-to-back diodes. These are rated at 75mA peak current, which corresponds to a peak input voltage of about 350V. But as the peak dissipation in the

4.7kΩ safety resistor under these circumstances would be over 25W, this should be regarded as only a momentary withstand voltage, or a 4.7kΩ resistor of the fusible variety could be used.

The input appears between the non-inverting inputs of the first stage of the instrumentation amplifier, which provides a gain of  $\times 20$ . When monitoring an earth-free source, e.g. a piece of battery operated kit,  $S_1$  can be closed, providing an earth for the item under test. Where a hum loop problem is encountered,  $S_1$  should be opened, breaking the loop.

The associated 15kΩ resistor provides a 'static drain', to keep the input amplifier earth-referenced, even if the input socket is left open-circuit. When the unit is connected to other equipment, any ground-line float is limited by the associated zeners to just over  $\pm 3V$

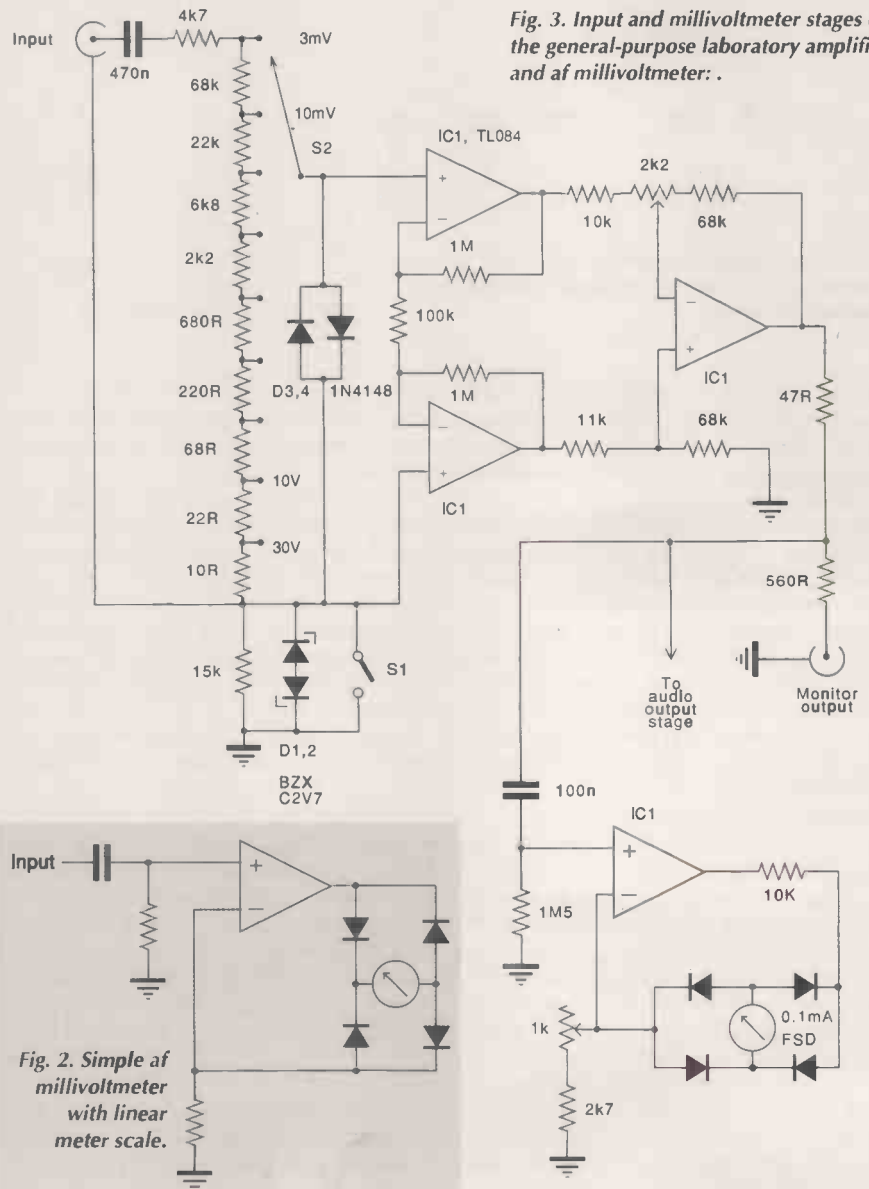


Fig. 3. Input and millivoltmeter stages of the general-purpose laboratory amplifier and af millivoltmeter.

Fig. 2. Simple af millivoltmeter with linear meter scale.

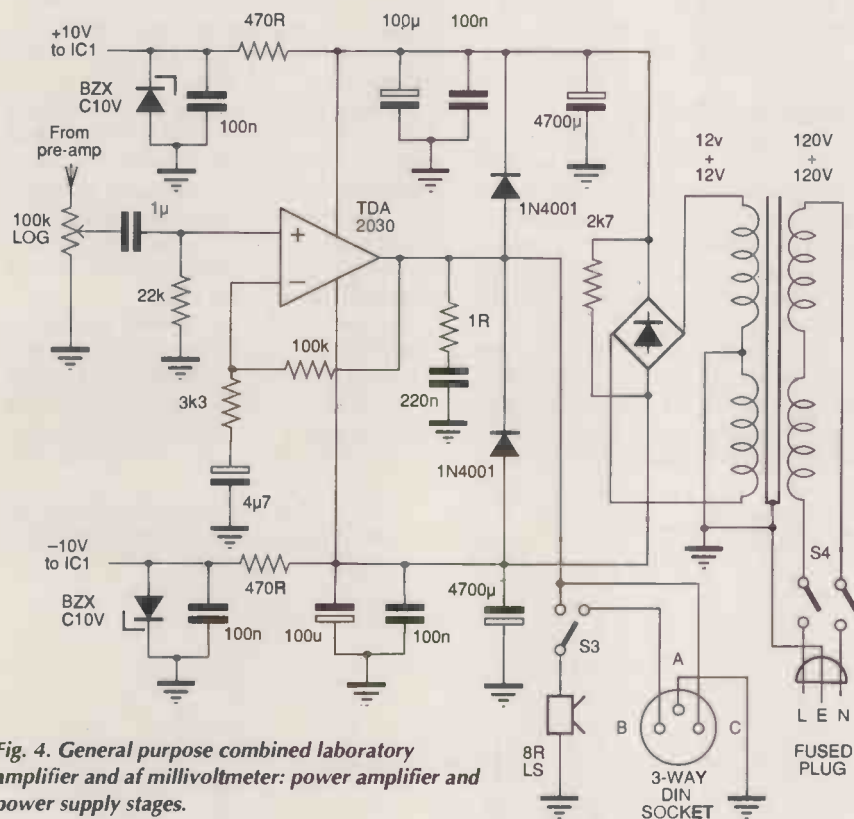


Fig. 4. General purpose combined laboratory amplifier and af millivoltmeter: power amplifier and power supply stages.

peak to peak. If the difference between grounds on the monitor and any equipment to which it is connected is greater than this, I suggest that further investigation is advisable, on possible safety grounds.

The third section of the quad op-amp provides a gain of around  $\times 6$ , the  $2.2k\Omega$  potentiometer permitting an adjustment for maximum common-mode rejection. This is obtained when the ratio of input resistor to feedback resistor on the inverting side equals the potentiometer ratio on the non-inverting side. Output of the instrumentation amplifier stage is made available at a BNC output socket, labelled 'Monitor', at an impedance of  $600\Omega$  unbalanced.

The outer of this socket connects to the circuit's 0V line, and hence is referenced to the input-socket outer, or the instrument's mains supply earth, according to whether  $S_1$  is open or closed. The low frequency  $-3dB$  point of the input amplifier is  $3.2Hz$ . This is much lower than the loudspeaker and enclosure are capable of, but it was chosen to provide a wider-than-audio frequency response at the monitor output.

The third section of the quad op-amp also drives the meter stage, which uses the final section of  $IC_1$ . Here again, the  $100nF$  coupling capacitor and  $1.5M\Omega$  resistor provide a fre-

quency response extending below the bottom of the audio range. Germanium gold bonded diodes were used in the meter circuit, for their low forward volt-drop.

Overall sensitivity is set up with the  $1k\Omega$  potentiometer. In normal operation, the  $10k\Omega$  resistor driving the bridge plays no useful part, but limits the current applied to the meter when a large input overload is applied. While inclusion of this resistor is not good for the frequency response, the instrument is nevertheless flat from  $20Hz$  to  $10kHz$ , and less than  $1dB$  down at  $20kHz$ .

Figure 4 shows the output amplifier and power supply stages. The power amplifier used is the  $TDA2030$ . For convenience, this device was mounted with its associated components on the matching ready made pcb,  $RS434-576$ . Power supplies, input stage and millivoltmeter stage, on the other hand, were all constructed on a piece of  $0.1in$  matrix copper-strip board.

Loudspeaker volume is controlled both by the setting of the input attenuator  $S_2$  and by the  $100k\Omega$  logarithmic volume control at the input of the  $TDA2030$ . The on/off switch  $S_4$  is ganged with the volume control. The  $TDA2030$  amplifier drives a wide-range twin cone loudspeaker type  $RS249-031$ , mounted in its matching cabinet  $RS249-801$ .

Alternatively, the loudspeaker may be switched to a three-pin socket, allowing it to be used as an extension speaker. For further versatility, the amplifier may be used to drive an external loudspeaker connected to pins A and C of the three way socket, either by itself or in parallel with the internal speaker, according to the setting of  $S_3$ .

The dual-rail power supply is conventional, providing about  $\pm 17V$  to the  $TDA2030$  under quiescent conditions. This is dropped to a stabilised  $\pm 10V$  for the preamplifier and millivoltmeter stages. A load resistor is fitted to ensure rapid discharge of the smoothing capacitors on switch-off, preventing a possible nasty surprise if the unit is opened up.

**Practical considerations**

With its fully enclosed cabinet, the loudspeaker creates considerable pressure inside the enclosure when reproducing low frequencies at volume. Care is therefore needed with construction to avoid rattles.

Both BNC sockets, the meter and  $S_1$  were mounted on a small Formica panel covering the lower third of the grille cloth, clear of the loudspeaker cut-out. The panel was firmly screwed into place, with the rear of the components projecting back through the front panel of the cabinet, in holes just large enough to accommodate them.

Switch  $S_1$  and the volume control were mounted on an aluminium subpanel the same size as the Formica panel, but mounted behind the enclosure's front panel, which had holes just large enough to accommodate the shafts of the controls. A rebate is formed on the inside of the front panel to clear the nuts and bosses. The aluminium panel also had a hole to clear the rear of the meter, and small holes to pass the leads to/from the BNC sockets and  $S_1$ .

Care is needed to avoid hum pickup - especially on the more sensitive ranges. Inside the cabinet, aluminium foil was fitted to cover half of the bottom of the case and the whole of the side where the stripboard input amplifier/af millivoltmeter was mounted. Like the aluminium subpanel, this foil was connected to the power supply 0V rail.

The mains transformer was bolted firmly to the base of the cabinet, on the opposite side from the input board.

**In summary**

The amplifier described here has been in use in my laboratory for months now and has proved entirely reliable. With its wide frequency response, it is much more informative than a small diecast-box-housed battery-operated squawk-box when used to monitor activity in an audio circuit. I have also made a simple diode probe, permitting signal tracing in radio and intermediate-frequency circuits. ■



**YOUR  
Ideal Partner  
in UHF and VHF  
COMMUNICATION**



**One stop solutions  
for all your radio  
telemetry module needs.**

When the success of your products depends on radio telemetry modules, you need a business partner you can trust. A skilled and experienced manufacturer that can offer modules of the highest quality, operating over a wide range of frequencies.

In other words, a partner like Wood & Douglas. Founded on technical excellence, Wood & Douglas is a British company that specialises in the design, development and production of radio-based products. With over 30 staff dedicated to meeting your requirements, the company is able to provide true one-stop purchasing - whatever your RTM needs.

All radio modules are highly functional, capable of meeting a wide range of requirements. Designed to offer efficient, easy-to-use radio telemetry components for system designers, they can open up a whole new world of product possibilities.



From portable bar-code readers to earthquake monitors, Wood & Douglas can help you make the most of the opportunities in radio telemetry.

To find out more about the possibilities, contact...



Lattice House, Baughurst, Tadley, Hampshire RG26 5LP, England  
Telephone: 0118 981 1444 Fax: 0118 981 1567  
email: info@woodanddouglas.co.uk  
web site: http://www.woodanddouglas.co.uk

CIRCLE NO. 122 ON REPLY CARD

**KENWOOD  
TEST AND MEASUREMENT**

**OSCILLOSCOPES**

With over 34 models including Digital, Analogue and Portables and bandwidths from 5Mhz to 150 Mhz plus sophisticated Triggering, single and dual timebases, multiple channels and large memory D50's. Kenwood offer the solution.

In fact there is a model that is suitable for almost any application.

Prices start from £220.00  
(20Mhz 2 Channel £359.00)



**POWER SUPPLIES**



From a low cost Analogue display to a multi output high power Digital, Kenwood provide the answer. The Power supply range consists of 61 models offering up to 250 volts and 120 Amps current.

Master-slave, RS 232 and GPIB are available on many models as are optional Rack mount facilities.

Prices start at only £180.00  
(PR 18-1.2a. 0 to 18 V-0 to 1.2A)

**AUDIO, VIDEO, RF**

The Audio Range includes Audio Oscillators, Analyser, Wow and Flutter and Distortion meters, Millivoltmeters and CD Test. The video line up includes Generators, Vectorscopes, Waveform Monitors plus Video Signal, Timing and Noise Analyser's.



There are three models of AM/FM Standard R.F. generators which offer a highly stable frequency range of 10KHz to 260MHz and provide digital readout of Level, Frequency, Memory address and Modulation.



**GENERAL PURPOSE**

The range of general Instruments includes Frequency counters, Digital multimeters plus a complete range accessories complimenting the complete line.

KENWOOD provide a full set of brochures with a complete specification for each product in the range.

Why not call for a full set.

FOR FURTHER INFORMATION  
PLEASE CONTACT:

**Trip Kenwood U.K. Ltd**

**Kenwood House, Dwight Road, Watford WD1 8EB  
Tel: 01923 816444 Fax: 01923 819131**

CIRCLE NO. 123 ON REPLY CARD

# Thermometer answers back

An addressable digital voice recorder chip can replace a panel meter in many applications, and is particularly useful for people with impaired vision. Here, **Heikki Kalliola** explains how such a device is used as a speaking thermometer.

The *ISD2560* chip is available from Sequoia Technology Limited, Tekelec House, Back Lane, Spencers Wood, Reading, Berks RG7 1PW. Telephone: 01734 258000 Fax: 01734 258020 BBS: 01734 258060.

The heart of this talking thermometer is an analogue memory chip, in which a binary addressable voice can be stored. In this case the meter scale is first spoken to the chip.

Temperature related voltage is produced by a sensor. An analogue-to-digital converter chip converts this voltage to binary data for

addressing the voice chip memory. When a reading is triggered a loudspeaker outputs the message in current address containing the temperature information.

## Circuit operation

The sensor connects to an 8-bit parallel output a-to-d converter whose seven most significant bits are used for memory addressing. Trimmers  $R_{1,2}$  are required for calibration.

Pushing  $S_1$  initiates a pulse from  $Tr_1$ 's collector, triggering conversion by pulling up the chip-select pin, /CS. The pulse starts conversion, the result of which remains at the output pins until next triggering.

Playback starts by taking pin /CE momentarily low and continues until memory overflow is reached. A logic high at the power-down pin, PD, keeps power consumption low. This pin must be pulled down when playing or recording. The pin also acts as reset switch should a memory overflow occur, in which case it must be pulled up then down again.

Playback starts from the address presented to the speech chip by momentarily pushing  $S_1$ . It continues until end-of-memory, or memory overflow. The button pulls down pin /CE and creates a reset pulse to pin PD via  $Tr_1$ . The same pulse starts a-to-d conversion and thus updates the address before the device 'speaks'.

Following address selection, recording is performed by pushing  $S_2$  and holding it down while speaking into microphone.

Switch  $S_1$  pulls down pins P//R and /CE via diodes. At the same time,  $Tr_1$  stops conducting for a moment as the result of ground to the base via  $C_1$  and creates a positive reset pulse from collector to pin PD.

Recording is stopped by releasing  $S_2$  and thus writing an end-of-memory mark to the

## Components used in the prototype

$R_1, R_2$	10k $\Omega$ trimmer
$R_3$	3k $\Omega$
$R_4$	100k $\Omega$
$R_5, R_{10}, R_{12}$	10k $\Omega$
$R_6$	220k $\Omega$
$R_7, R_8, R_9$	47k $\Omega$
$R_{11}$	470k $\Omega$
$R_{13}$	2k $\Omega$
$R_{14} - R_{20}$	1k $\Omega$
$C_1, C_4, C_{10}, C_{11}, C_{13}$	100nF
$C_2$	1nF
$C_3$	10 $\mu$ F
$C_5$	2,2 $\mu$ F
$C_6, C_7$	0,22 $\mu$ F
$C_8, C_{12}$	22 $\mu$ F
$C_9$	.1 $\mu$ F
$IC_1$	ISD2560
$IC_2$	ADC0804
$IC_3$	7805
$Tr_1$	2N2222 or equivalent
$D_1, D_2$	1N4001 or equivalent
$LD_{1-7}$	e.g. SLR-34VR
A	LM335
L	loudspeaker, $\geq 16\Omega$
M	electret microphone

memory. Recording of course also stops if the end of memory is reached.

DIL-switch  $S_3$  is used for scaling by feeding user-settable addresses to the memory chip. During normal operation, addresses are received from the converter chip. The light-emitting diodes are only needed for making a clear indication of the binary address. Without them, the address can be read directly from the DIL-switch, but only during setting up.

During setting of the scale, it is essential that the converter outputs are tri-stated at all times.

Under normal use, the DIL-switch elements must all be open, and the leds show the address coming from the converter.

### Making the scale

I used the *ISD2560* speech memory chip with 60s recording capacity for the prototype. By varying seven most significant address bits, this time can be divided into about 70 slices, each containing a spoken number and end-of-memory mark. The 7-bit address space is greater than this of course, but the upper part is used by the chip itself.

Thus there is about one second for each number – which requires quick dictating. You

might find it better to use an *ISD2590* which is compatible, gives 90s recording time and also longer time slices.

The method is to select the address with  $S_3$ , push  $S_2$ , speak the number and immediately release  $S_2$ . The result can be checked with  $S_1$  and renewed whenever desired.

At first, the numbers may have the tendency to be too long and occupy space from the next address slot. However with a little practice they can be easily kept in their own address slices and the whole scale spoken in about ten minutes.

Dictated information depends on the desired scaling. If, for example, the device is needed to tell the temperature between  $-30^{\circ}\text{C}$  and  $+40^{\circ}\text{C}$ , the corresponding numbers are spoken starting from address 0, with  $S_3$  totally off. Thus the lowest figure corresponds to address 0, the highest to address 70 and  $0^{\circ}\text{C}$  to address 30 – all set in binary steps via  $S_3$ .

Because of the shortness of the time slices, you might find it useful to differentiate the frost figures by using, for example, a female voice instead of speaking the minuses before each numerical value.

More time for a unit is of course available, if

a coarser or restricted scale is acceptable. By tying address line A3 to ground for example, remaining bits represent half the scale but double length time slots.

### Calibrating the thermometer

After the scale is defined, the device has to be calibrated. Because the sensor's temperature dependency is linear, it is enough to fix two points on the scale.

It would be useful to be able to calibrate with icy water at  $0^{\circ}\text{C}$  and boiling water at  $100^{\circ}\text{C}$ . But boiling water is above the device rating. One possibility is to use body temperature of  $37^{\circ}\text{C}$ , or water temperature measured previously against a standard thermometer. Note that for fluid measurements, the sensor must be sealed, for example by casting it in epoxy resin.

First let the sensor rest in ice water for a few minutes. By turning  $R_1$  and pressing  $S_1$  you can find the point where response is 'zero'.

