The month's top new products – page 39

ELECTRONICS WORLD

OCTOBER 2002 £2.95

DIY MFB loudspeaker

Budget T&M on a PC

VI protection in power amps

Capacitor sound part 3

Circuit ideas:
Speaking clock

Novel combination lock

CAD on a shoestring

9 770959 833080

Telnet

Quality second-user test & measurement equipment

Hewlett Packard 3314A Function Generator 20MHz	£1250
Hewlett Packard 3324A synth. function/sweep gen. (21MHz)	£2250
Hewlett Packard 3325B Synthesised Function Generator	£3250
Hewlett Packard 3326A Two-Channel Synthesiser	£3000
R/F Imp. Analyser (1GHz)	£4995
L.F. Imp. Analyser (13MHz)	£4000
Hewlett Packard 4193A Vector Impedance Meter (4-110MHz)	£3000
Hewlett Packard 4278A 1kHz/1MHz Capacitance Meter	£3750
Mod. Domain Analyser (opt 1/31)	£6750
Hewlett Packard 8349B (2 - 20 GHz) Microwave Amplifier	£2500
Hewlett Packard 8904A Multifunction Synthesiser (opt 2+4)	£1950
3GHz Signal Gen	£6995
Marconi 6310 – programmable sweep generator (2 to 20GHz) – new	£2500
Marconi 6311 Prog'ble sig. gen. (10MHz to 20GHz)	£2995
Marconi 6313 Prog'ble sig. gen. (10MHz to 26.5GHz)	£4750
R&S SMG (0.1-1GHz) Sig. Generator (opts B1+2)	£2750
Fluke 5700A Multifunction Calibrator	£12500
Fluke 5800A Oscilloscope Calibrator	£9995
H.P 8341B Synth. Sweep Gen. (20GHz)	£15000
H.P 4284A Precision LCR meter	£6500
H.P 3458A DMM (8.5 digits)	£3750
Tek 371A PProgrammable Curve Tracer	£15000

OSCSILLOSCOPES

Gould 400 20MHz - DSO - 2 channel	£695
Gould 1421 20MHz - DSO - 2 channel	£425
Gould 4068 150MHz 4 channel DSO	£1250
Gould 4074 100MHz - 400 Ms/s - 4 channel	£1100
Hewlett Packard 54201A - 300MHz Digitizing	£750
Hewlett Packard 54502A - 400MHz – 400 MS/s 2 channel	£1600
Hewlett Packard 54520A 500MHz 2ch	£2750
Hewlett Packard 54600A - 100MHz – 2 channel	£675
Hewlett Packard 54616B 500MHz – 2Gs/s 2 Channel	£2500
Hewlett Packard 54810A 'Infinium' 500MHz 2ch	£3500
Hitachi V152/V212/V222/V302B/V302F/V353F/V550BV650F	from £100
Hitachi V1 100A - 100MHz - 4 channel	£750
Intron 2020 - 20MHz. Dual channel D.S.O (new)	£450
Iwatsu SS 5710/SS 5702 -	from £125
Kikusui COS 5100 - 100MHz - Dual channel	£350
Lecroy 9314L 300MHz - 4 channels	£2750
Meguro MSO 1270A - 20MHz - D.S.O. (new)	£450
Philips 3295A - 400MHz - Dual channel	£1400
Philips PM3070 - 100MHz - 2 channel - cursor readout	£650
Philips PM3392 - 200MHz - 200Ms/s - 4 channel	£1750
Philips PM3094 - 200MHz - 4 channel	£1500
Tektronix 468 - 100MHz D.S.O.	£500
Tektronix 2213/2215 - 60MHz - Dual channel	£300
Tektronix 2220 - 60MHz - Dual channel D.S.O	£850
Tektronix 2221 - 60MHz - Dual channel D.S.O	£850
Tektronix 2235 - 100MHz - Dual channel	£500
Tektronix 2245A - 100MHz - 4 channel	£700
Tektronix 2430/2430A - Digital storage - 150MHz	from £1250
Tektronix 2440 - 300MHz/500MS/s D.S.O.	£2100
Tektronix 2445 - 150MHZ - 4 channel +DMM	£850
Tektronix 2445/2445B - 150MHz - 4 channel	£800
Tektronix 2465/2465A /2465B - 300MHz/350MHz 4 channel	from £1250
Tektronix 7104 - 1GHz Real Time – with 7A29 x2, 7B10 and 7B15	from £1950
Tektronix TAS 475 - 100MHz - 4 channel	£850
Tektronix TDS 310 50MHz DSO - 2 channel	£750