Accordingly the upper reference point is adjusted via  $R_2$  with the sensor in a known temperature environment. This second reference point should be as near the  $70^{\circ}$  maximum as possible. ■

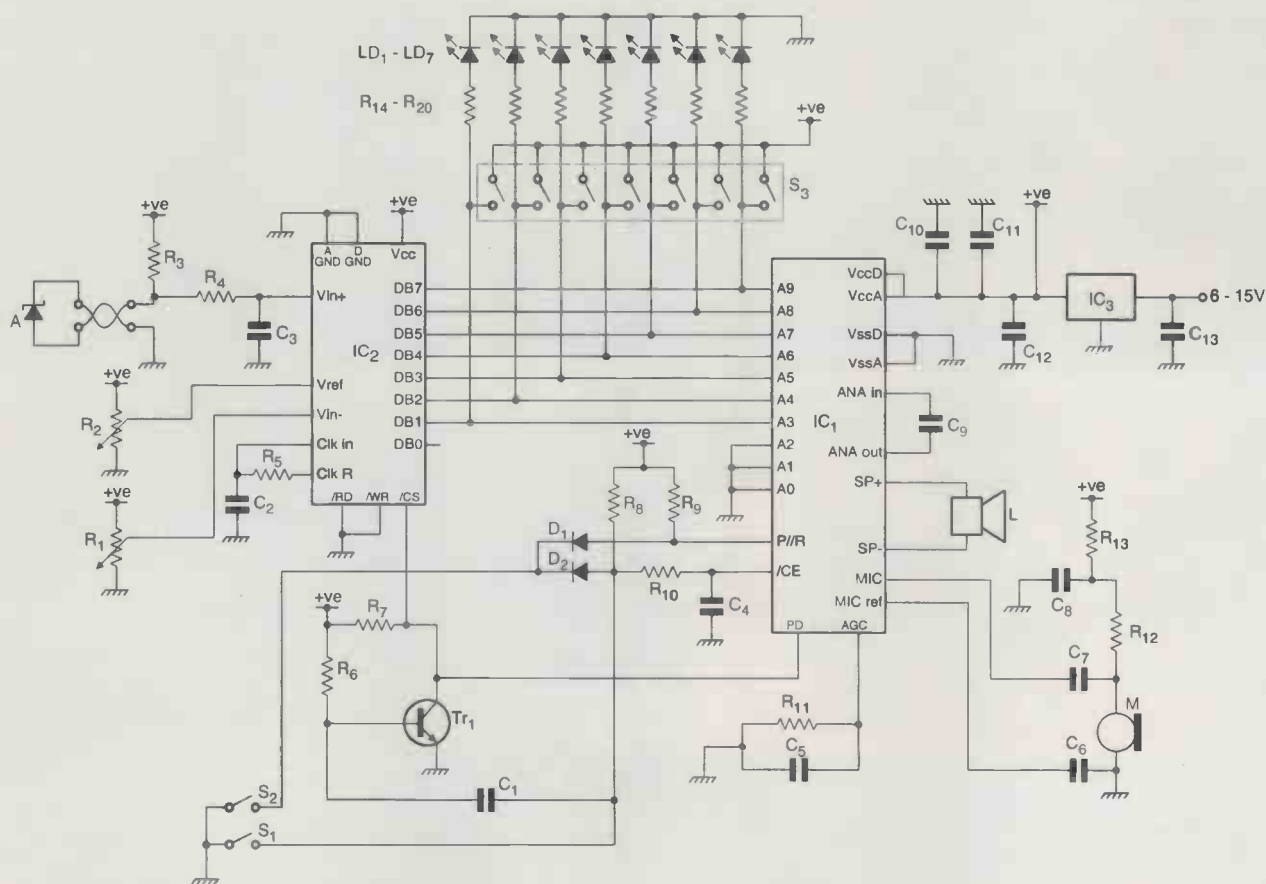
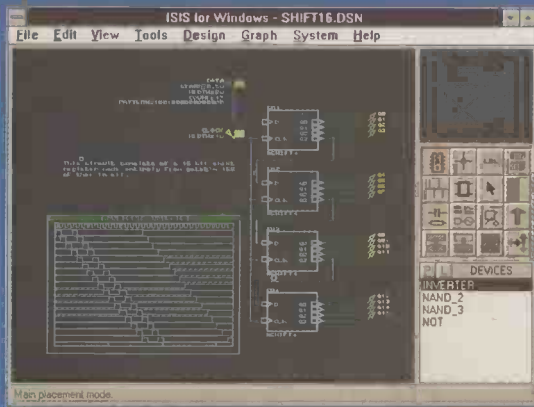


Fig. 1. Talking thermometer using a National Semiconductor sensor IC that operates between  $-40$  to  $100^{\circ}\text{C}$ . Since the speaking memory chip can store up to 70 announcements, the system can be calibrated to handle any 70 degree window within the sensor's limits.

# PROTEUS

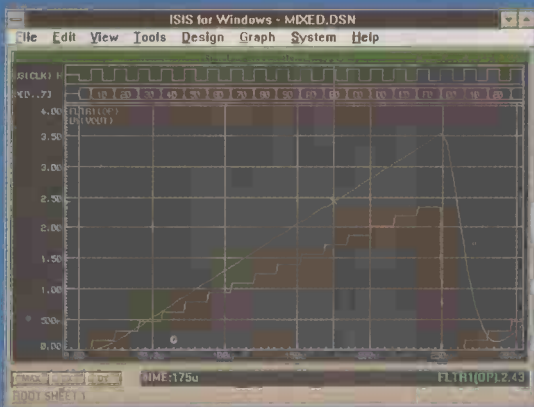
*New for Windows 3.1, 95 & NT*

**The Complete Electronics Design System - Now With RIP-UP & RETRY!**



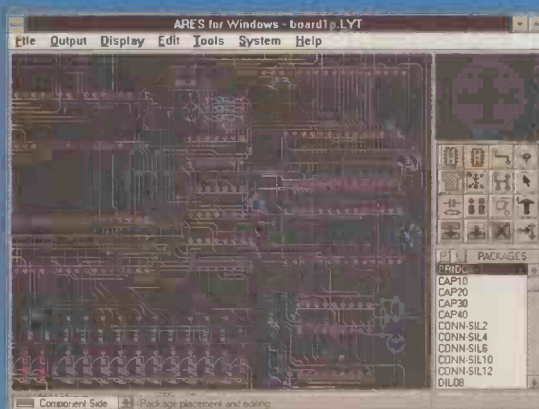
## Schematic Capture

- Easy to Use Graphical Interface under both DOS and Windows.
- Netlist, Parts List & ERC reports.
- Hierarchical Design.
- Extensive component/model libraries.
- Advanced Property Management.
- Seamless integration with simulation and PCB design.



## Simulation

- Non-Linear & Linear Analogue Simulation.
- Event driven Digital Simulation with modelling language.
- Partitioned simulation of large designs with multiple analogue & digital sections.
- Graphs displayed directly on the schematic.



## PCB Design

- 32 bit high resolution database.
- Multi-Layer and SMT support.
- Full DRC and Connectivity Checking.
- RIP-UP & RETRY Autorouter.
- Shape based gridless power planes.
- Output to printers, plotters, Postscript, Gerber, DXF and clipboard.
- Gerber and DXF Import capability.

**Labcenter**  
Electronics

*Write, phone or fax for your free demo disk, or ask about our full evaluation kit.*  
**Tel: 01756 753440. Fax: 01756 752857.**  
**53-55 Main St, Grassington. BD23 5AA.**

Proteus runs as a 32 bit application under both DOS and Windows (3.1, 95 and NT).  
Prices start from £470-ex VAT; full system-costs £1645 for DOS, £1875 for Windows. Call for upgrade pricing and/or information about our budget and educational products. All manufacturers' trademarks acknowledged.

# LETTERS

CONTINUED FROM PAGE 590

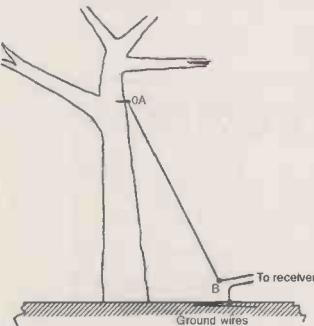
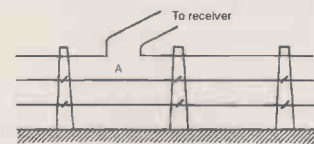
## Up a tree

I found Ian Hickman's regression to the early days of radio most fascinating and it pointed me to my library.

One of the most bizarre suggestions I found in the early works is the tree aerial in Morecroft's *Principles of Communication, 1921*, which comprises a wire nailed to the top of a tree. While he concedes in the caption to the picture that the tree is nothing more than a support for the wire, in the text he suggests that the tree provides top capacity and that the conductive juices of the tree could pick up signals. Another thing that is brought out in Morecroft is the large power output and the large physical size of some of these early equipments which belie the simplicity of their circuitry.

What I find interesting about the early days is how the terminology of these quasi-mechanical generators of rf energy carried on into the valve era. When I started work at Rugby R.S. in 1936 the original short-wave building, in which two transmitters were installed was known by the old hands as the 'Arc room'. An arc transmitter had been built there for testing insulator and other components when GBR was built.

Similarly the ground floor of the GBR building, where the banks of valves were installed was known as the 'Valve room'. This title was continued in the newer short-wave building erected in 1929. Also the term 'tank circuit' was not used but the anode circuit was always called the 'intermediate circuit' or 'inter circuit'. This was a throw back to the Leafield arc where a tuned circuit had been interposed between



**Wire fence and tree antennas.** The original caption says that the tree is only acting as a support (but in the past trees themselves have been used as antennas – ed).

the arc and the aerial circuit to reduce the harmonic emissions. Some arc transmitters had a dummy load to absorb the power output during space intervals and this had taken the term 'Tank circuit' (vide Palmer, *Wireless Principles and Practice*). In the Post Office the terms 'Transmitter room' and 'Tank circuit' didn't come into their current usage until the GBZ transmitter was built during the war by a newer generation of engineers. **S. Brown**  
*Oswestry*  
*Shropshire*

## Current feedback

I refer to J R Allison's letter in the December 1995 issue, regarding the effect of current feedback when applied to loudspeakers.

Some years ago, while testing our design of constant current amplifiers for induction loops for hearing aid users, I noticed that a mediocre loudspeaker had a rather 'punchy' sound when current driven. The effect was like adding a tweeter, and the bass response was also improved.

For further tests, I built a constant voltage/current pan circuit. At Aeac we custom build sound systems and I had this in mind for an optional feature. The benefit of the current drive is to give some extension of frequency response similar to the fashionable U shape setting on graphic equalisers, but without the disadvantage of the loss of middle frequencies which makes many PA rigs so tiring to listen to.

Why does current drive have this effect? The loudspeaker is an inductive complex load. Above that frequency at which the resistive and inductive impedances are equal, the current falls off with frequency. Since the loudspeaker as a motor depends upon the current passing through the voice coil, both the transient response and the high frequency response fall off. Also the series inductor in a crossover network adds to the voice coil inductance and degrades the transient response. This is compensated in the RCF Monitor 5, a passive crossover loudspeaker with active crossover performance and which helped to inspire my research.

By cancelling the effects of series inductance, the current drive power amplifier produces the best available transient and high frequency response from any loudspeaker. One benefit over a graphic equaliser is the inherent compensation for any irregularities in the impedance versus frequency response.

The improved bass, however, does not fit this explanation. Indeed, having improved the treble, one would expect to hear relatively less bass. The bass response of a loudspeaker, which depends on its enclosure, is again a complex mathematical function.

By including the loudspeaker in a feedback loop and phase as well as amplitude controlling its voice coil current, the whole mechanism causing bass response to change has been altered. Current drive, as a servo system, compensates for such phenomena as bass resonance in a way that improves the perceived sound.

Amongst my listening tests, I tried a pair of Monitor 5s in series. Thanks to the quality of these, the change in transient and treble response was clearly heard. Panning from voltage to current drive, the quality was restored, and the control could be set at a point which exactly restored the original sound quality. **Robert Higginson, BSc., BD**  
*Birmingham*

## The runaway pc

Regarding Frank's Comment, 'A computerised confidence trick' in the March '96 issue, it is pleasing indeed to see that I am not the only one to believe that we, corporately and individually, are the paying victims of the most colossal software/hardware conspiracy. So far, this conspiracy shows signs of running, unchecked, to eternity.

I am often laughed at for lauding, say, *Wordwise* running on a BBC-B; true, it is rather clumsy, crude, and not even vaguely wysiwyg, but nevertheless, it does function as a wordprocessor – and using only 32k of RAM. Perhaps I should ram the point home by expressing it as 0.032Mbyte. More recent products running on a pc are indeed much easier to use, but need say 4Mbyte of ram. Are they really 128 times better?

It will be interesting to see if a network-based machine will undermine the conspiracy. But I am concerned that pc manufacturing costs, produced as they are in such enormous quantities, are so low, that it will take a very deep breath on the competitor's part to compete with this. Still, we can but live in hope. **Peter O. Fraser**  
*Milton Keynes*

## Wake up to the music

My interest in hi-fi has recently been re-awakened after a lapse of many years largely due to your excellent magazine.

The subject of speaker cables is

now of interest as – horror of horrors – I was until recently using 10A lawnmower extension lead. The hi-fi press is full of adverts and claims for all manner of cables the dearest of which runs at £1000 per foot and at age 57, with an estimated upper hearing limit of 14kHz, I wondered how much benefit there would be by upgrading from lawnmower cable.

Ben Duncan's article on modelling cable was most interesting, as was the subsequent correspondence from Douglas Self, Donald Pierce and Allen Wright. I have been working on the development of pulse induction metal detectors for both industrial and hobby applications over the past 30 years. I have had to solve cable and wire problems with regard to the search head and I feel that there could be a common factor here – that of localised eddy currents within the wire cross section. Ben Duncan mentions this and from my experience it is a more plausible explanation than 10mV diodes.

In a typical P.I. metal detector, the transmitter is required to switch a current pulse of an amp or so through a coil of wire at a prf of about 5kHz. The current must switch off cleanly without ringing or overshoot in approximately 5µs. A sensitive wide band amplifier connected across the coil senses the induced emf from any metal object within the collapsing magnetic field set up by the coil.

The signal seen at the receiver output is an exponentially decaying waveform whose time constant depends on the mass and conductivity of the metal object. Obviously the time constant of switch off of the current in the coil has to be several times faster than the object time constant otherwise the object signal will be degraded.

One fact that emerged very early on was that the performance of a coil wound with solid wire was markedly inferior to one wound with stranded wire all other things being equal ie total coil inductance, resistance and self capacitance. Comparison of the amplified waveforms of the two coils showed a relatively long exponentially decaying signal that can only be due to eddy currents generated in the wire cross section of the solid core.

Even though the strands in stranded wire are in intimate contact the eddy current path is sufficiently attenuated so as to give a much faster cross sectional time constant and better performance. ■

**Eric Foster**  
*Oxford*

# QUESTIONS & answers

## War and peace

I notice from the little listening I do on 500KHz that the UK coast stations appear to have gone QRT. Some European stations are still audible at night. Perhaps a reader can throw some light on what the plans are for the mf cw shipping band, in that, as I understand it, Morse is being phased out in the near future. This, I happen to believe is a grave mistake, but such is the price of the march of 'progress'.

It could be a good idea to retain, at least, a small segment of that band for the Amateur Radio Service for cw only, given that there is no allocation for experimental radio in that part of the spectrum. In that way a small part of the spectrum could be preserved for a useful purpose and a fitting monument to the services of countless Radio Officers in all the Merchant Services who literally lived and died on 500KHz, in war and peace.

Ted Crowley  
Ireland

## Can I plate through?

Could anybody explain to me how I can produce pcbs with plated-through holes for double-sided pcbs, or let me know of any publications where I can find detailed information on the subject?

The aim of Questions & Answers is to solve readers' problems relating to electronic design and circuitry. If you have such a problem, jot it down and fax it on 0181 652 8956, e-mail it to martin.eccles@rbp.co.uk or mail it to Q&A, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Note that requests for help in locating equipment and similar enquiries will not be considered. But subscribers should remember that they can advertise for free.

I am currently producing pcbs using a photosensitive system and am making the connections between the layers by soldering pins designed for the purpose in the through holes.

Ian Tran  
Switzerland

## Transmission line problem

Can anyone explain in a simple way the answers to the following related questions?

If a short pulse is generated at one end of an open circuit transmission line then that same pulse can be observed to return at a time proportional to the line length and

the line velocity factor. Conducting the same test but with the line terminated in a short circuit returns an inverted pulse.

Why does this pulse inversion take place?

If you take a snapshot of the voltage and current when the pulse was halfway down the line, eg a quarter of total elapsed time, what would we see that would indicate if the pulse was going away from or towards the generator? That is, how does the pulse, when it is half way down the cable, know in which direction it is supposed to be travelling?

PW Fry  
Southampton

## On a more perfect note

I am in the process of composing two pieces of music which I would like to reproduce in a 360° horizontal sound field with sounds occurring everywhere and equal frequency response. I understand the initial recording – a dawn chorus – would be best recorded using a SFM MKV microphone but I am unable to buy one as I don't have £4500 to spare. I wish to record the information from the microphone directly to four mono channels of a pc 'direct-to-hard-disk' recording system which I already have.

All of this is fairly straightforward but the actual manipulation of the data once this is done may be a little more difficult. If any of you have any articles or ideas about the manipulation of audio data in a 360° field or would like to make any suggestions or comments I would be pleased to hear from you. I am also finding it impossible to locate a SFM MKV that I can use for a couple of weeks to make the initial recordings. If any readers are in possession of one I'd love to be able to loan or hire it.

I have spent all my funds on the PC hardware and software and so any sponsorship help would be great as would the loan of any equipment.

## Big inverter capacitor

This inverter circuit delivers output at constant power without any special control circuitry being required. The two capacitors  $C_2$  and  $C_3$  in the half-bridge are made deliberately small so that they will resonate with the leakage inductance of the transformer during operation – at about 65kHz. The transistors  $Tr_1$  and  $Tr_2$  (igbts), are simply switched alternately from a vco. A small amount of negative switching overlap preventing shoot-through as well as providing the transistors with zero voltage at turn-on with assistance of the transformer primary self-inductance. This circuit requires a low inductance, low-loss capacitor  $C_5$  directly across the dc output for proper termination of

the  $C_{2-3}$  and  $L$  series-resonating circuit. Transistors  $Tr_1$  &  $Tr_2$  are switched well below the resonance of the series resonating circuit, to produce output in discrete half cycles. Excellent filtering is provided by the mere 35µF of capacitor  $C_5$  in conjunction with the self inductance of the converter output leads, which easily exceeds 4µH in application. The degree of smoothness that can be expected at about 190A output is also shown.

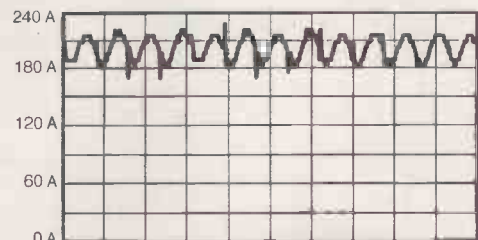
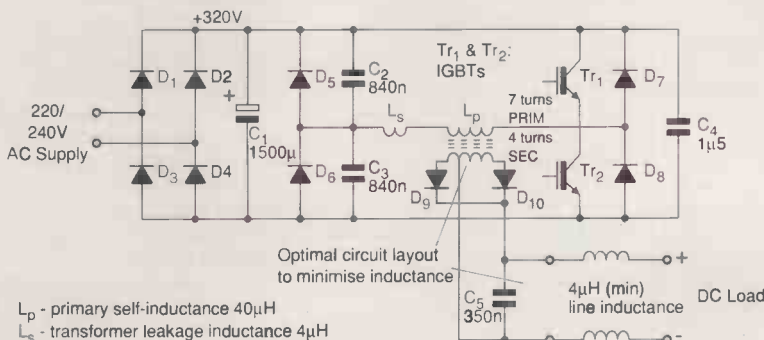
The converter delivers very high current into a low impedance load, with the current falling off as the impedance is increased, maintaining  $V \propto I$  at a single value determined by the frequency setting of the vco. This makes it ideal for arc welding, industrial battery charging and

the like. It can be used to start a tractor engine directly.

Significantly it uses no inductors other than the step-down transformer. But unlike transformer manufacturers, who can often be relied upon to help with the design and manufacture of smoothing inductors for inverter power supplies, I have not been successful in locating even a single capacitor manufacturer willing to tackle the design and making of the 35µF capacitor for use in the present circuit,  $C_5$ .

Other than parallelling tribes of smaller capacitors, can any reader offer a solution?

John Fetter  
Bryanston,  
South Africa



Circuit of an inverter said to be capable of starting a tractor engine, and its ripple at 190A.

I have already applied to most national funding bodies but the music I am proposing to make falls outside their funding guidelines although most of the replies I received expressed interest in the idea.

Ian McNaughton  
Bristol

### Amalgamated Wireless Valve Co

If you know what happened to Amalgamated Wireless Valve Co, of Sydney NSW, or you knew of K Langford Smith, would you write to me, Martin Eccles, at the editorial offices please? The address is on the comment page. Alternatively, you can ring me on 0181 652 3128 or fax 0181 652 8956.

### Good vibrations

Can anyone help here with information on frequency counters

for Schumann Resonance and seismic-signals research?

Schumann Resonance is believed to occur in an insulating gap between the surface of the earth and a boundary at an altitude of 50 to 100km<sup>1</sup>. Using the formula:  $f=c/2\pi R$ , the range of SR frequencies corresponding to the gap is 7.42 to 7.37Hz. However, SR is often quoted as having a specific value of 7.83Hz, which would correspond to a layer just below the asthenosphere, at a depth of 100 to 250km.

Using a Wisler WFC308 frequency meter without an antenna (I bought in 1993 via the columns of *EW+WW*), I have found SR to vary between 7.06 and 7.39 to 7.44 in August of each year. The values show that SR is bounded by the outer reaches of Earth's atmosphere and the tropopause (-60°C), with 'clustering' at the mesopause (-100°C).

Schumann Resonance values read over a three month period

1996/7	Initial value	Saturating value, H <sub>2</sub>
May	7.35	7.70
June	7.25	7.60
July	7.15	7.50

Winter values, from December to February, vary more widely in the range 7.69 to 8.45, corresponding to the middle of the asthenosphere (173km deep) and a layer just below the upper and lower mantle boundary (731km deep). In February 1996, however, 'quantum jumps' from the boundary layer (8.45) to about 14Hz suggest that the process is also correlated with the gutenberg-wiechert discontinuity at a depth of 2900km.

If any readers could spare a few minutes to look at their frequency counters it could be of considerable

value in helping to better understand volcanic activity and earthquake prediction if they send me details of their display.

Note that not all frequency counters give the desired effect. Settings I used were: range 0 to ~1200MHz (50Ω input impedance), count time ~0.001 second, display rate ~1s<sup>-1</sup>.

† *EW+WW*, May 1990, pp 408-411.

Tony Callegari  
Much Hadham  
Herts

## Answers to questions

### How does the 340MHz transmitter/receiver work?

Mr Collins' receiver is a 'super-regenerative' type - an oscillator oscillating so hard that it cuts itself off and restarts at a frequency above the audio range. Such a receiver is very sensitive indeed and directly produces the modulation of the incoming signal at its output - whether the signal is amplitude or frequency modulated.

'Cathode Ray' produced a design in *Wireless World* for a one-triode fm receiver for headphones at around 1956. I built many examples of this, but such receivers radiate strongly and would now cause tremendous interference problems. The transistor oscillator used here operates at much lower power and appears from the diagram to have no proper antenna. As a result, its radiation is presumably acceptably low.

So the chain of inverters is fed with the modulation and the first and third are working as low-pass filters. The second and fourth are biased as analogue inverters. The circuitry around  $D_1$  is a pulse-stretcher.

The transmitter is amplitude-modulated (or one could say pulse-modulated because the modulation factor is 100%) by the variable base voltage from pin 17 of the *VD5012*. Its frequency cannot be calculated from the component values because stray capacitances and inductances are comparable in value with those of the discrete components.

John Woodgate  
Rayleigh  
Essex

### More magnetic lines of force

Referring to Guy Moore's Letters in the May issue, having studied the mechanics of magnetic forces for a number of years I agree

with the explanation given by Douglas Rice and Guy Moore for the formation of concentric lines around the wire. However, there are two errors in Guy Moore's letter which should not go uncorrected.

First, the iron filings become magnetised normal to the field and not parallel to the field otherwise the magnetic lines would not repel one another. Also, if the card is tapped gently the diameter of the lines will be seen to decrease as the filings are attracted to the wire.

Secondly, energy in the system is increased and not reduced. The proof comes from the fact that the wire forms part of an electric circuit possessing inductance and a stored energy of  $\frac{1}{2}LI^2$  joules. The iron filings store a greater amount of magnetic flux which increase the inductance of the circuit and the energy stored.

Gareth Jones  
Gwynedd  
Wales

### How can headphones produce so much bass?

As an acoustician, I can explain quite easily the phenomena of bass transmission by small headphones. It is basically a tube duct. The small phone can produce the necessary bass by moving the diaphragm front and backwards. As the air is imprisoned in the ear tube to the diaphragm, this closed system requires nothing more to have the sound transmitted by the 'imaginary piston' of the diaphragm of the headphone. What goes in, gets out at the other end, as in a command tube of a boat or a tuba.

Jon Mathys  
Lasne  
Belgium

Contrary to popular belief, headphone transducers do not work in the same way as loudspeakers. For the latter, the major component of the mechanical impedance of the diaphragm (cone, surround and suspension) is its compliance below the bass resonance frequency and its mass above that frequency.

A headphone transducer's diaphragm, however, is designed so that the major component of its mechanical impedance is resistive at all useful frequencies. Since also it radiates into a closed tube - the auditory canal - its acoustic environment is quite different from that of a loudspeaker cone and analogies cannot usefully be drawn. See 'Loudspeaker and headphone handbook', Borwick (ed.) 2nd ed. Focal Press 1994 ISBN 0 240 51371 1. JW

### Anyone know anything about Schumann resonances?

Detection of ELF radiation is only practicable by means of loop antennas unless one has the resources and privileges of the military. The major problem is eliminating man-made interference. A Faraday screen helps and so does balanced operation of the loop but there are still severe problems with power-frequency (and its harmonics) magnetic fields. The combination of a loop with a microphone-type amplifier having a (proper) electronically-balanced input and a high overload margin, followed by a set of notch filters at 50Hz, 150Hz and 250Hz seems worth trying. One might add a tunable band-pass filter covering 7 to say 45Hz with 1Hz bandwidth. This is only general information as I am not involved in this sort of work. ■

JW

Unless mentioned otherwise, these answers are for questions that appeared in the previous issue.

# STEREO STABILIZER 5



- Rack mounting frequency shifter for howl reduction in public address and sound reinforcement.
- Mono version, box types and 5Hz fixed shift boards also available.

- ★ Broadcast Monitor Receiver 150kHz-30MHz.
- ★ Advanced Active Aerial 4kHz-30MHz.
- ★ Stereo Variable Emphasis Limiter 3.
- ★ 10-Outlet Audio Distribution Amplifier 4.
- ★ PPM10 In-vision PPM and chart recorder, also as expansion board for Acorn Computers.
- ★ Twin Twin PPM Rack and Box Units.
- ★ PPM5 hybrid, PPM9 microprocessor and PPM8 IEC/DIN -50/+6dB drives and movements.
- ★ Broadcast Stereo Coders.
- ★ Stereo Disc Amplifiers.
- ★ Peak Deviation Meter for FM broadcasting

## SURREY ELECTRONICS LTD

The Forge, Lucks Green, Cranleigh, GU6 7BG.  
Telephone: 01483 275997. Fax: 276477.

# SYNTHESISED SIGNAL SOURCE

an innovative design from an established 'Off-Air' Company

- Custom designed chip set
- Sinewave output 0dBm into 50Ω
- Can be run independently or genlocked to external source
- dc to 16MHz in 0.1Hz steps, with option 0.0001 Hz steps
- Freestanding rack mounting, or OEM options available
- Increased resolution and increased stability options available

CIRCLE NO. 125

Models available October, contact us for prices

NEW from Halcyon

# 'OFF-AIR' FREQUENCY STANDARD



CIRCLE NO. 126

- ★ Provides 10MHz, 5MHz & 1MHz
- ★ Use it for calibrating equipment that relies on quartz crystals.
- ★ TCXOs, VXCOs, oven crystals
- ★ Phase locks to DRO/TWICH (rubidium controlled and traceable to NPL)
- ★ For ADDED VALUE also phase locks to ALLOUIS (cesium controlled and traceable to OP - French eq to NPL)
- ★ British designed and British manufactured
- ★ Options available Include enhanced receiver, sine wave outputs and 13MHz output for GSM. Prices on application.

Output frequencies - 10MHz, 5MHz, 1MHz  
Short term stability - better than  $1 \times 10^{-9}$  (1 sec)  
Typical -  $4 \times 10^{-9}$  (1 sec)  
Long term - tends to  $2 \times 10^{-12}$  (1000 sec)  
Call for 'Off-Air' Standard list

# TEST EQUIPMENT

CIRCLE NO. 127

We are well known for our quality, new and used Test Equipment. Our list is extensive, ranging through most disciplines. Call for details and a complete list



## HALCYON ELECTRONICS



423, KINGSTON ROAD, WIMBLEDON CHASE, LONDON SW20 8JR  
SHOP HOURS 9-5.30 MON-SAT. TEL 0181-542 6383. FAX 0181-542 0340

OSCILLOSCOPE LIVE CHOP Page -0.25

MEASURE MODE  
CH 1  
CH 2  
CHOP  
ADD  
COMPARE  
X-Y PLOT

1.06  
0.40  
-0.26  
-0.93  
-1.60  
-2.26  
-2.93  
-3.60  
-4.26

0.30(sec) 0.30 0.90

16.5  
13.8  
11.2  
8.53  
5.8

0.33  
-2.13  
-4.80

FREEZE ONE SHOT MODE CH1 SET CH2 SET ZOOM  
TIME DIV TIME-MAG TIME-OUT HYSTERESIS SLOPE + TRIGSOURCE  
PRINT COMMENT SETTINGS

FREE

INPUT 20 volt max.

100 kHz sampling

μScope

to PC printerport

You get a free μScope when you buy a TP508 or a HS508 until september 1st 1996

resolution 8 bits  
sampling speed 100 kSamples/sec  
input range 2.5V, 5V, 10V and 20V  
connects to PC parallel printer port

SPECTRUM ANALYZER CH 1 5.987 U

3.70  
3.20  
2.70  
2.20  
1.70  
1.20  
0.70  
0.20  
-0.30

WINDOW  
RECTANGLE  
HANNING  
HANNING  
BLACKMAN  
BARTLETT

0(Hz)

MEASURE HOLD-YFFT MODE  
FREQUENCY FREQ-MAG  
PRINT COMMENT SETTINGS

### Software for the PC-based instruments

contains an Oscilloscope, a Spectrum analyzer, a Voltmeter, and a Transient recorder. All instruments are controlled in the same intuitive way and provide for saving and recalling waveforms and settings, cursor measurements, hardcopy on matrix/laser printer and online help. Minimum requirements: a 80286-based PC with 2MByte and running MS-DOS 3.3 or higher.

Fax for a free demo disk and catalog of all our products

Easy installation: just plug in and measure

### TiePieSCOPE HS508

- ▶ interface PC parallel printer port
- ▶ sampling speed 50 Msamples/sec
- ▶ resolution 8 bits
- ▶ input range 50 mV/div - 20V/div
- ▶ record length 32KByte/channel
- ▶ price £597.00, incl. software, user manual and 2 probes (1:1/1:10 switchable)

### TP508

- ▶ interface PC-XT/AT ISA slot
- ▶ sampling speed 50 Msamples/sec
- ▶ resolution 8 bits
- ▶ input range 5 mV/div - 20 V/div
- ▶ record length 32 KByte/channel
- ▶ price £ 630.00 incl. software, user manual and 2 probes (1:1/1:10 switchable)

Prices are excluding V.A.T.

TiePie engineering (NL)  
P.O. Box 290 Koperslagersstraat 37  
8600 AG Sneek 8601 WL Sneek  
The Netherlands The Netherlands  
Tel: +31 515 415 416 Fax: +31 515 418 819



TiePie engineering (UK)  
28, Stephenson Road, Industrial Estate,  
St. Ives, Cambs, PE17 4WJ,  
United Kingdom  
Tel: +44 1480 460028 Fax: +44 1480 460340

CIRCLE NO. 128 ON REPLY CARD





Do you have an original circuit idea for publication? We are giving **£100** cash for the month's top design. Additional authors will receive **£25** cash for each circuit idea published. We are looking for ingenuity in the use of modern components.

## WIN A TTI PROGRAMMABLE BENCH MULTIMETER

"High accuracy, resolution and bandwidth - performance beyond the capability of handhelds"



This high-performance bench multimeter could be yours in exchange for a good idea. Featuring a dual display, the 4.5-digit 1705 multimeter resolves down to 10µV, 10mΩ and 0.1µA and has a basic dc accuracy of 0.04%. Frequency measured is 10Hz to 120kHz with an accuracy of 0.01% and resolution to 0.01Hz. Capacitor and true rms measurements are also featured.

Recognising the importance of a good idea, Thurlby Thandar Instruments will be giving away one of these excellent instruments once every six months. This incentive is in addition to our monthly £100 'best circuit idea' award and £25 awards for each circuit published.

## Towards a better 30W amplifier

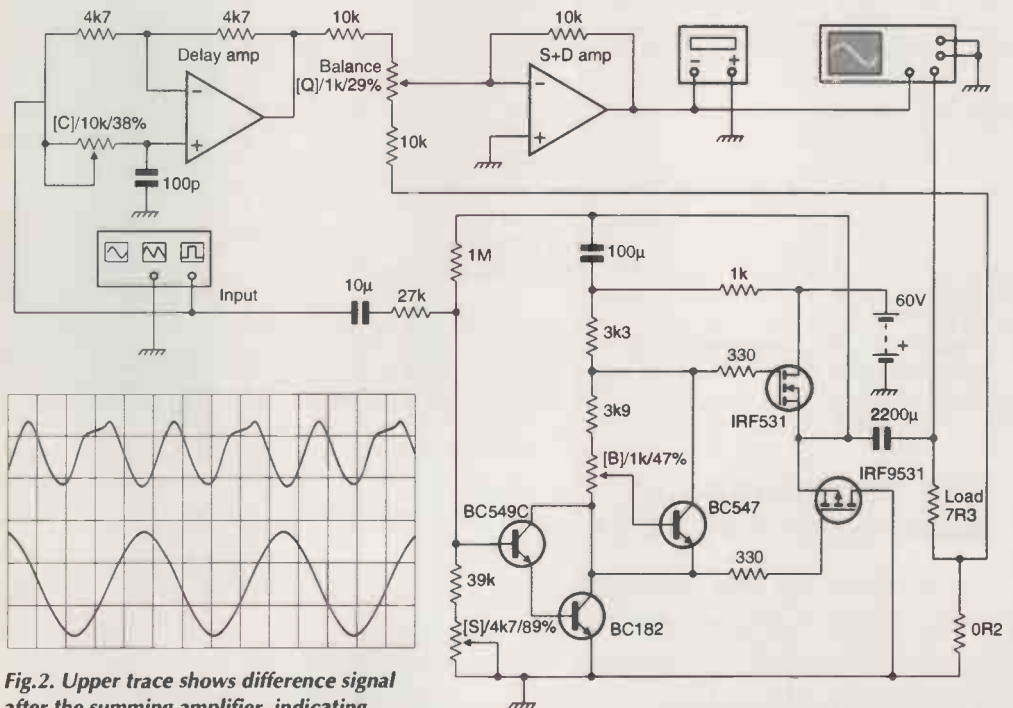
A computer simulation by *Electronics Workbench* of Jeff Macaulay's 30W amplifier in September 1995's CIs showed up some small errors, the process also provoking some improvements to the design. The program cannot measure distortion, other than by displaying it on an oscilloscope, so I developed the technique described here.

Input and output signals combine in a summing amplifier to give a difference signal, delay through the test amplifier being matched by that through the all-pass delay amplifier and the signal levels being balanced by control Q.

With the modifications to the original as shown, symmetrical clipping sets in with a load of 48W at 1kHz into 7.5Ω, after balancing the dc reference point by control S; quiescent current was set to 65mA by control B.

At 36W, the upper trace shows a mean level of 3.4mV and dominant second harmonic. Thd was 0.02%.

**Reg Williamson**  
Kidsgrove  
Staffordshire



**Fig.2.** Upper trace shows difference signal after the summing amplifier, indicating 0.02% thd. Lower trace are input and output signals.

**Fig.1.** Modified design by Jeff Macaulay and the test setup to measure it's thd.

£100 WINNER

# 30W audio bridge amplifier with preamp

Driving 30W into an 8Ω speaker, this amplifier consists of two Class AB stages in a bridge configuration.

To reduce crossover distortion, it does not rely on diodes or current sources, but on the quiescent 30mA forced by the op-amps.

Volume control is based on an arrangement due to R. Williamson<sup>1</sup>, the potentiometer having a linear law for the log. response, and the tone control was described by T H O'Dell<sup>2</sup>. This has a flat response when centred and gives 15dB treble and bass cut and boost.

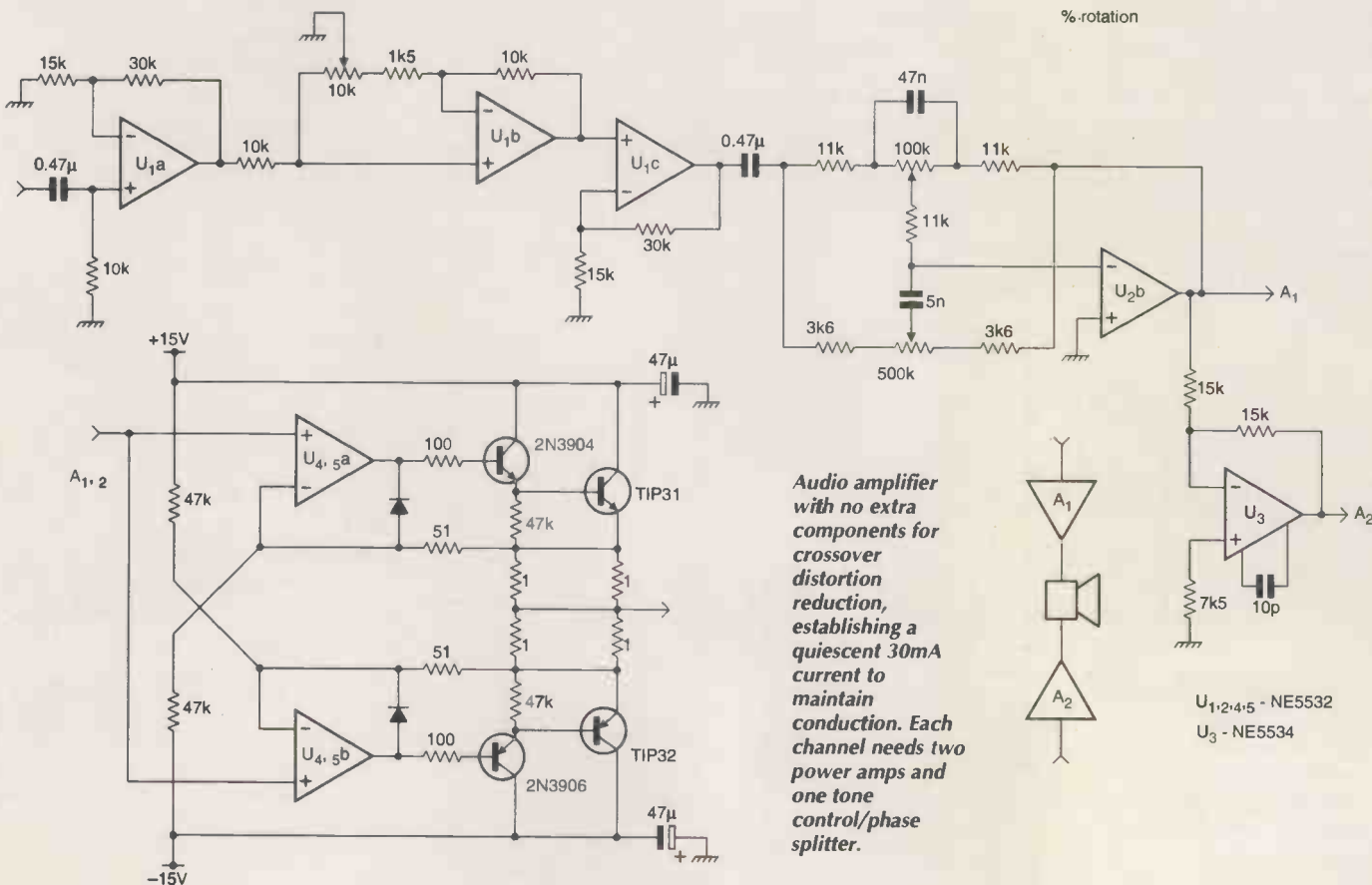
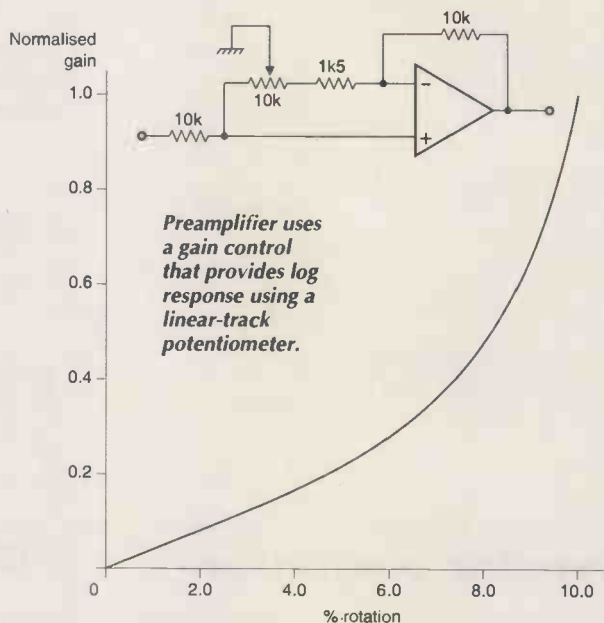
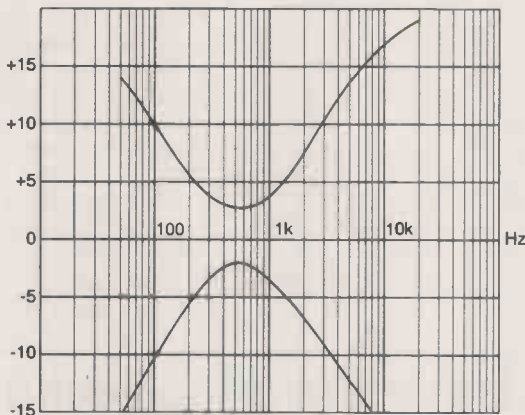
The TIP31/32 output transistors are mounted on a common heat sink with insulators; no forced cooling is needed when the circuit is contained in a 6 by 6.5 by 3in enclosure.

**John A Haase**  
Fort Collins  
Colorado  
USA

References

1. Williamson R. Circuit Ideas. *Electronics World + Wireless World*, p.29, January 1991.
2. O'Dell T H. *Electronic Engineering*, October 1985.

Op-amp based tone controls provide 15dB boost and cut.



Audio amplifier with no extra components for crossover distortion reduction, establishing a quiescent 30mA current to maintain conduction. Each channel needs two power amps and one tone control/phase splitter.