SPECTRUM ANALYSERS

Advantest 4131 (10kHz – 3.5GHz)	£3750
Advantest/TAKEDA RIKEN - 4132 - 100KHz - 1000MHz	£1350
Ando AC 8211 - 1.7GHz	£1500
Avcom PSA-65A - 2 to 1000MHz	£750
Hewlett Packard 182T Mainframe + 8559A Spec.An. (0.01 to 21GHz)	£2000
Hewlett Packard 853A Mainframe + 8559A Spec.An. (0.01 to 21GHz)	£2500
Hewlett Packard 3582A (0.02Hz - 25.5kHz) dual channel	£1500
Hewlett Packard 3585A 40 MHz Spec An.	£3000
Hewlett Packard 3561A Dynamic Signal Analyser	£3500
Hewlett Packard 8560A (50MHz–2.9GHz) High performance with Tracking Generator option (02)	£5500
Hewlett Packard 8567A -100Hz - 1500MHz	£3400
Hewlett Packard 8590A (opt 01, 021, 040) 1MHz–1.5MHz	£2500
Hewlett Packard 8596E (opt 41, 101, 105,130) 9KHz - 12.8GHz	£9950
Hewlett Packard 8713C (opt 1 E1) Network An. 3 GHz	£6000
Hewlett Packard 8752A - Network Analyser (1.3GHz)	£4995
Hewlett Packard 8753A (3000KHz - 3GHz) Network An.	£3250
Hewlett Packard 8753B+85046A Network An + S Param (3GHz)	£6500
Hewlett Packard 8754A - Network Analyser 4MHz -1300MHz)	£1500
Hewlett Packard 8756A/8757A Scaler Network Analyser	from £900
Hewlett Packard 70001A/70900A/70906A/70902A/70205A - 26.5 GHz Spectrum Analyser	£7000
IFR A7550 - 10KHz-GHz - Portable	£1750
Meguro - MSA 4901 - 30MHz - Spec Anaylser	£600
Meguro - MSA 4912 - 1MHz - 1GHz Spec Anaylser	£750
Tektronix 492P (opt1,2,3) 50KHz - 21GHz	£3500
Wiltron 6409 - 10-2000MHz R/F Analyser	£1250
Tektronic 2782 (100Hz-33GHz) Spec. An.	£9995

Radio Communications Test Sets

Anritsu MT 8801C Radio Comms Analyser 300kHz - 3GHz (opt 1,4,7)	£6500
Hewlett Packard 8920B (opts 1,4,7,11,12)	£6750
Marconi 2955	£1250
Marconi 2955A	£1750
Marconi 2955B/60B	£3500
Marconi 2955R	£1995
Racal 6111 (GSM)	£1250
Racal 6115 (GSM)	£1750
Rohde & Schwarz CMD 57 GSM test set (opts B1/34/6/7/19/42/43/61	£7995
Rohde & Schwarz CMT 90 (2GHz) DECT	£3995
Rohde & Schwarz CMTA 94 (GSM)	£4500
Schlumberger Stabilock 4031	£2750
Schlumberger Stabilock 4040	£1300
Wavetek 4103 (GSM 900) Mobile phone tester	£1500
Wavetek 4106 (GSM 900, 1800, 1900) Mobile phone tester	£2000