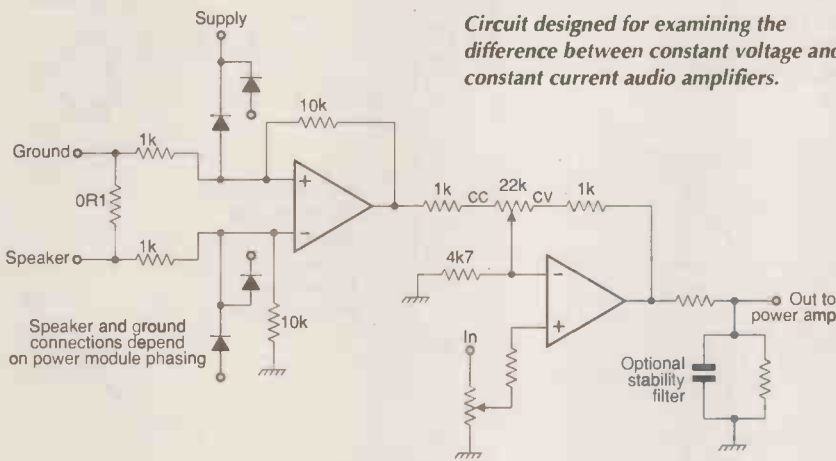
U<sub>1,2,4,5</sub> - NE5532  
U<sub>3</sub> - NE5534

## Constant-current/voltage control

Originally built to test the change sound quality from a loudspeaker when driven by constant

current and constant voltage, this circuit, derived from the AREAC c-c driver for induction loop amplifiers,

can be used with any suitable power amplifier, one of its uses being to compensate for the reactance of loudspeaker leads.



Circuit designed for examining the difference between constant voltage and constant current audio amplifiers.

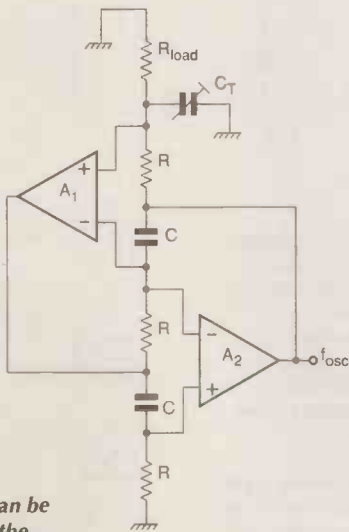
A voltage proportional to load current comes from a very small resistor in series with the load, followed by a gain stage. Output from this is compared with the signal input in an op-amp in a manner similar to that of the Baxandall tone control. Depending on the setting of the potentiometer, the output is either current or voltage or something between the two.

Stability may be a problem; low-frequency stability depends upon correct connection of the sensing resistor relative to the polarity of the power amplifier, while hf stability

## Gyrator oscillator

Balancing the frequency-dependent negative resistance with a physical resistance produces an RC oscillator with a reasonably wide range of frequencies. In the circuit shown, the frequency of oscillation is that at which the negative resistance and real resistance  $R_{load}$  are equal in magnitude, this being given by  $f=1/2\pi RC$ , assuming all resistors to be equal. Trimmer  $C_T$  provides a little negative damping to ensure start-up with minimum distortion.

John Paul  
Nottingham



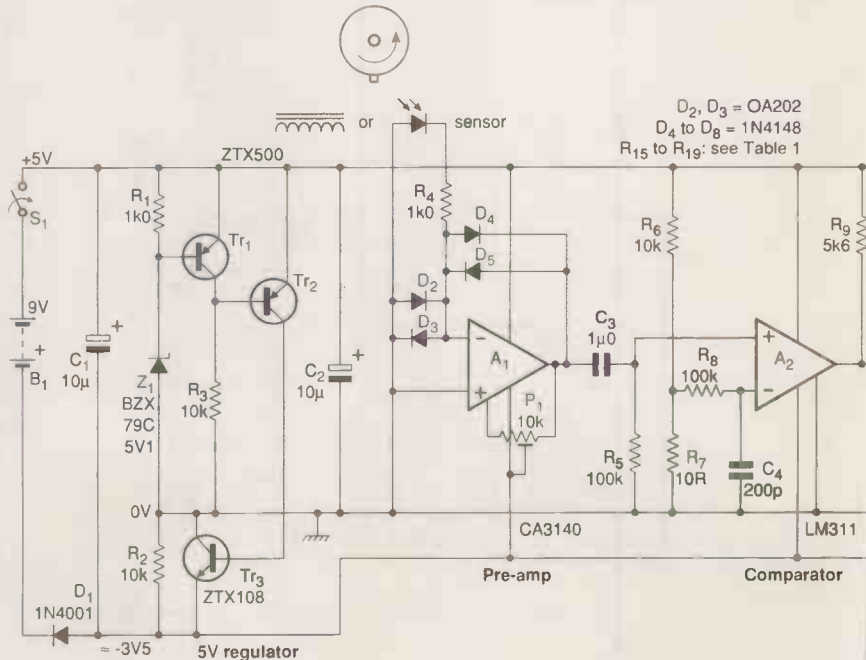
Gyrator oscillator can be made to operate in the 1Hz-200kHz range with R and  $R_{load}$  10k $\Omega$ , C at 470pF and  $C_T$  at 2-22pF.

## Pulse integrating tachometer

A common method of indicating the frequency of a pulse train by moving-coil meter is to connect a large capacitor across the meter. Since, in this case, the pulse train originates in rotating machinery and can be less than 1Hz, a very large capacitor indeed would be needed –

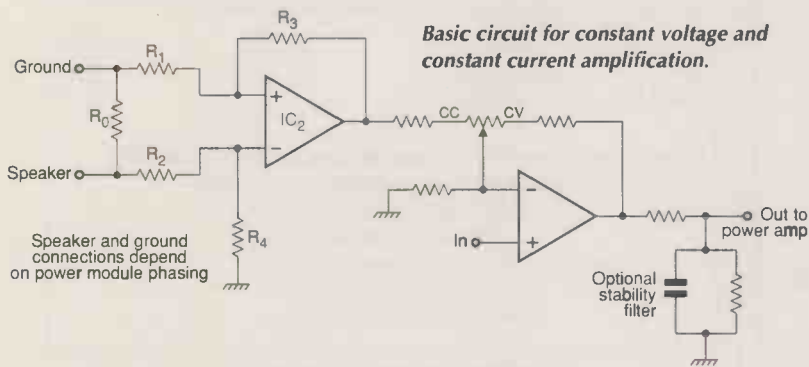
30,000 $\mu$ F or more – hence the use of this integrating circuit. It also possesses better linearity.

Input comes from a photodiode or magnetic pickup and is amplified in the op-amp  $A_1$ , which has diode feedback to provide a simple automatic gain control. This, via



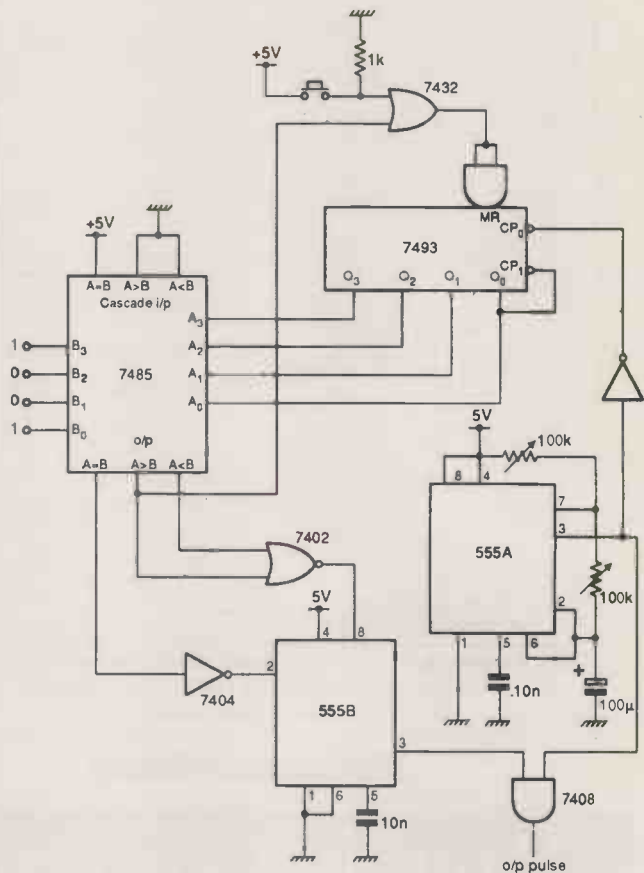
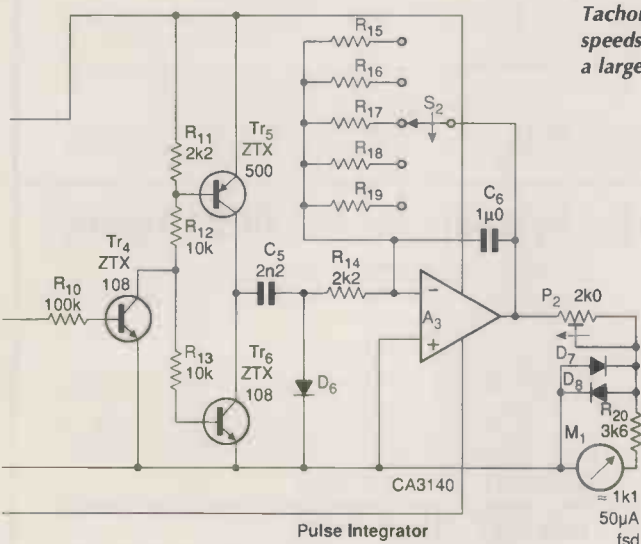
may call for the shunt capacitor across the power amplifier input. Tests using a simple loudspeaker have shown that treble and transient response significantly improved; almost as though a tweeter had been added, but without the inductance of

a crossover. It is also educational to watch the waveforms of voltage and current into a pure inductance.  
**R J Higginson**  
 AREAC Midlands Ltd  
 Halesowen  
 West Midlands



buffer  $Tr_4$ , drives the  $Tr_{5,6}$  complementary pair which provides the input to the pulse-forming network  $C_5D_6R_{14}$ . Integrator  $A_3$  has a single fixed capacitor  $C_6$ , but five 1% switched resistors to give full-scale meter deflection for 1Hz to 10kHz.

Calibration is thereby reduced to an adjustment of  $P_2$ , the values shown giving a reading of frequency; readings in rev/min will need a different set of values. The value of  $C_6$  does not enter into this calculation.  
**C J D Catto**  
 Cambridge



## Programmable pulse delay

*Pulse "catcher" produces a pulse after a delay determined by a preset binary input and the clock frequency.*

In response to a preset binary input, possibly from switches, this delay circuit produces a single pulse after a delay corresponding to the binary input and clock frequency.

Magnitude comparator 7485 takes input from the 7493 4-bit binary counter on the A pins and the binary input on B pins. The counter takes its drive from a 555 oscillator and reset from the gated A>B output of the comparator.

When the push-button switch is pressed momentarily, the counter is reset and counts up until its 4-bit output is equal to the binary input, whereupon the 555 bistable is triggered; this is gated with the clock output and an output pulse appears.

Nored comparator outputs A>B and A<B reset the 555 bistable and the counter is reset by A>B.

**V Gopalakrishnan**  
 National Aerospace Laboratory  
 Bangalore India



# Differentiator enables RS232/485 converter

A differentiator I have designed is used in this RS232/485 converter to enable the RS485 driver. It is based on just two low-cost ICs – a 74HC14 Schmitt trigger and a DS75176 transceiver.

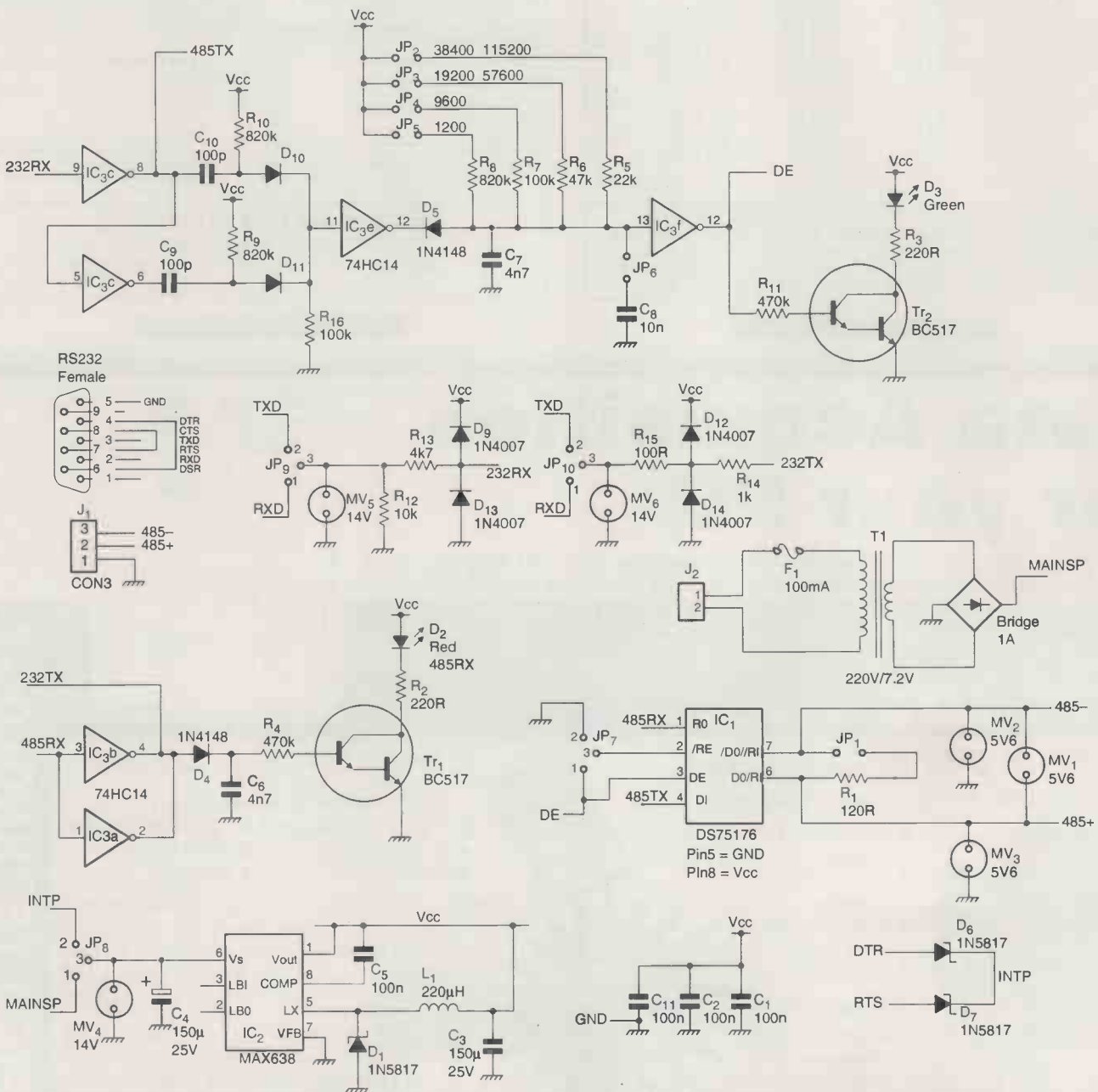
Jumpers JP2-6 allow selection of different turn-around times. Turn-around time is about one character period for the respective bit rates.

Output levels do not comply with RS232 specifications, but where RS485 conversion is concerned, cable lengths to DTE and DCE equipment are normally very short so TTL levels suffice.

Input circuitry to the DS1489 RS232 line receiver is similar to that shown. Jumper JP7 allows local echo of transmitted information. Jumpers

JP9,10 allow DTE or DCE connection formats while JP8 provides the option for powering the circuit via mains or modem control signals. The green led is on when the RS485 driver is enabled and the red led is on when data is received on the RS485 bus.

**Deon Marais**  
Brackengardens  
South Africa



In this RS232/485 converter, a differentiator is used to enable the RS485 driver after a one-character period, switch selectable to suit the bit rate.





## Two-component oscillator

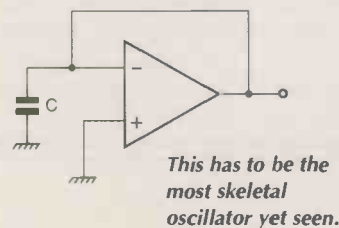
An analysis of an internally compensated amplifier having two poles at  $\omega_a$  and  $\omega_b$  shows that the circuit will oscillate at a frequency of

$$\omega_o^2 = \omega_a \omega_b + \frac{\omega_a + \omega_b}{CR_o}$$

where  $R_o$  is the op-amp output resistance.

Using a HA741 op-amp with  $C$  adjusted over the range 40-15nF, frequency was 0.9-1.2MHz.

Muhammad Taher Abuelma'atti  
and Sami Saud Buhalmi  
King Fahd University of  
Petroleum and Minerals  
Dahran  
Saudi Arabia



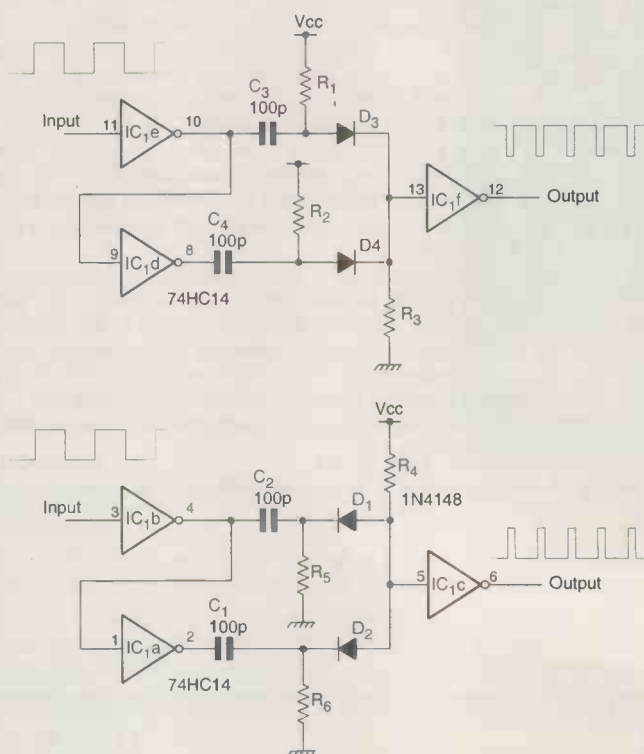
## Frequency doubler/differentiator

Frequency doublers seen in these pages in the past use more components than is necessary; this one is rather more frugal.

The negative output pulse period can be changed by varying  $C_{10}R_{10}$ ,  $C_9R_9$  and  $R_{16}$ , the values shown giving about 10µs. For positive output pulses, use the circuit in the second diagram.

Deon Marais  
Brackengardens  
South Africa

Circuit producing unidirectional pulses for each input transition, for frequency doubling or "differentiation".



## 50dB logarithmic meter

Using ordinary 1N4148 diodes, this meter amplifier indicates direct or ac voltages from 10mV to 3.5V in one range.

Current forced in to the meter circuit of Fig. 1 is

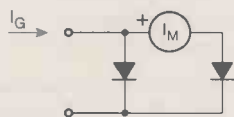


Fig. 1. Basic logarithmic metering circuit.

$$I_G = I_m \left[ 1 + \exp\left(\frac{R_M I_M}{n U_T}\right) \right]$$

$I_M$  being meter current,  $R_M$  meter coil resistance and  $V_T$  temperature voltage  $kT/q = 26mV$ . Constant  $n$  is 1.9, found experimentally for 1N4148 diodes, and with a 1.7kΩ meter coil, the equation is

$$I_G = I_M \left[ 1 + \exp\left(\frac{I_M}{29\mu A}\right) \right]$$

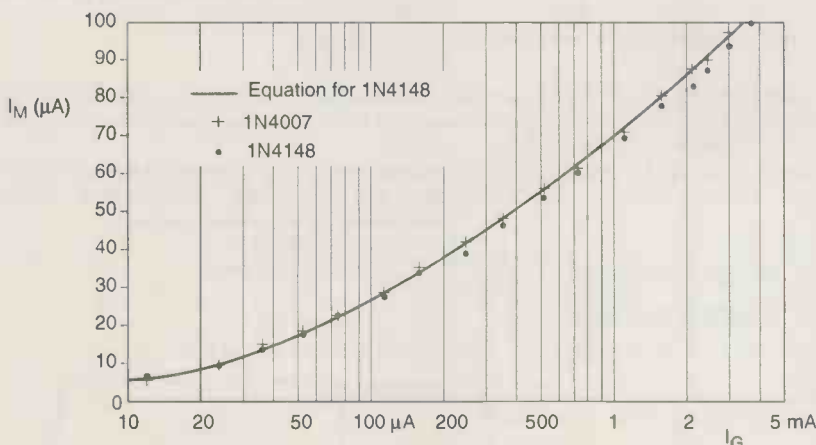


Fig. 2. Measured meter current for 1N4148 and 1N4007 diodes, the full line showing the calculated curve for a 1N4148.

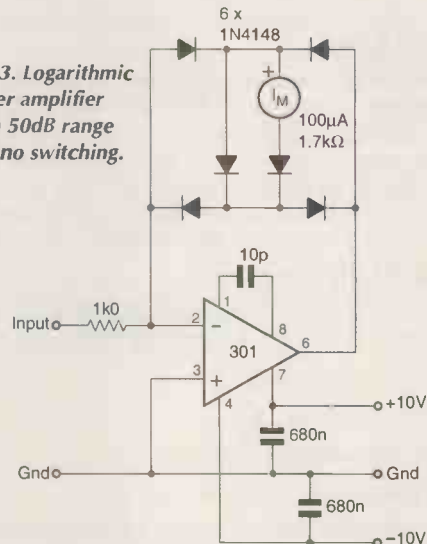
which is plotted as Fig. 2.

Temperature coefficient of the diode is 0.17%/°C at 50% of full scale and 0.26% at full scale, the copper in the meter coil opposing this change to give a nett coefficient of 0.1%/°C.

Bandwidth of the circuit shown is 50kHz-3dB at 15% of full scale and 100kHz-3dB at 50%. Amplifier input voltage offset should be no more than 2mV.

Tore A Nielsen  
Malov  
Denmark

Fig. 3. Logarithmic meter amplifier with 50dB range and no switching.



# SMART CARD EVALUATION SYSTEM

## Low Cost Introduction to Microprocessor Smart Cards

### SMART CARD EVALUATION PACKAGE

Comprising of Presentation case containing:-

- ◆ Smart Card Reader / Writer ( Programming Interface)
- ◆ 244 page Hard Back reference book, covering all aspects of Smart Card design and programming.
- ◆ Smart Card Interrogation System, to identify the commands accepted by a target Smart Card.
- ◆ Evaluation application, for use with Smart cards provided in the package.
- ◆ 'C' Library & Command descriptions. For the user to design their own Smart card applications using the cards provided.
- ◆ Programmers Development Suite. Text Editor Assembler, Simulator for programming the Cards provided.
- ◆ Development Boards for use with the programming interface. Allowing the user to simulate a Smart Card
- ◆ Selection of real Smart cards with full programming details.

This package is all that is required to understand and develop, your first Smart Card application. The comprehensive documentation and specially written applications, give the user a valuable insight into Card architecture and Programming techniques. Comprehensive 'C' listings are included as is a complete 'RISC-like' processor development system. The package includes development PCB's to allow the user to program and Simulate a Smart Card, also included are REAL SMART CARDS along with access commands and complete UNRESTRICTED programming information. The unique SMART CARD INTERROGATION SYSTEM allows the user to Communicate with a Target card and extract the command set used by that card !

For more detailed product information please send a LARGE SAE with your request.

**£225.00**

discounts are available for multiple orders and Educational establishments.

### THE SMARTEST SOLUTION

*Crownhill can offer a broad range of processor based smart cards. Crownhill are not aligned to any single microprocessor or die supplier. This allows us to work with you the customer, in the selection of the optimal processor for your application.*

*Crownhill can supply over 150 different types of IC from more than 12 silicon suppliers, all can be incorporated into smart card format. Some cards are available from stock, most are manufactured to the customers specification.*

## JOHN MORRISON

### DEVELOPMENT SOFTWARE & OEM PROGRAMMING MODULES

#### PIC PROGRAMMER

PIC16C54, 16C55, 16C56, 16C57, 16C58A, 16C61 16C64, 16C65, 16C71, 16C74, 16C84, 16C620, 16C621, 16C622 & Memory Chips 24LC01, 24LC02, 24LC16, 24LC 32, 24LC65

Supplied with powerful editing software allowing the user to Read, Write & Copy PIC devices including data memory and fuse areas. Supplied with an integrated Editor Assembler software suite. Sample files and notes. (PIC 16C84 copy protection removal is possible with the enhanced version)

**£69.95**

#### PIC IN CIRCUIT EMULATOR

A low cost ICE to emulate all 18 or 28 pin PIC devices. All ports are Bi-Directional with OSC2 output and RTCC input. An onboard A/D converter allows emulation of the PIC16C71. Supplied with PIC DEV software suite, user manual, connecting leads, headers and sample programs and projects.

Note the ICE is not 'real time' the speed of emulation is determined by the host PC. However a local clock output is available to enable real time measurements to be taken.

**£99.95**

#### MEGA PROM II

A versatile EPROM programmer capable of handling EPROMS, EEPROMS, Flash Memory from 2Kb to 8Mb NOW Including Microchip 24LC Series serial memory chips.

The programmer operates with a host PC via the centronics port using a standard printer cable. The unit features AC / DC input Voltage handling and production quality ZIF socket.

**£89.95**

#### SMARTIE EEPROM PROGRAMMER

EEPROM programmer covering: 24xx01, 02, 04, 08, 16, 32, 65, 164, 174, 29xx, 59xx, 85xx, 93xx, NMC, PCF. Smart little unit, just plugs into a free parallel port on the IBMPC and auto detects Microwave or 12C types. Simple to use and fast operation make this little programmer indispensable.

**£49.95**

Although this unit can be used to decode Car Radio's and Cassette players, we offer no advice or support for that use.....please do not ask!

#### EPROM Emulator

A versatile EPROM pEmulator for ROM from 1Kb to 32Kb

The Emulator operates with a host PC via the centronics port using parallel cable. The unit features very fast Download to target board EPROM socket and complete integration with our development software suites.

Will also operate without our development software suite with no loss of functionality.

**£59.95**

We stock the full range of JOHN MORRISON development software for PIC devices, Microprocessors and Microcontrollers. Each software suite has a **FULLY INTEGRATED TEXT EDITOR, ASSEMBLER, SIMULATOR and DISASSEMBLER.**

Code can be downloaded directly to our Emulators. All software is supplied with sample code and operating instructions. Devices catered for include: MCS-8051/52/552, MCS-8048/49, PIC-16C54/55/56/57 and compatible, PIC 16C71/84 and compatible. HD-63/6809, 6502.

**£19.95**

**CROWNHILL ASSOCIATES LIMITED**  
PO BOX 845  
Waterbeach  
Cambridge  
CB4 9JS

**TEL 07010 700017**  
**01223 235895**  
**FAX 01223 441645**  
**BBS 07010 700018**

**CHEQUE**  
**POSTAL ORDER**  
**SWITCH**  
**DELTA**  
International Money order

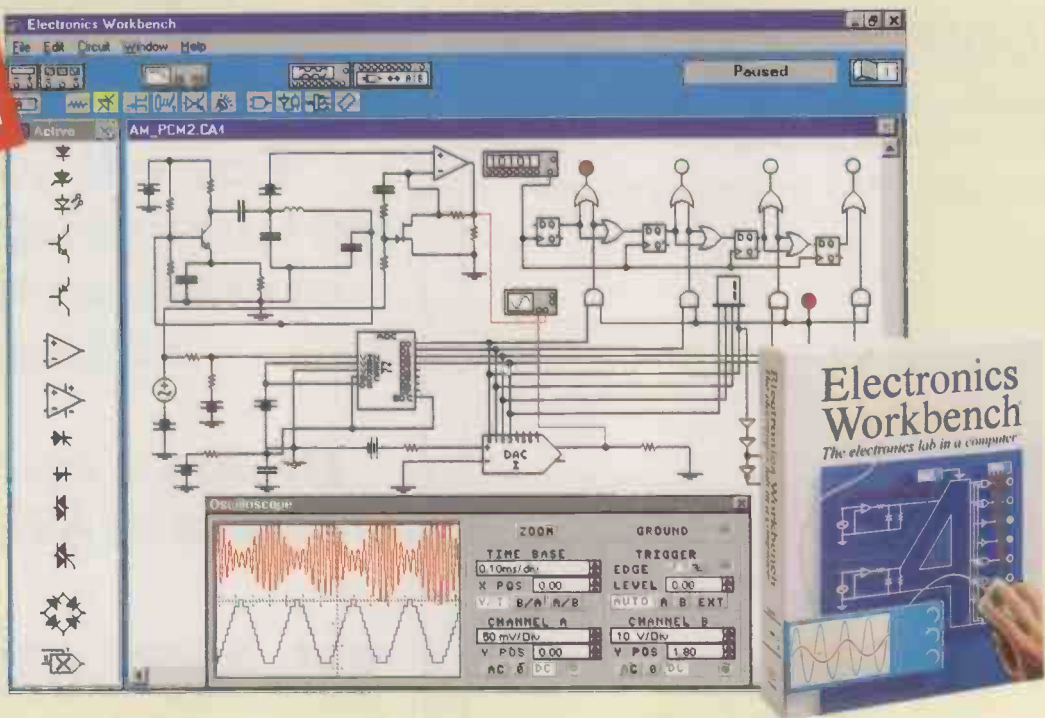
◆ **VISA**  
◆ **ACCESS**  
◆ **MASTER CARD**  
Subject to 5% Surchargo

All prices are subject to VAT at the prevailing rate (\*17.5%) for EC orders.

**CIRCLE NO. 137 ON REPLY CARD**

# Electronics Workbench<sup>®</sup> Version 4.1

**NEW**  
WINDOWS 95/NT  
32 BIT VERSION



## Design and Verify Circuits Faster

Join over 40,000 customers using *the affordable mixed-signal simulator*

Design faster with Electronics Workbench. Mix the analog and digital components and ICs in any combination. And with a click of the mouse, try 'what if' scenarios and fine tune your designs. The built-in SPICE simulator gives you real-world waveforms.

All without programming or netlist syntax errors.

And in minutes. Not hours or days.

You'll be up and running sooner. And create better designs faster with Electronics Workbench. We guarantee it!

### **RM** Robinson Marshall (Europe) Plc

Nadella Building, Progress Close, Leofric Business Park, Coventry CV3 2TF  
E-mail: sales@rme.co.uk Fax: 44 (0) 1203 233210

Shipping charges UK £6.99 All prices are plus VAT.

All trade marks are the property of their respective owners.

Electronics Workbench is a trademark of Interactive Image Technologies Ltd., Toronto, Canada.

**Electronics Workbench: £199**

- Click & drag schematic capture
- Mixed analog/digital SPICE simulator
- Instant Bode plots and scrollable waveforms
- 50 analog components with 350 models
- 140 digital components and ICs in TTL and CMOS
- Windows 95/NT/3.1, DOS and Macintosh versions
- Free unlimited technical support
- 30-day money-back guarantee

**Engineer's Pack: £399**

- Electronics Workbench
- 2,450 models
- Import/Export SPICE netlists
- Export to PCB packages

To discover more about *the affordable mixed-signal simulator*, call us today at:

**44-(0)-1203-233216**

Fax: 44-(0)-1203-233210



Australia: 2519-9933 • Belgium: 2384-7309 • Brazil: 11-453-5588 • Chile: 22360900 • Cyprus: 262-1068 • Czech Republic: 42-4823454 • Denmark: 33-250109 • Finland: 0287-5093 • France: 149089000 • Germany: 711-627740 • Greece: 15249981 • Hungary: 1-2150082 • India: 11-544-1343 • Indonesia: 21-4700815 • Israel: 3-647-5613 • Italy: 11-437-5549 • Japan: 3-33823136 • Malaysia: 3-774-2189 • Mexico: 5-993-5260 • Netherlands: 18031-7666 • New Zealand: 9-267-1756 • Norway: 22-16-7045 • Philippines: 973-27-0118 • Portugal: 1-81-46609 • Singapore: 777-2303 • Slovenia: 61-317-890 • South Africa: 331-68909 • South Korea: 22-222-3431 • Spain: 1-383-8335 • Sri Lanka: 1-86-5970 • Sweden: 8-740-9500 • Taiwan: 886-2-366-0080 • Thailand: 66-2-398-6952 • UAE: 4-453505 • UK: 203-23-3216



# KESTREL ELECTRONIC COMPONENTS LTD

- ☆ All items guaranteed to manufacturers' spec.
- ☆ Many other items available.

'Exclusive of V.A.T. and post and package'

	1+	100+		1+	100+
27C64-15	2.60	1.57	628128LP-85	8.30	6.90
27C128-15	2.40	2.20	62256LP10	3.60	2.45
27C256-15	2.20	1.55	6264LP-10	2.60	1.45
27C512-15	2.20	1.75	MM58274CN	4.90	3.75
27C010-15	3.95	2.75	ULN2003A	0.43	0.28
27C020-15	6.00	3.80	7805	0.32	0.25
27C040-15	8.60	6.00	MAX232	1.35	0.88
80C31-12	2.10	1.95	7406	0.35	0.23
80C552-5-16	10.50	7.50	7407	0.35	0.23
Z80A CPU	1.80	1.00	74HC244	0.35	0.21
LM317T	0.50	0.40	74HC245	0.35	0.21
75176BP	1.35	0.50	74HC373	0.35	0.21
68w PLCC skt	0.90	0.70	74HC374	0.32	0.21

Phone for full price list

All memory prices are fluctuating daily, please phone to confirm prices

178 Brighton Road, Purley,  
Surrey, England CR8 4HA

Tel: 0181-668 7522. Fax: 0181-668 4190

CIRCLE NO. 139 ON REPLY CARD

# ADVERTISERS PLEASE NOTE

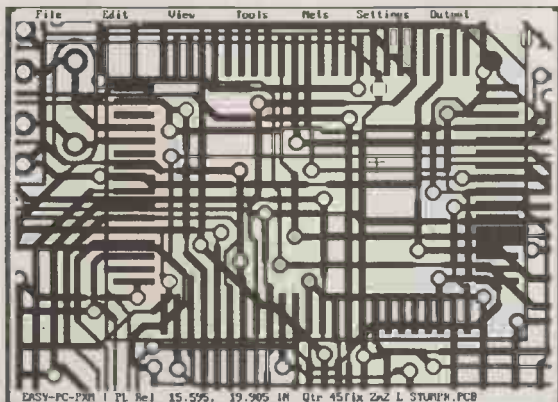
For all your  
future enquiries  
on advertising  
rates

Please contact  
Malcolm Wells on

Tel: 0181-652 3620  
Fax: 0181-652 8956

## NEW -- MultiRouter!

There are autorouters and *AutoRouters*....



"The Best Autorouter that I have seen costing less than £10,000!" R.H. - (Willingham, UK)

- Uses the latest 32 bit, Shape based, Multi-pass Technology
- Extremely Fast - Do in Minutes what would normally take Days
- AutoRoute very large and complex boards
- 100% Completion where other autorouters fail
- Could Easily Pay For Itself On The First Job

## Number One Systems

World Leaders in Affordable Electronics CAD

UK/EEC: Ref: WW, Harding Way, St.Ives, Cambridgeshire, ENGLAND, PE17 4WR.  
Telephone UK: 01480 461778 (7 lines) Fax: 01480 494042  
USA: Ref: WW, 126 Smith Creek Drive, Los Gatos, CA 95030  
Telephone/Fax: (408) 395-0249

Email: [sales@numberone.com](mailto:sales@numberone.com)  
International +44 1480 461778



CIRCLE NO. 141 ON REPLY CARD

# Faster filters

**Kamil Kraus explores the design of high-speed filters using a high performance current-mode op-amp.**

**D**esigning active filters with cut-off frequencies of 1MHz or more requires amplifiers having low transit times, wide bandwidth and high gain. Burr-Brown's OPA603 satisfies these demands. Low-pass, high-pass and band-pass filter designs shown here are not new<sup>1</sup>, but the design procedure and their use at high frequencies have not previously been fully explored.

To illustrate the method, consider the low-pass filter shown in Fig. 1. Its general transfer function of is,

$$F(s) = \frac{R}{kR_1} \frac{1}{\{1 + s[C_2(R+R_3) + C_1R(1-1/k)] + s^2C_1C_2RR_3\}}$$

where  $R=R_1R_2/(R_1+R_2)$  and  $k=R_5/(R_4+R_5)$ . Cut-off frequency,  $Q$  and gain  $G$  are then,,

$$\frac{1}{\omega_0} = \sqrt{C_1C_2RR_3}$$

$$\frac{1}{Q} = \omega_0[C_2(R+R_3) - C_1RR_4/R_5]$$

$$G = R/kR_1$$

Sensitivity  $S$  to variation in  $Q$  with changes in  $R$  is given by,

$$S = \frac{R}{Q} \frac{dQ}{dR} = \frac{.1}{2} \frac{C_2(R_3 - R) + mRC_1}{C_2(R_3 + R) - mRC_1}$$

where  $m=R_4/R_5$ . Solving these equations for  $R$  and  $m$  produces expressions for the practical design of the filter, namely,

$$R = \frac{4Q^2C_2R_3}{C_1B^2}$$

$$m = \frac{ABC_1 + 4Q^2C_1}{4Q^2C_1}$$

where  $A$  is  $2S-1$  and  $B$  is  $2S+1$ . These expres-

sions are simplified by making  $C_1=C_2=C$ .

Suppose the low-pass filter requires a 1MHz cut-off,  $Q$  of 25 and must exhibit sensitivity to variation in  $R$  of no more than 9. The above equations in  $R$  and  $m$  give  $R=10k\Omega$  for  $R_3=1.5k\Omega$  and  $m=1.1292$ , making  $k=0.469$ .

The value of  $G$  must be less than  $1/0.469$  and is chosen to be 2, so that  $R_1=R/kG=11k\Omega$  and  $R_2=167k\Omega$ . If  $R_5$  is made  $5k\Omega$ ,  $R_4=mR_5=3.4k\Omega$ .

For the equivalent high-pass filter, interchange  $R$ s and  $C$ s to give the circuit of Fig. 2, in which the sensitivity  $S$  now involves variation of  $Q$  with capacitance  $C=C_1+C_2$ ; the following expression shows the effect

$$S = \frac{1 - mA - x}{2(1 + x - mA)}$$

where  $A=R_2/R_1$  and  $x=C/C_3$ .

When calculating component values, the conditions  $1-mA \geq 0$  and  $A > Q^2$  must be met. Suppose the requirements are  $Q=10$  and  $f_0=1MHz$ . Then  $A > 100$  and 120 is chosen, so that  $m=1/A=0.008$ , giving  $R_4=0.008R_5=160\Omega$  for  $R_5=20k\Omega$  since  $R=R_2/R_1=120$ ,  $R_1=1k\Omega$  and  $R_2=120k\Omega$ .

Values of  $m$ ,  $Q$  and  $A$  set  $x=C/C_3$  at 0.2; with  $C_3$  at  $0.1\mu F$ ,  $C_{1,2}=0.01\mu F$ .

Figure 3 shows the band-pass design, which

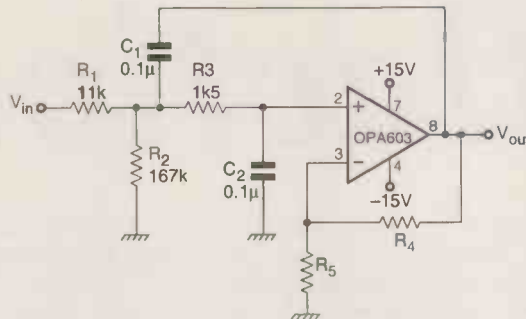


Fig. 1.

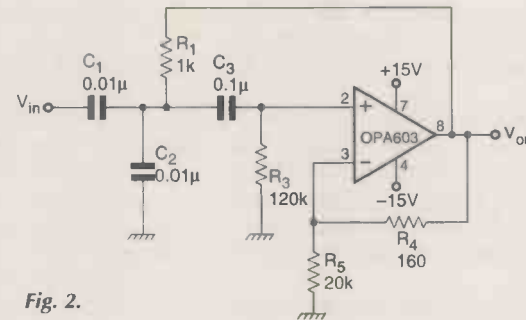


Fig. 2.

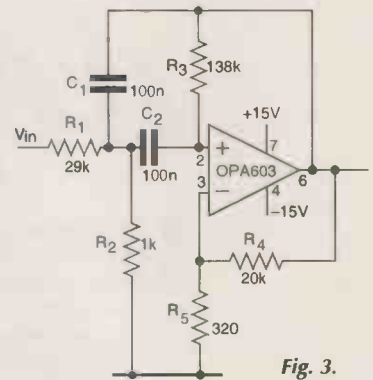


Fig. 3.

Current-feedback op-amps such as the OPA603 lend themselves to high-frequency active-filter design. Detailed design methods for the three basic configurations are described here. All three filters above have an  $f_0$  of 1MHz. Top is low pass with a  $Q$  of 25, middle is high pass with a  $Q$  of 10 and bottom is band pass with a  $Q$  of 50.

is governed by the following equations,

$$\frac{1}{\omega_0} = \sqrt{RR_3C_1C_2}$$

$$\frac{1}{Q} = \omega_0[R(C_1 + C_2) - mR_3C_2]$$

$$G = \frac{R_2}{R_1 + R_2}(1+m)Q\sqrt{x}$$

where  $x=R_3/R$  and  $m=R_5/R_4$ .

$$S = -\frac{1}{2} \frac{2 + mx}{2 - mx}$$

Solving the  $Q$  and  $S$  equations for  $m$  and  $x$  gives,

$$m = \frac{4S^2 - 1}{8Q^2}$$

$$x = \frac{2(2S+1)}{m(2S-1)}$$

For a band-pass filter with  $f_0=1MHz$ , and a -3dB bandwidth ( $B$ ) of 20kHz, sensitivity to resistance variation must be less than 9.  $Q=f_0/B=10^6/2 \times 10^4=50$ , so  $m=0.01615$  and  $x=138.4083$ . For  $G=-20$ ,  $R_1=29R_2$ , for  $R_2=1k\Omega$ ,  $R_1=29k\Omega$  and  $R=1k\Omega$ . If  $R_4$  is made  $20k\Omega$ ,  $R_5=0.016R_4=320\Omega$  and for  $x=138$ ,  $R_3=xR=138k\Omega$ . ■

**Reference**

1. Moschytz, G S. and Horn, P. *Active Filter Design Handbook*, J Wiley, New York, 1981.

In Part 2 of his article **David Sharples** discusses the mechanisms by which tv and monitor deflection transistors fail.

# DESIGNING CRT *deflection*

Unfortunately, horizontal deflection transistors do fail from time to time. However, failure rates to low parts-per-million levels can be achieved if the correct investigations are carried out during the design stage. The following notes discuss the potential failure modes and how these should be addressed at the design stage.

Studies of device failure patterns show that a device could fail either soon after the tv set is built or after some years use. The fundamental cause of failure is quite different for these two cases.

Immediate or short-term device failure can be attributed to one of the following: circuit design weakness, a set manufacturing fault, or a weak device shipped by the supplier. Long term failures are the result of a chronic change in the load and/or the drive. Current information suggests that long term failures due to device degradation are remote and, therefore, insignificant.

By nature and design, power semiconductor devices often act as a fuse when something goes wrong elsewhere in the circuit. The semiconductor industry is moving towards new technologies that produce non-destructive fuses, but many of these benefits are unlikely to be applied to deflection transistors within the next few years.

## Short-term failures

Careful design can achieve short-term failure rates at a very low ppm levels. Television and monitor manufacturers cannot tolerate percentage fall-offs in the production line, or high warranty returns from the field.

The key component status given to the deflection transistor allows detailed investigations to be carried out during set development to eliminate the significant failure modes. However, short-term failure modes are not always eliminated completely and problems can occur in production.

A device can fail simply from too much load current, too little drive in the on-state, or by too much voltage in the off-state. These failure modes are easy to detect and are usually corrected before they become a major embarrassment.

Physical analysis of device failures suggests a more complicated common failure mode: exceeding the reverse-bias safe operating area, or *rbsoa*. The *rbsoa* defines the current-voltage,  $I_C$ - $V_{CE}$ , boundary a device can withstand during turn-off, i.e. base reverse biased. The *rbsoa* of a bipolar transistor is very application dependent and can also be device-to-device dependent. For this reason data is often not given and a 100% production test even less so. The *rbsoa* for a Philips *BU2522AF* is shown in Fig. 1.

For any deflection transistor, the critical region is above the  $V_{CEO}$  limit. This is usually 600-800V for a device with  $V_{CES}$  of 1500V. Failures are most likely to occur as the

device turn-off trajectory passes through the 600-1000V region. Physically, the devices are driven into a secondary breakdown state; the transistor then becomes a path of low resistance. There is sufficient energy stored in the flyback capacitor to then damage the transistor beyond repair.

For television, there is one acknowledged fault condition that can lead to a device exceeding the *rbsoa* - 'picture tube flash'. This is when the eht required for the crt finds a low resistance path to ground, or a point of lower potential. The eht is generated by the line output transformer and deflection transistor; a low resistance path effectively shorts the secondary of the transformer.

As the system recovers, large currents are drawn from the secondary which in turn lead to large currents in the primary. The deflection transistor can then see several cycles with the  $I_C$  much higher than for normal operation. Such an occurrence can lead to the *rbsoa* being exceeded and, possibly, the failure of the device.

The causes of such an occurrence are beyond the scope of this report, but the phenomenon is acknowledged throughout the industry as a serious fault condition.

The deflection transistor suppliers' response to this problem is to provide *rbsoa* curves for new product releases and develop more 'rugged' products. One recent trend is an increase in the  $V_{CES}$  limit to 1700V; this gives a more 'rugged' product but at a higher cost. Philips Semiconductors offer a range of 1700V deflection transistors for tv and monitor applications.

Some monitor designs incorporate a separate circuit to generate the eht. In such designs, the deflection transistor is no longer vulnerable to 'picture-tube flash'. However, some multi-frequency monitor designs present another fault condition that can lead to the *rbsoa* of the deflection transistor being exceeded - namely mode change.

As a monitor switches mode, several functions are performed that lead to a change in the horizontal line rate; for instance a typical pc monitor can operate between VGA mode at 31.5kHz and enhanced resolution 1280x1024 mode at 64kHz. If the integrity of the drive is not maintained during a transition the deflection transistor can be forced outside its *rbsoa*.

Recent monitor designs have much greater control during mode change which leads to products less likely to fail.

## Long-term failure

Long term failure modes can either be associated to the ageing of the tv or an infrequent but gross overstress event. A knowledge of the deflection transistor can sometimes assist in a speedy solution.

A tv several years old is not likely to fail due to some

David Sharples is with Philips Semiconductors.

strange and interesting phenomenon associated with the set and ambient. Experience suggests that the more likely failure mode is an electromechanical degradation of a component in the drive or load of the deflection transistor.

Power devices often act as fuses when things go wrong and a parametric shift in one component value can result in the functional failure of the deflection transistor and, hence, the tv or monitor. In such cases, replacing the deflection transistor with a new part often produces the same failure in quick succession. Without either a wealth of previous experience, or an oscilloscope analysis of the waveforms, a true fix is often not possible. A knowledge of the characteristics of deflection transistors can help.

Physically, the failure modes of 'new' and 'old' deflection transistors are identical. The phenomena outlined in the short-term failure section are relevant to long-term failures. Some simple tests can be done without any instruments to detect the cause of failure. Where fails can be almost immediately reproduced an experienced television engineer will be able to arrive quickly at the true cause. If subsequent fails are not found how can we be sure that a complete repair has been made? This is illustrated in the panel 'Fault finding...' from last month's article.

### Alternatives to bipolar devices?

As design engineers develop a greater affinity with their pcs at the expense of their soldering irons so the trend to find an alternative to the bipolar high-voltage transistor gathers pace. Everyone knows that you can feed the output of a typical IC into the gate of a mosfet to turn it on and off; there is no need for a drive transformer. Mosfet switching times tend to be measured in nanoseconds rather than microseconds so the concept of storage time can be eliminated. Simple mosfet device models are available making a mosfet deflection circuit a dream to simulate.

However, the dream soon becomes a nightmare. The on resistance of high voltage mosfets is dominated by the bulk epitaxial silicon which has to be very thick – many tens of micrometres – to sustain 1500V. This makes the on-state voltage across equivalent sized bipolar and mosfet devices much higher for the mosfet.

To reach parity with the bipolar device, the mosfet requires a much larger piece of silicon, which in turn requires a bigger package; both of these increase costs. Mosfet processing involves more mask stages and processes that are inherently more expensive. At today's prices, the cost of a drive transformer and bipolar high-voltage device is less than the mosfet equivalent.

The high on resistance of the mosfet brought about the birth of igbt's. Fundamentally, these devices combine the ease of mosfet drive with bipolar high-voltage transistor type voltage drops in the on-state. Considerable investments in igbt technology have been made by all the leading discrete semiconductor suppliers, and 1000V igbts for applications up to 10kHz are readily available.

The cost of such devices is still considerably higher than a bipolar transistor equivalent but the igbt price is likely to drop to narrow the difference. However, bipolar devices are unlikely to come under a real price threat from igbts in the next five to ten years.

The larger an igbt or mosfet gets, the larger the gate area gets. The larger the gate area, the more charge is required to enhance conduction. A 1500V device would require a significant amount of charge to be applied, and then removed, from the gate; it cannot be assumed to be a simple voltage controlled switching device.

Experiences with igbts below 1000V at frequencies up to 20kHz have shown that a whole new set of peculiar device characteristics have to be appreciated to achieve a successful design. Many of the skills required for designing in

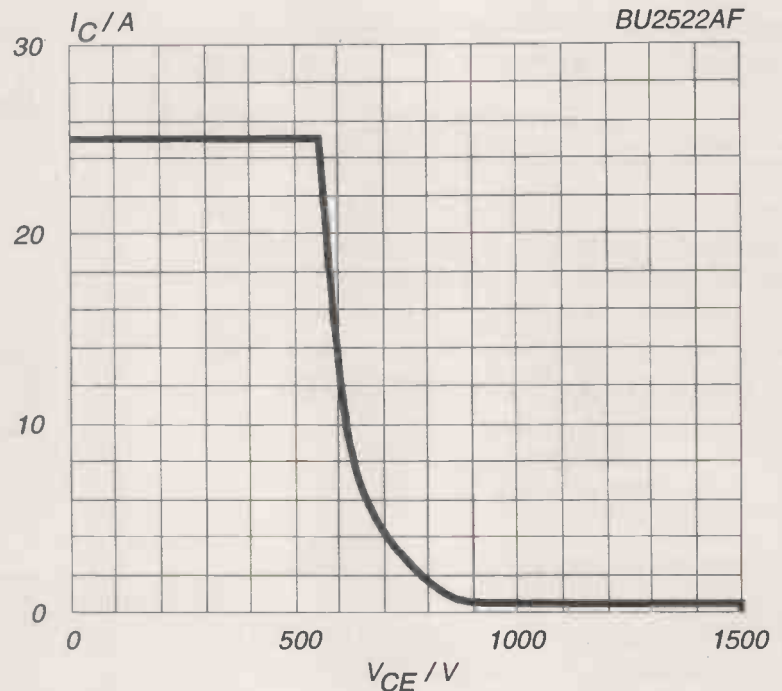


Fig. 1. Reverse-bias safe operating area, rbsoa, for the Philips BU2522AF horizontal deflection transistor.

a bipolar high-voltage transistor will just be replaced by a new set of skills. It is unlikely that any easy to drive power device for horizontal deflection will ever be achieved within the life-span of the crt.

### The future

A few semiconductor suppliers are taking tentative steps with the alternative technologies outlined above. But, in the world of horizontal deflection transistors, most of the development resource is dedicated to advancing bipolar technology.

The basic requirements of functionality with minimum dissipation and an ability to survive all fault conditions will determine future deflection transistor developments. The highly competitive nature of the tv and monitor industries means that cost reduction will always feature high on the list of requirements for new devices. The cost requirement alone is sufficient to restrict the ingress of new device technologies.

The emphasis that the television and monitor industries apply to these requirements is not identical. This is reflected in device designs that are specifically for each market. It is apparent that the differences will become more exaggerated in the next few years.

Bipolar deflection transistors, like most other discrete semiconductors, do not demand state-of-the-art processing. For a deflection transistor minimum feature sizes tend to be tens of micrometres rather than sub-micrometre. Because of this, established and mature processes are utilised that keep the production costs down: deflection transistor prices do not have to support the overheads associated with 8in wafer Class 1 fabrication lines.

But as the IC industry continuously strives for smaller, high quality, high throughput products so a range of tried and tested processes become available to discretetes. Integrated-circuit processes cannot be directly transferred to deflection transistors but the processes can be adapted using commercially available equipment.

To summarise, advances in bipolar high-voltage transistor devices will ensure that the requirements for horizontal deflection will be met with ever-improving, reliable designs. ■







# Multiprocessor motherboards

**How do multiple processors talk to each other? John Mitchell explores the utopian world of multiprocessors where all tasks are shared equally.**

Intel has just released the first of its new multiprocessing motherboards for servers using the Pentium processor. This cpu is ideal for use in multiprocessing systems due to its advanced architecture, separate on-chip code and data caches, chip sets for controlling external caches, and sophisticated data integrity features.

The term symmetrical multiprocessing, or smp, refers to the operating system's ability to schedule code for execution on the first available cpu, rather than a specific cpu. That is, in an smp system the next piece of code for execution always goes to an idle cpu. Thus the total amount of processing in the system becomes shared equally between all the processors, with each one executing very nearly the same amount of code, Fig. 1.

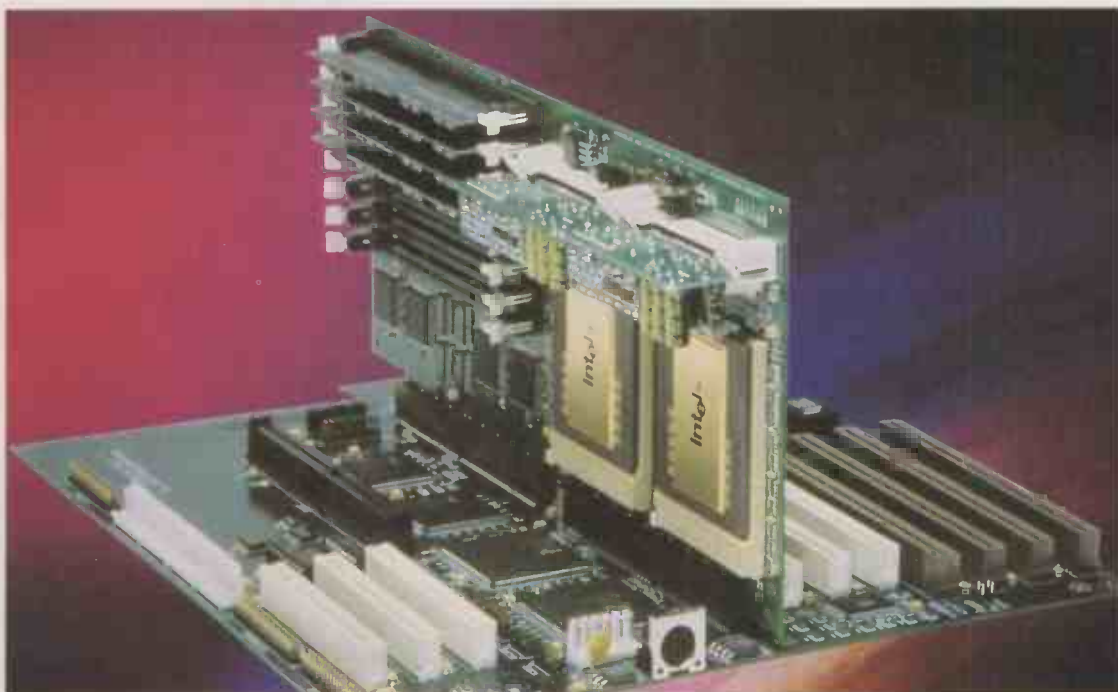
Many applications will benefit from running

on an smp system, with some of the most common being on-line analytical processing, simple client/server setups and communications – including remote-access servers, e-mail routers and World Wide Web servers. Symmetrical multiprocessing benefits these applications because they come under a heavy user and processing load, in that large amounts of information are read into memory, processed and then written back to disk.

## Everything old is new again

Using multiple processors on a single motherboard, or even in a single computer, is nothing particularly new, especially in mini-computers. But Intel's offering will be the first that adheres fully to the company's own MultiProcessor Specification, which has been developed by the Intel Architecture Labs, IAL,

*One of American Megatrends' multi-processing motherboards for up to four Pentium Pros. Atypical of the multiprocessor motherboard series, this one has the processors on a daughter board making more room for expansion slots.*



in cooperation with leading oems, osvs and bios vendors.

Many current vendors of multiprocessing systems based on Intel architecture cpus use proprietary designs that require operating systems to be customised to run on specific hardware. The high cost of supporting multiple versions of the operating system and platforms makes it uneconomical for multiprocessing system vendors to make their products more widely available. This results in a lack of choice of hardware and operating systems for end users.

The multiprocessor specification defines a standard way for the operating system to communicate with the hardware. This will make it easy for osvs and oems to support a wide range of platforms with one operating system version – a benefit they already enjoy in the uniprocessor desktop market.

Further, multiprocessor capable operating systems will be able to run without modification on all multiprocessor systems that comply with this specification. The result of this will be that end users who purchase a compliant multiprocessor system will be able to run their choice of operating system.

The specification covers PC/AT-compatible multiprocessor platform designs based on Intel processor architectures and the all-important Advanced Programmable Interrupt Controller, or APIC, architectures. In the specification, Intel uses the term 'PC/AT compatible' to refer to software-visible components of the PC/AT – not to hardware features. Thus an implementation of the multiprocessor specification may include one or more bus types, such as ISA, EISA, VESA local bus, PCI or other proprietary buses.

The goal of the multiprocessor specification is to enable scalable, high-end workstations and enterprise server systems that provide computer users with superior price/performance and have the ability to execute all existing AT binaries as well as multiprocessor-ready software packages on shrink-wrapped multiprocessor operating systems. The specification defines a system architecture based on the following hardware components:

- One or more processors that are Intel architecture instruction set compatible, such as cpus in the Intel 486 or Pentium processor family
- One or more APICs, such as Intel's 82489DX, or an integrated APIC such as that on the Intel 735/90 and 815/100 processors, together with a discrete i/o APIC unit.
- Software-transparent cache and shared memory subsystem
- Software visible components of the PC/AT platform

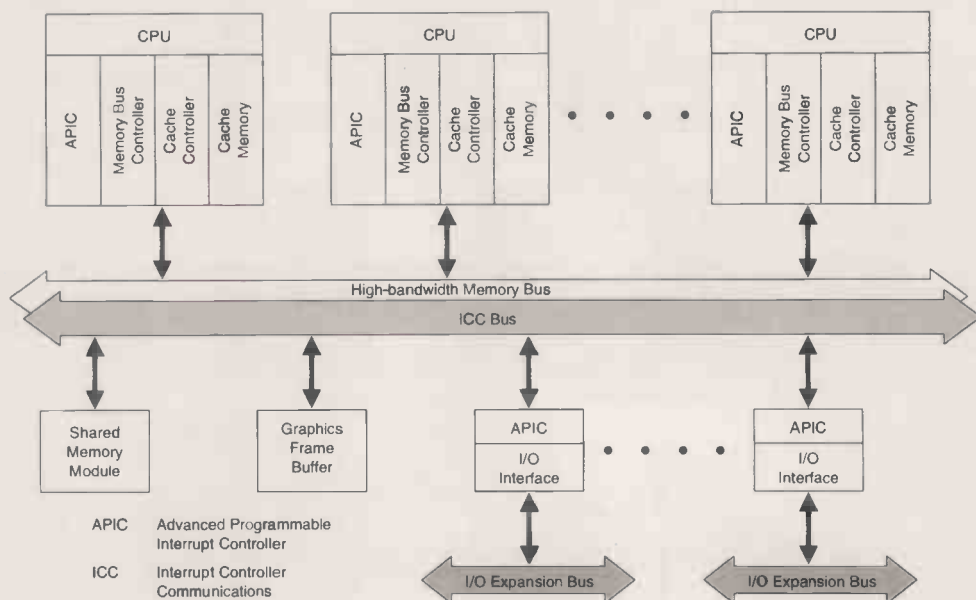


Fig. 1. General structure of a design based on Intel's Multi-Processor Specification.

**Choose your system**

There are several models and connection schemes that can be used to tie together the various components of a multiprocessing system. Intel's multiprocessor specification incorporates a tightly coupled, shared memory architecture with a distributed interprocessor and i/o interrupt capability. It is fully symmetrical in that all the processors are identical, have equal status and can communicate with

every other processor. This symmetry has two important aspects:

**Memory.** Memory is symmetrical when all the processors share the same memory space and access that space using the same addresses. This confers a particularly important feature onto the system: the ability for each processor to execute its own copy of the operating system.

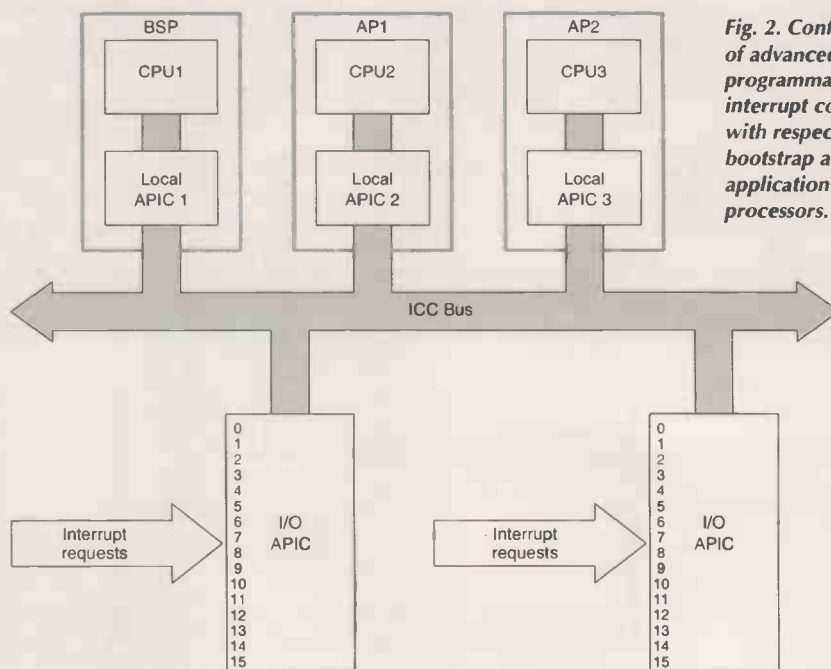


Fig. 2. Configuration of advanced programmable interrupt controllers with respect to bootstrap and application processors.

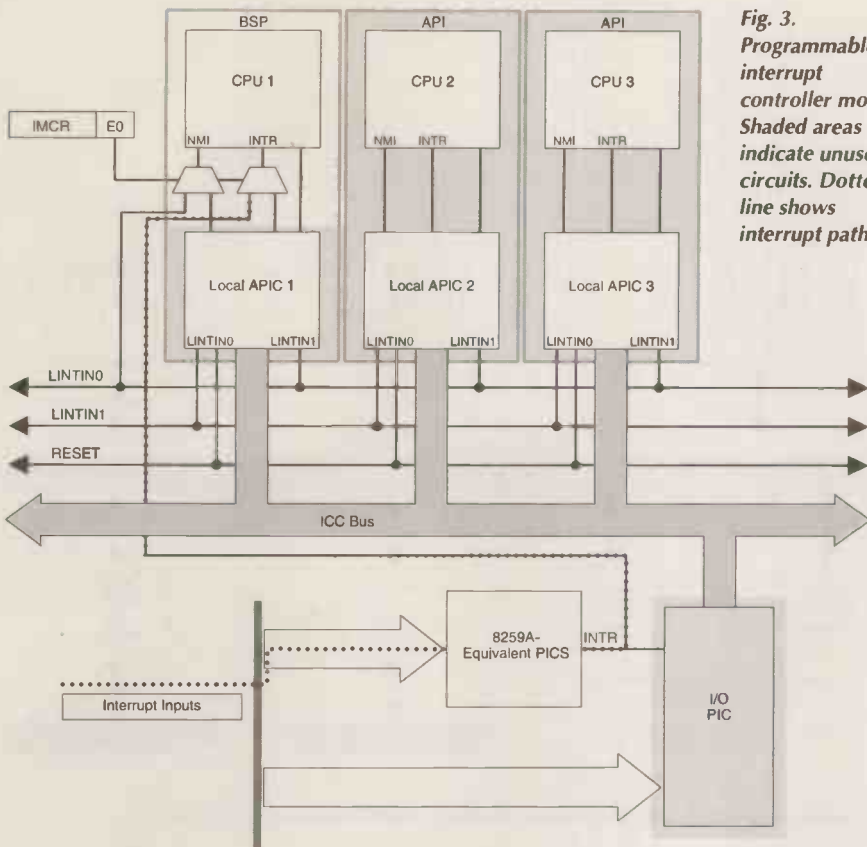


Fig. 3. Programmable interrupt controller mode. Shaded areas indicate unused circuits. Dotted line shows interrupt path.

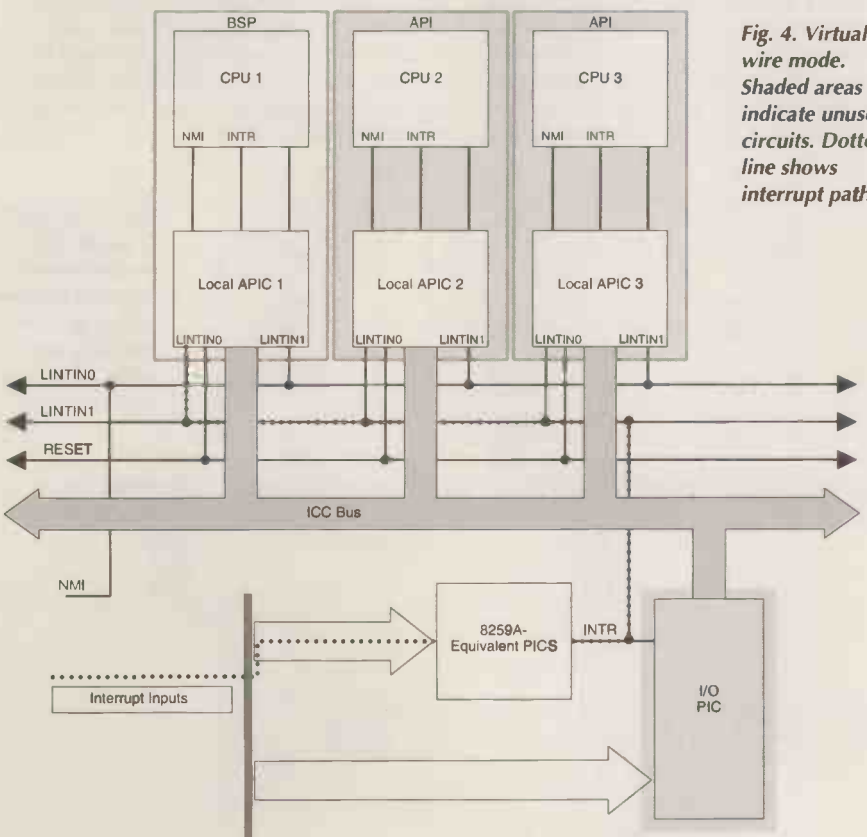


Fig. 4. Virtual wire mode. Shaded areas indicate unused circuits. Dotted line shows interrupt path.

**Input/output.** The i/o system is symmetrical when all the processors share access to the same ports and interrupt controllers, and any processor can retrieve interrupts from any source. Such an arrangement increases system scalability by helping to reduce i/o bottlenecks.

Figure 2 shows the configuration of the APICs with respect to the cpus. While all the processors in an multiprocessor system are functionally identical, this arrangement classifies them into two types: a single bootstrap processor, or bsp, and one or more application processors, aps. This differentiation is only apparent during the initialisation and shut-down processes, as the bsp is responsible for initialising the system and booting the operating system and aps are only subsequently activated.

APICs are based on a distributed architecture in which interrupt control functions are distributed between the local and the i/o APIC. These two units communicate via a bus called the interrupt-controller communications, or ICC, bus, as shown in Fig. 2, with multiple units operating together as a single entity. The i/o unit senses an interrupt input, addresses it to a local unit, and sends it over the ICC bus.

The APICs are collectively responsible for delivering interrupts from sources to destinations throughout the entire system. In multiprocessor system each cpu requires a single local APIC, but depending on the total number of interrupt lines there may be more than one i/o APICs used.

The APICs help to achieve the goal of system scalability by off-loading interrupt traffic from the memory bus, thereby making greater bandwidth available for processor use. They also help processors share the interrupt-processing load with other processors.

**Interrupts and write back cache**

The local APICs also provide interprocessor interrupts, or IPIs, which allow any processor to interrupt any other, or any set of processors.

Compared with a single-processor system, symmetrical multiprocessing puts great demands on memory bus bandwidth, proportional to the number of processors in the system. A well-designed system will therefore implement a high-performance secondary (external) cache. Use of such a cache can push the scalability limit upwards by reducing traffic on the bus and increasing bandwidth.

In this regard, the Pentium processor's data cache uses an important technique called write-back caching. The write-back method transfers data to the cache without going out to main memory, with data being written to main memory only when it is removed from the cache.

In contrast, previous-generation write-through cache implementations transferred data to the external memory each time the processor wrote data to the cache. The write-back technique increases performance by reducing bus utilisation and preventing needless bottlenecks in the system.

A potential source of problems that designers must guard against is the question of cache

coherency. That is, when one processor accesses data in another processor's cache, it must not retrieve incorrect data. Further, if a processor modifies data, other processors that access that data from a cache must not receive out-of-date data.

To ensure that data in the cache and in main memory are consistent, the Pentium processor's data cache implements an algorithm called the *mes*i, for modified-exclusive-shared-invalid, protocol. By obeying the rules of the protocol during cache reads and writes, the Pentium processor can maintain cache consistency and circumvent problems that might be caused by multiple processors using the same data.

**Snooping around for memory**

Another common technique that is used to ensure memory coherence is called bus snooping, which refers to the ability of a cpu to monitor memory addresses placed on the system bus by other cpus or devices. When a cpu detects a memory address on the system bus that the cpu knows it already has stored in its on-board cache, the cpu writes that memory address from its cache to system memory before the completion of the bus cycle.

Intel's MultiProcessor Specification defines three different interrupt modes:

- PIC mode: bypasses all APIC components and forces the system to operate in single-processor mode
- Virtual-wire mode: uses an APIC as a virtual wire, but is otherwise the same as PIC mode
- Symmetrical i/o mode: enables the system to operate with more than one processor.

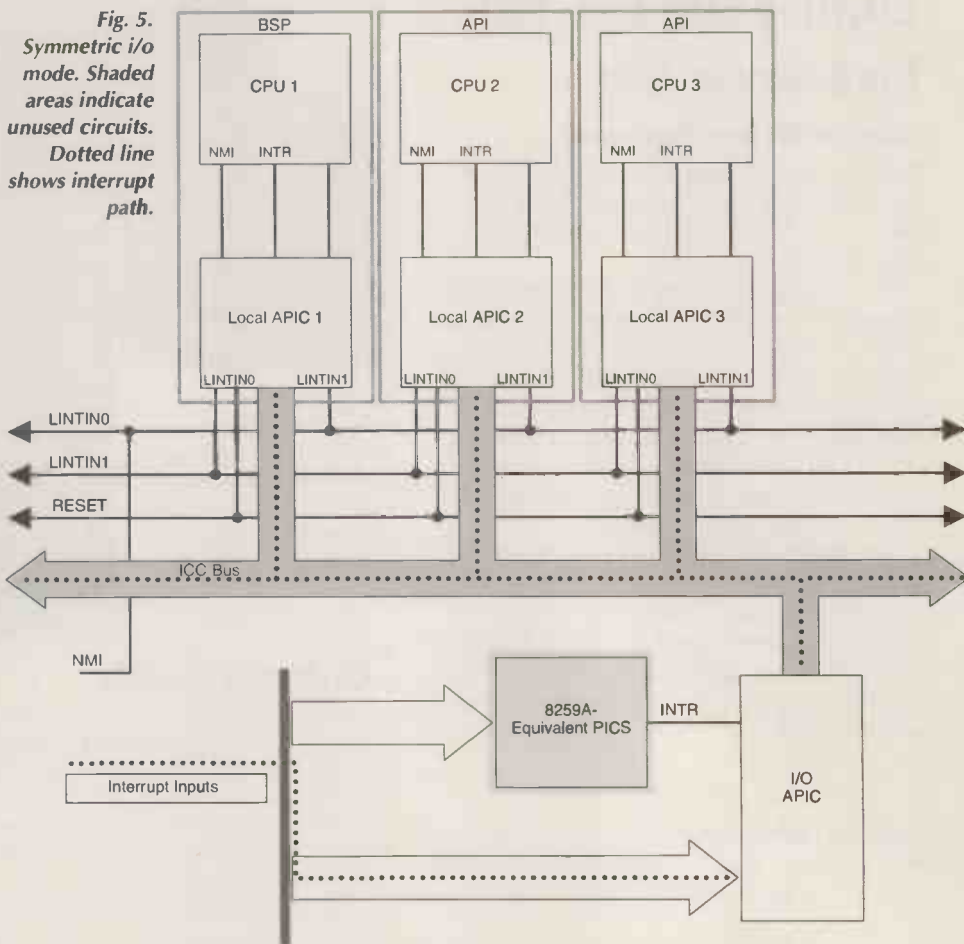
The first two modes are included to provide PC/AT compatibility, and at least one of them must be included. A multiprocessor system is booted under one of these modes; later the operating system switches to symmetrical i/o mode for full multiprocessing.

The PC/AT software compatibility of PIC mode stems from the fact that it uses the same hardware interrupt configuration. As shown in Fig. 3, the hardware for PIC mode bypasses the APIC components by using an interrupt mode configuration register, which controls whether the interrupt signals that reach the bsp come from the master PIC or the local APIC. Before entering symmetrical i/o mode, either the bios or the operating system must switch out of PIC mode by changing the interrupt mode configuration register.

Virtual-wire mode provides the equivalent of a uniprocessor system that is capable of running all dos software. Figure 4 shows that in virtual-wire mode the 8259A-equivalent PIC accepts all interrupts, and the local APIC of the bsp becomes a virtual wire, which delivers interrupts from the PIC to the bsp via the local APIC's local interrupt 0 (LINT0). The i/o APIC is not used.

Finally, as shown in Figure 5, we have symmetric i/o mode, the heart of a multiprocessing system. In this case i/o interrupts are generat-

**Fig. 5.** Symmetric i/o mode. Shaded areas indicate unused circuits. Dotted line shows interrupt path.



**Multiprocessing Pentium terminology**

APIC	Advanced Programmable Interrupt Controller
aps	application processor
bios	basic input/output system
bsp	bootstrap processor
cpu	central processing unit
IAL	Intel Architecture Labs
ICC	interrupt-controller communications
imcr	interrupt mode configuration register
IPI	interprocessor interrupt
mes	modified-exclusive-shared-invalid (protocol)
mps	multi-processor system
MPS	MultiProcessor Specification
oem	original equipment manufacturer
osv	original systems vendor
PIC	Programmable Interrupt Controller
smp	symmetrical multiprocessing

performance returns begin to diminish. This is partly because of the processing overhead required to manage individual threads and processes as they are started, suspended and restarted across the system.

However these problems may be solved with the introduction of the new intelligent input/output device driver specification, which distributes i/o functions across multiple processors, and hierarchical PCI buses. Systems with these features do hold the promise of greater scalability with fewer problems caused by i/o bottlenecks.

ed by the i/o APIC and all 8259 interrupt lines are either masked or work together with the i/o APIC in a mixed mode.

**Fly in the ointment**

All this may paint a very rosy picture of smp, but there are a few greenfly in the garden. The main problem is that the standard AT bus does not have sufficient bandwidth. Theoretically an smp machine should provide a 100% performance increase every time you add a processor.

It has been found that this is indeed so up to a total of four processors, but that after this,

There is one thing we can be sure of. It will be a simple matter for developers to get a new Intel motherboard, shove four cpus into it and make a cheap machine that has enough punch to keep many corporates happy, even if it does not have the processing power – and price – of a top-end Sun Sparc. As usual, market forces will propel viable systems forward. ■

# Eight year EW index

## Hard copy or disk

Includes over 600 circuit idea references

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 eight years.

The computerised index of *Electronics World* magazine covers the eight years from 1987 to 1995 - volumes 94 to 101 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.

Even though the disk-based index has been expanded significantly from five years to eight, its price is still only £20 inclusive. Please specify whether you need 5 1/4in, 3.5in DD or 3.5in HD format. Existing users can obtain an upgrade for £15 by quoting their serial number with their order.

### Hard copy *Electronics World* index

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

The image shows two screenshots of the 'Circuit Ideas' software interface. The top screenshot displays a list of circuit ideas with 'SIMULATOR, INSERTION & RETURN LOSS' selected. The bottom screenshot shows a 'Design: RF' list with 'Microwaves, New wave' selected. The interface includes a menu bar at the top and a status bar at the bottom.

### Photo copies of

#### *Electronics World* articles

Photo copies from back issues of *Electronics World* are available at a flat rate of £3 per article or 50p per circuit idea, both excluding postage.

## 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 enquiries about photocopies, etc,

please send an sae to SoftCopy Ltd at the address below.

Send your order to SoftCopy Ltd., 1 Vineries Close, Cheltenham GL53 0NU, tel 01242 241455, or e-mail at 100556.112@compuserv.com. Please make cheques payable to SoftCopy Ltd - not EW or Reed Business Publishing. Please allow up to 28 days for delivery.

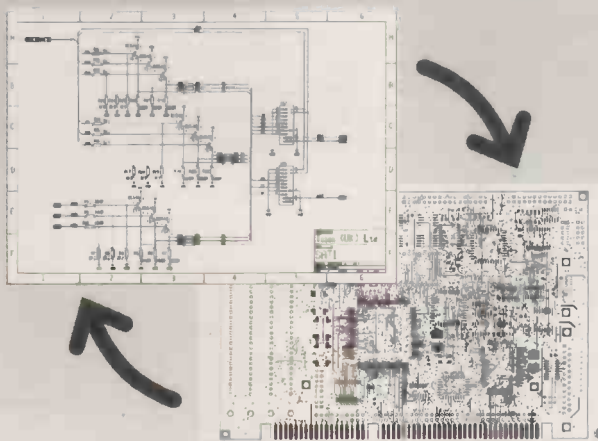
Finally an upgradeable PCB CAD system to suit any budget ...

# Board Capture

## BoardCapture - Schematic Capture

- Direct netlist link to BoardMaker2
- Forward annotation with part values
- Full undo/redo facility (50 operations)
- Single-sheet, multi-paged and hierarchical designs
- Smooth scrolling
- Intelligent wires (automatic junctions)
- Dynamic connectivity information
- Automatic on-line annotation
- Integrated on-the-fly library editor
- Context sensitive editing
- Extensive component-based power control
- Back annotation from BoardMaker2

£395



# Board Maker

## BoardMaker1 - Entry level

- PCB and schematic drafting
- Easy and intuitive to use
- Surface mount support
- 90, 45 and curved track corners
- Ground plane fill
- Copper highlight and clearance checking

£95

## BoardMaker2 - Advanced level

- All the features of BoardMaker1 plus
- Full netlist support - OrCad, Schema, Tango, CadStar
- Full Design Rule Checking - mechanical & electrical
- Top down modification from the schematic
- Component renumber with back annotation
- Report generator - Database ASCII, BOM
- Thermal power plane support with full DRC

£395

# Board Router

## BoardRouter - Gridless autorouter

- Simultaneous multi-layer routing
- SMD and analogue support
- Full interrupt, resume, pan and zoom while routing

£200

## Output drivers - Included as standard

- Printers - 9 & 24 pin Dot matrix, HPLaserjet and PostScript
- Penplotters - HP, Graphtec, Roland & Houston
- Photoplotters - All Gerber 3X00 and 4X00
- Excellon NC Drill / Annotated drill drawings (BM2)

Contact Tsien for further information on  
Tel 01354 695959  
Fax 01354 695957



tsien

Tsien (UK) Ltd Ayleby House Wenny Road Chatteris Cambridge PE16 6UT

CIRCLE NO. 147 ON REPLY CARD

## CONSULTANCY ROLES

# Open Systems and their potential in military information systems

Junior to Senior Level: £16,000 – £30,000 & benefits · Malvern

The Defence Research Agency's mission is to be one of the prime providers of technical advice to the MOD. We also provide technical services to other Government departments and to private industry.

The Open Software Systems Group at DRA Malvern has a mission to maximise the MOD's access to – and benefit from – the commercial Open Systems marketplace. Our innovative research activities develop techniques and technologies to help bridge the gaps between civil and military needs, with consultants advising project managers and policy staff on a wide range of issues.

We need to strengthen our consultancy teams and we're interested in people with varying levels of experience and expertise. The common denominators will be a relevant computing-related degree and a broad appreciation of technology with a particular interest in the Open Systems arena and software portability. At least two years' relevant experience will be required, and applications are invited from people from all kinds of commercial, academic or research backgrounds. Training for specific areas of activity will

be given, although your ability to communicate at all levels is a natural prerequisite. Also vital is the ability to produce concise written reports to tight deadlines. The work is likely to involve a significant amount of travel within the UK.

This is an opportunity to enter the Open Systems debate from a stimulating new angle and develop new dimensions to their capability. We can also promise attractive rewards including generous holidays, non-contributory pension scheme and relocation assistance where appropriate. These appointments are offered on a permanent basis.

DRA welcomes applications from suitably qualified people regardless of sex, marital status, race or disability.

Please contact us for an application form quoting reference CIS/79. CIS/LS Recruitment Office, DRA Malvern, St Andrews Road, Malvern, Worcestershire WR14 3PS. Tel: (01684) 895642 (24 hour answer phone). Closing date for receipt of completed applications 2nd August 1996.

# DRA

DRA is a division of DERA an Agency of the MOD

### Part time/Full time DESIGN ENGINEERS WANTED

Experienced in power supply design, Inverters (DC to AC) Ups Design, Chargers etc.

Work from home at your spare time, very good pay offered

Fax CV now to:

**MD, BTS (UK) Ltd**

**Tel: 01582 487878**

**Fax: 01582 26226**

### COURSES

AUDIO AMPLIFIER DESIGN. Full or part time PhD research at Kings College, London. Contact Dr. Sandman: 0171 8732522.

## ARTICLES FOR SALE

Consider . . . . .

Your costs to continue to stock  
UNWANTED SURPLUS . . . EXCESS . . . OBSOLETE  
STOCKS OF:-  
ELECTRONIC-ELECTRICAL COMPONENTS &  
ACCESSORIES

**RELEASE**  
for  
**PAYMENT IN ADVANCE**  
OF COLLECTION  
contact

**K.B. Components,**  
21 Playle Chase, Gt. Totham, Maldon, Essex, CM9 8UT  
Tel:- 01621 893204 Fax:- 01621 893180 Mobile:- 0802 392745  
REGISTER TO RECEIVE MONTHLY PUBLISHED STOCK LISTS AT NO CHARGE OF  
ALL EXISTING NEW, UNUSED, STOCKS OF ALL COMPONENTS AND ACCESSORIES.

## Clearance Sale

Quantity of quality used  
Test & Measurement Equipment  
to clear - HP, Tek, Phillips etc.

**Call us now for full list**

Intec Systems Int'l Ltd

**01702 258700**

or fax us on

01702 258461

Credit cards welcome

TEKTRONIX OSCILLOSCOPES for sale. 250 Mhz, 100 Mhz & 60 Mhz. Phone 01438 811053.





# CLASSIFIED

TEL 0181 652 3620

FAX 0181 652 8956

## ARTICLES FOR SALE



### SUPPLIER OF QUALITY USED TEST INSTRUMENTS



CONTACT

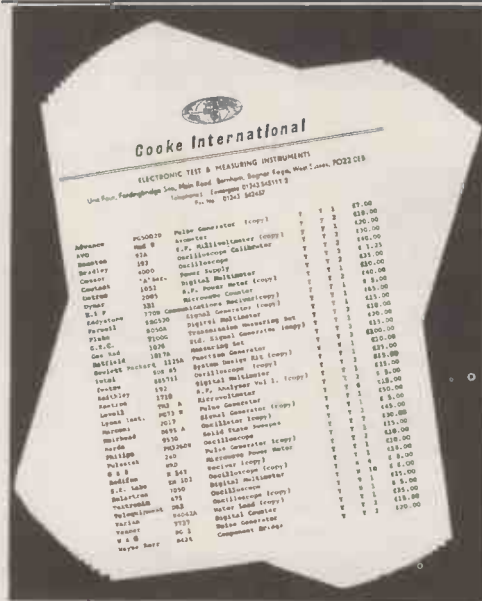
### Cooke International

ELECTRONIC TEST & MEASURING INSTRUMENTS  
Unit Four, Fordingbridge Site, Main Road, Barnham,  
Bognor Regis, West Sussex, PO22 0EB, U.K.  
Tel: (+44)01243 545111/2 Fax: (+44)01243 542457

CIRCLE NO. 148 ON REPLY CARD



### OPERATING & SERVICE MANUALS



CONTACT

### Cooke International

ELECTRONIC TEST & MEASURING INSTRUMENTS  
Unit Four, Fordingbridge Site, Main Road, Barnham,  
Bognor Regis, West Sussex, PO22 0EB, U.K.  
Tel: (+44)01243 545111/2 Fax: (+44)01243 542457

CIRCLE NO. 149 ON REPLY CARD

## INDEX TO ADVERTISERS

	PAGE		PAGE		PAGE
Anchor	595	Jenving	594	Ralfe	632
Bamber	536	Johns	579	Robinson	617
Bateman	530	JPG	612	Seetrax	622
Bull	564	Kenwood	599	Stag	591
Bull	565	Kestrel	618	Stewart	614
Crownhill	616	Labcenter	602	Surrey	606
Dataman	OBC	Langrex	614	TDC	591
Display	557	M & B Radio	607	Technology	561
Equinox	612	Milford	IFC	Telford	623
Field	612	Number One	618	Telnet	622
Halcyon	606	Olson	IBC	Those	623
Hart	547	Pico	614	Tie Pie	606
Ice	551	Quickroute	530	Tsien	628
Iosis	591	Radio-Tech	530	Ultimate	532
				Wood & Douglas	599

**SPECTRUM ANALYSERS**



- HP3580A 5Hz-50kHz audio frequency spectrum analyser £750 to £1250
- HP8568B high-specification 1.5GHz spectrum analyser £10000
- MARCONI 2386 100Hz-26.5GHz (in 1Hz steps) £15000
- AVCOM - portable, battery operated, to 1000 MHz £2000
- TEKTRONIX 492 21GHz portable spectrum analyser, with options 2 (digital storage and Rack-mount option) £6000 or £7000 with mixers to 60GHz.
- TEK7623A/7L18 (1.8GHz) with tracking generator in TM503 £1750

**MARCONI INSTRUMENTS**

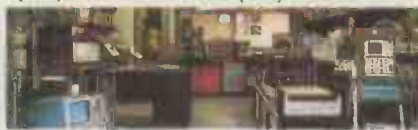


- 2018A synthesized AM/FM signal generator 80kHz-520MHz £1250
- 2019A synthesized AM/FM signal gen 80kHz-1040MHz £2000
- 2828A/2829 digital simulator/analyser £500
- 2955B radio communication test sets - LATEST 'B' MODEL £4000
- 6460/6421 power meter & sensor 10MHz-12.4GHz £350
- 6514 waveguide detector for use with 6500-scalar analyser 26-40GHz £350
- 6960 microwave power meter with 6910 power sensor 10MHz-20GHz £900
- TF2910 TV interval timer £250

**ralfe electronics** exclusively professional T&M ©

• 36 Eastcote Lane • South Harrow • Middx HA2 8DB • England •  
TEL (+44) 0181-422 3593 • FAX (+44) 0181-423 4009

EST  
41  
YRS



DISTRIBUZIONE E ASSISTENZA, ITALY: TLC RADIO, ROMA (06) 871 90254

**TEST EQUIPMENT**

- BRUEL & KJAER 2023 single channel audio spectrum analyser £2500
- BRUEL & KJAER 2511 vibration meter (field set with 1621 filter) £1500
- BRUEL & KJAER 2307 level recorder £1000
- BRUEL & KJAER 2317 portable level recorder £1500
- BRUEL & KJAER 2308 analogue X-Y pen recorder £750
- CHASE LFR1000 interference measuring receiver 9kHz-150kHz £1000
- DATRON 1061 & 1061A - various, digital multimeter & 1065 - call from £500
- DATRON 1065 digital multimeter all ranges plus IEEE £500
- FARNELL PSG2400A signal generator 100kHz-2.4GHz £3500



CERT.: 95/013

**ISO9002 ACCREDITED STOCKIST  
MEASUREMENT & TEST EQUIPMENT**

- PHILIPS PM5167 1mHz-10MHz function generator £275
- RACAL 9008 automatic modulation meter £350
- RACAL-DANA 9300 milli-voltmeter £400
- RACAL-DANA 9301A true RMS RF milli-voltmeter £350
- TEKTRONIX P6201 FET PROBE £350
- WANDEL & GOLTERMANN WM30 level tracer £500
- WANDEL & GOLTERMANN PJM-4S Jitter meter for SONET & SDH £5500
- WAVETEK 23 synthesized function generator 0.01Hz-12MHz £1250
- WAVETEK 1067 opt 522 1-500MHz sweep generator £500
- WAYNE KERR 3220 20A bias unit (for 3245 inductance analyser) £1250
- TEKTRONIX 1502B/03/04 short-range metal-cable dir tester £3500

**HEWLETT PACKARD**



- 1640B serial data generator £500
- 3561A dynamics signal analyser (opt 01) £5500
- 3764A digital transmission analyser £1500
- 3335A synthesizer/level generator £2000
- 3400A voltmeter, analogue 10Hz-10MHz £250
- 3235A switch/test unit £1000
- 3324A synthesized function generator £2000
- 3325A synthesizer/function generator, 21MHz £1750
- 3580A audio frequency spectrum analyser £750 to £1250
- 3581C selective voltmeter £1250
- 3779D primary multiplex analyser £5000
- 4140B pA/meter, DC voltage source £4000
- 4339A high resistance meter c/w lead set 16117B £2000
- 4275A multi-frequency Icr meter £3500
- 435B microwave power meter, analogue £400
- 5386A 3GHz frequency counter £1500
- 54100A 1GHz digitizing oscilloscope £2250
- 8007B pulse generator 100MHz £950
- 8018A serial data generator £1000
- 8082A pulse generator 250MHz £2000
- 8111A pulse generator 20MHz £1250
- 816A slotted line 1.8-18GHz with 809C & 447B probe £500
- 8444A tracking generator with option 059 £1000
- 8656B synthesized signal generator to 990MHz £3000
- 87510A gain-phase analyser 100kHz-300MHz £6500
- 8901A modulation analyser with option 02/010 £3500
- J2215A FDDI portable multimode test set £1500
- J2219A 486-based, colour option main-frame £1000
- J2219A/J2171A 486-based colour screen option network advisor £3000

**SEND FOR LATEST STOCK LIST. WE FAX LISTS  
AND SHIP WORLDWIDE. ALL FULLY  
LAB-TESTED AND NO-QUIBBLE GUARANTEED**

**CIRCLE NO. 150 ON REPLY CARD**

**ELECTRONIC UPDATE**

Contact Malcolm Wells on  
0181-652 3620

A regular advertising feature enabling  
readers to obtain more information  
on companies' products or services.



**New Flight Electronics  
International Catalogue Set**

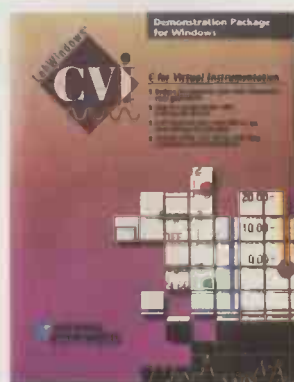
You now have access to the world's latest:  
★ Electronics Training Equipment  
★ Microprocessor Training Equipment  
★ Test and Measurement Equipment  
★ PC Cards

via "Flight's" latest catalogue set.

We are specialists in the provision of  
innovative top quality electronics  
trainers, breadboards, test and  
measurement, PC cards and  
microprocessor evaluation  
equipment.

Our extensive range covers every  
need, call today for your free  
catalogue set.

**CIRCLE NO. 151 ON REPLY CARD**

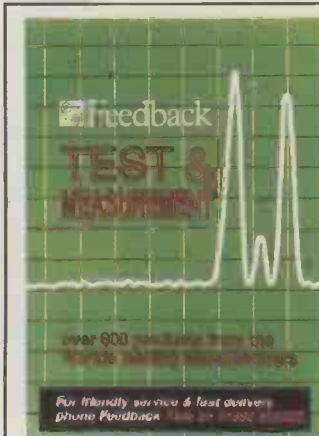


**FREE DEMO DISK**

The LabWindows/CVI Demo Disk  
is a free evaluation copy of  
LabWindows/CVI. You can follow  
instructions to build Windows  
applications using GPIB, VX1,  
Serial, and plug-in DAQ  
instrumentation. The guide  
illustrates code-generation  
techniques, GUI development  
tools, event-driven programming  
techniques, instrument drivers,  
debugging and editing tools.

**NATIONAL INSTRUMENTS**  
For your Free Demo Disk call,  
01635 523545

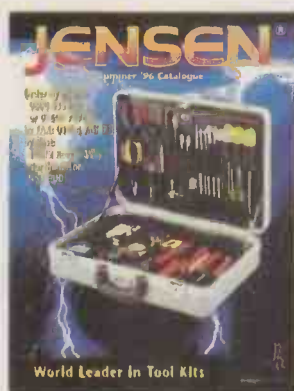
**CIRCLE NO. 154 ON REPLY CARD**



**NEW Feedback T&M  
Catalogue**

The latest edition of the Feed-  
back Test & Measurement cata-  
logue is now available. Over 60  
pages packed with more than  
800 products divided into over  
20 sections. The catalogue is  
indexed for both product and  
manufacturer and is fully illus-  
trated. Whether you are looking  
for an individual product, a com-  
plete workstation, or a solution  
to a particular Test & Measure-  
ment need the NEW Feedback  
catalogue will solve your prob-  
lems, send for a copy NOW!

**CIRCLE NO. 153 ON REPLY CARD**



**NEW JENSEN TOOLS  
CATALOGUE**

Colourful new Catalogue, hot off  
the press from Jensen Tools,  
presents unique new tool kits for  
service/support of  
communications equipment. Also  
latest test equipment from many  
major manufacturers. Includes  
hard-to-find tools, PC/LAN  
diagnostics, bench accessories,  
static control, technical manuals  
and more.

Ring 0800 833246 or  
Fax 01604 785573 for a free copy.  
Jensen Tools, 10-12 Ravens Way,  
Northampton NN3 9UD

**CIRCLE NO. 152 ON REPLY CARD**

# OLSON<sup>®</sup>

**For all your Power Distribution Olson offer a varied choice**

**OLSON** Distribution Units

**ELECTRONICS LIMITED**

**OLSON** DISTRIBUTION PANELS FUSED, WITH R.F. FILTER AND R.C.D. PROTECTION

**ELECTRONICS LIMITED**

**OLSON** FUSED WITH RCD PROTECTION AND OVER-CURRENT SWITCHED 50A/47.5

**ELECTRONICS LIMITED**

**OLSON** 'The Rack Range' mains distribution panels for 19" rack mounting

**ELECTRONICS LIMITED**

**OLSON** Office Furniture Cable Management Manufactured to BS 5396

**ELECTRONICS LIMITED**

**OLSON** Mains Distribution Panels with Non Standard Sockets

**ELECTRONICS LIMITED**

**OLSON** FUSED SUPER SLIM MAINS DISTRIBUTION PANELS WITH DOUBLE-POLE SWITCHED SOCKETS

**ELECTRONICS LIMITED**

**OLSON** Earth Leakage Distribution Units

**ELECTRONICS LIMITED**

**OLSON** Distribution Units

**ELECTRONICS LIMITED**

**OLSON** PANELS with 10AMP CEE22/IEC SHUTTER SOCKETS FUSED SOCKETS COVERED WITH SHIELD FILTER AND RCD PROTECTION

**ELECTRONICS LIMITED**

**OLSON** The Rack Range WITH AMERICAN SOCKETS 125V 15A

**ELECTRONICS LIMITED**

**OLSON** Mains Distribution Panels INTERNATIONAL RANGE

**ELECTRONICS LIMITED**

**OLSON** FUSED SUPER SLIM WITH ELECTRAK PLUG CONDUIT AND DOUBLE POLE SWITCHED SOCKETS

**ELECTRONICS LIMITED**

**OLSON** DATA PROTECTOR 16 AMP double pole filter with Earth-line check and frequency suppression

**ELECTRONICS LIMITED**

**OLSON** INDUSTRIAL RANGE 16 AMP 110V AND 240V TO BS 4343/IEC 309

**ELECTRONICS LIMITED**

TYPE	NO. OF SOCKETS	Substantial ability of mounting additional sockets for protection or self monitoring use
16AMP 110V	16/8	IEC, with standard or specialised outlet sockets of various configurations
16AMP 240V	16/8	Standard IEC type or Single phase supply
16AMP 240V	16/8	The standard can be used in conjunction with all international plug configurations as all cables are 16/10/5/25 mm <sup>2</sup> 13.8mm

SPECIAL ORDER TO ORDER

**OLSON** Distribution Units

**ELECTRONICS LIMITED**

**OLSON** 19" FAN TRAYS

**ELECTRONICS LIMITED**

**OLSON** The Rack Range CEE22 I.E.C SOCKETS

**ELECTRONICS LIMITED**

**OLSON** SERVICE PILLAR FOR THE OPEN-PLAN OFFICE

**ELECTRONICS LIMITED**

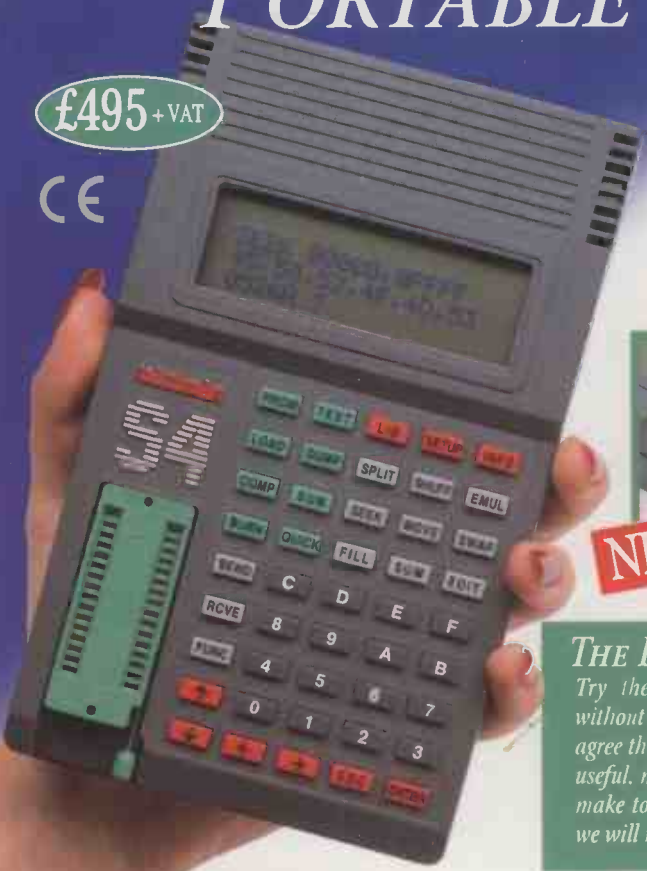
The service pillar is easily installed from under the desk and is designed to be used with or without the using for secondary protection against the common lightning or static discharge. It has complete protection between mains and data services. (Patent held worldwide) LOW COST 50 STOCKS 1000'S FROM 20/000/00

**OLSON** Distribution Units FRENCH AND GERMAN STANDARDS 16/10/5/25/13.8

**ELECTRONICS LIMITED**

# THE WORLD'S MOST POWERFUL, PORTABLE PROGRAMMERS

£495 + VAT



## S4 GAL module

Programs a wide range of 20 and 24 pin logic devices from the major GAL vendors. Supports JEDEC files from all popular logic compilers.

£195 + VAT



NEW

## THE DATAMAN CHALLENGE

Try the Dataman S4 or Dataman-48 without obligation for 30 days. If you do not agree that these are the most effective, most useful, most versatile additions you can make to your programming toolbox, we will refund your money in full.

## Dataman S4

Compare the Dataman S4 with any other programmer and you'll see why it's the world's undisputed number one.

S4 is capable of programming 8 and 16-bit EPROMs, EEPROMs, PEROMs, 5 and 12V FLASH, Boot-Block FLASH, PICs, 8751 Microcontrollers and more. S4 also emulates ROM and RAM as standard!

S4 is the only truly hand held programmer that ships complete with all emulation leads, organiser-style manual, AC charger, spare library ROM, both DOS and Windows terminal software, and arrives fully charged and ready to go! Who else offers you all this plus a three year guarantee?

Customer support is second to none. The very latest programming library is always available free on the Internet, and on our dedicated bulletin boards. Customers NEVER pay for upgrades or technical support.

## Dataman-48

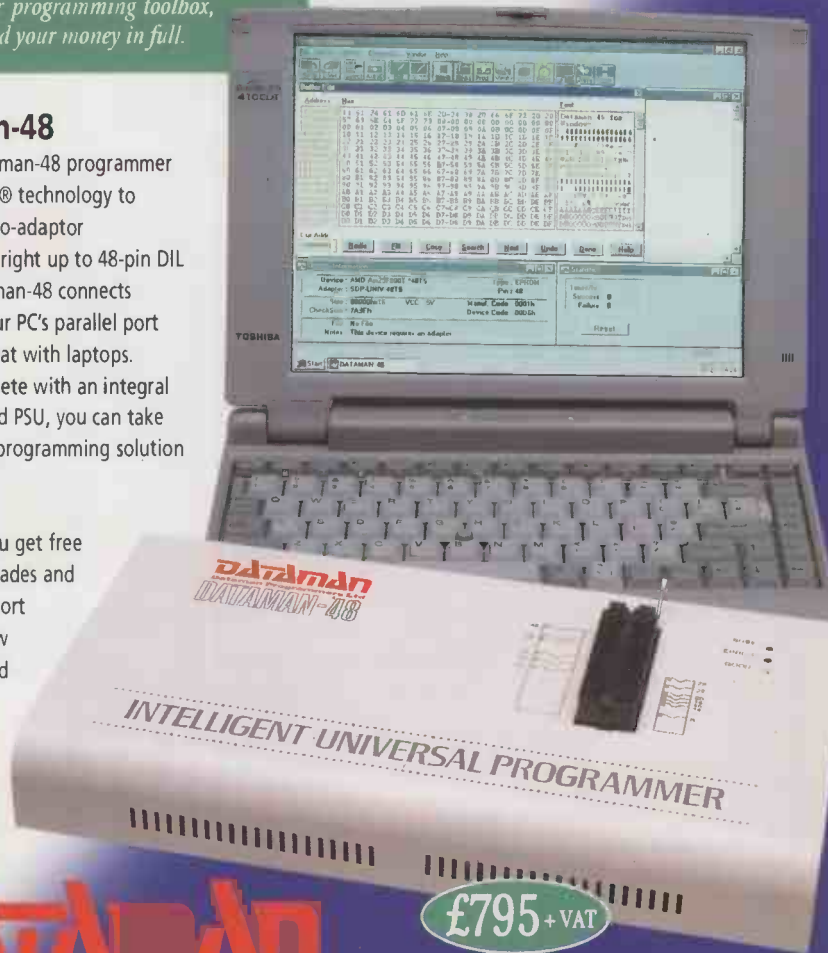
Our new Dataman-48 programmer adds PinSmart® technology to provide true no-adaptor programming right up to 48-pin DIL devices. Dataman-48 connects straight to your PC's parallel port and works great with laptops. Coming complete with an integral world standard PSU, you can take this one-stop programming solution anywhere!

As with S4, you get free software upgrades and technical support for life, so now you don't need to keep paying just to keep programming.

The current device library contains over 1800 of the most popular logic and memory devices including GALs, PALs, CEPALs, RALs, 8 and 16-bit EPROMs, EEPROMs, PEROMs, FLASH, BOOT-BLOCK, BIPOLAR, MACH, FPGAs, PICs and many other Microcontrollers. We even include a 44-pin universal PLCC adaptor.

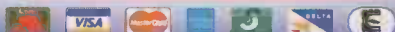
If you need to program different packaging styles, we stock adaptors for SOP, TSOP, QFP and SDIP. The Dataman-48 is also capable of emulation when used with memory emulation pods.

Order your Dataman programming solution today via our credit card hotline and receive it tomorrow. For more detailed information on these and other market leading programming products, call now and request your free copy of our new colour brochure.



£795 + VAT

hotline  
01300 320719



Orders received by 4pm will normally be despatched same day.  
Order today, get it tomorrow!

**Dataman**

Dataman Programmers Ltd, Station Road, Maiden Newton, Dorset DT2 0AE. UK  
Telephone +44/0 1300 320719 Fax +44/0 1300 321012 BBS +44/0 1300 321095 (24hr)  
Modem V.34/V.FC/V.32bis Home page: <http://www.dataman.com>  
FTP: <ftp.dataman.com> Email: [sales@dataman.com](mailto:sales@dataman.com)