TELNET

MISCELLANEOUS

Ballantine 1620A 100Amp Transconductance Amplifier	£1750
EIP 545 Microwave Frequency Counter (18GHz)	£1000
EIP 548A and B 26.5GHz Frequency Counter	from £1500
EIP 575 Source Locking Freq.Counter (18GHz)	£1200
EIP 585 Pulse Freq.Counter (18GHz)	£1200
Genrad 1657/1658/1693 LCR meters	from £500
Gigatronics 8541C Power Meter + 80350A Peak Power Sensor	£1495
Gigatronics 8542C Dual Power Meter + 2 sensors 80401A	£1995
Hewlett Packard 339A Distortion measuring set	£750
Hewlett Packard 436A power meter and sensor (various)	from £750
Hewlett Packard 3335A – synthesiser (200Hz-81MHz)	£1995
Hewlett Packard 3457A muli meter 6 1/2 digit	£850
Hewlett Packard 3784A - Digital Transmission Analyser	£3750
Hewlett Packard 37900D - Signalling test set	£2950
Hewlett Packard 4274A LCR Meter	£2000
Hewlett Packard 4276A LCZ Meter (100MHz-20KHz)	£1400
Hewlett Packard 5342A Microwave Freq.Counter (18GHz)	£850
Hewlett Packard 5350B 20KHz Microwave Freq.Counter	£2000
Hewlett Packard 5385A - 1 GHz Frequency counter	£495
Hewlett Packard 6033A - Autoranging System PSU (20v-30a)	£750
Hewlett Packard 6060A and B Electronic Load 300W	from £750
Hewlett Packard 6622A - Dual O/P system p.s.u	£1250
Hewlett Packard 6624A - Quad Output Power Supply	£2000
Hewlett Packard 6632A - System Power Supply (20v-5A)	£695
Hewlett Packard 8350B - Sweep Generator Mainframe	£1500
Hewlett Packard 8642A – high performance R/F synthesiser (0.1-1050MHz)	£2500
Hewlett Packard 8656A - Synthesised signal generator	£750
Hewlett Packard 8656B - Synthesised signal generator	£995
Hewlett Packard 8657A - Synth. signal gen. (0.1-1040MHz)	£1500
Hewlett Packard 8657B - 100MHz Sig Gen - 2060 MHz	£3950
Hewlett Packard 8657D - XX DQPSK Sig Gen	£3950
Hewlett Packard 8901B - Modulation Analyser	£2250
Hewlett Packard 8903A, B and E - Distortion Analyser	from £1000
Hewlett Packard 11729B/C Carrier Noise Test Set	from £2500
Hewlett Packard 53131A Universal Frequency counter (3GHz)	£850
Hewlett Packard 85024A High Frequency Probe	£1000
Keithley 228A Prog'ble Voltage/Current Source IEEE.	£2000
Keithley 237 High Voltage - Source Measure Unit	£4500
Keithley 238 High Current - Source Measure Unit	£4500
Keithley 486/487 Picoammeter (+volt.source)	£1350/£1850
Keithley 8006 Component Test Fixture	£1750
Marconi 2840A 2 Mbit/s Transmission Analyser	£1100
Marconi 6950/6960/6960A Power Meters & Sensors	from £400
Philips 5515 - TN - Colour TV pattern generator	£1400
Philips PM 5193 - 50 MHz Function generator	£1350
Phillips PM 6654C System Timer Counter	£750
Sig. Gen. (100KHz-140MHz) AM/FM/CW	as new £650
Rohde & Schwarz FAM (opts 2,6 and 8) Modulation Analyser	£3750
Rohde & Schwarz NRV/NRVD Power meters with sensors	from £1000
Schlumberger 1250 Frequency Response Analyser	£2250
Tektronix 1720 Vectorscope	£1150
Tektronix 1735 Waveform Monitor	£1150
Wavetek 178 Function generator (50MHz)	£750
Wayne Kerr 3245 - Precision Inductance Analyser	£1850
Bias unit 3220 and 3225L Cal.Coil available if required.	(P.O.A)
Wayne Kerr 3260A + 3265A Precision Magnetics Analyser with Bias Unit	£5500
Wayne Kerr 6245 - Precision Component Analyser	£2250
W&G PCM-4 PCM Channel measuring set	£3750

All equipment is used - with 30 days guarantee and 90 days in some cases

Add carriage and VAT to all goods.

Telnet, 8 Cavans Way, Binley Industrial Estate, Coventry CV3 2SF.

Tel: 02476 650 702

Fax: 02476 650 773

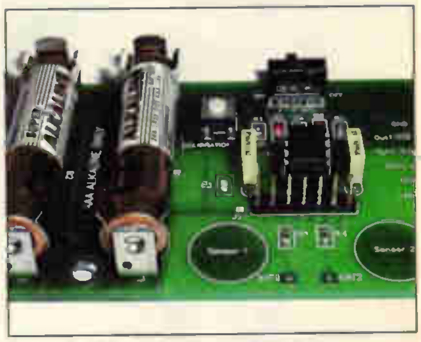
Web: www.telnet.uk.com

Email: sales@telnet.uk.com

CONTENTS

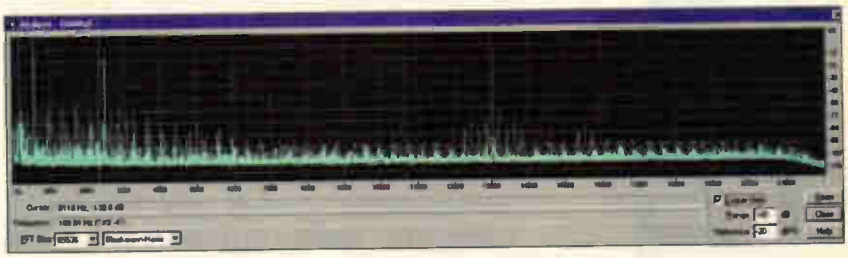
OCTOBER 2002 VOLUME 108 NUMBER 1798

Illustration: Hashim Akib



A newly released programmable touch sensor IC from Quantum Research Group, see page 42.

Budget T&M on a PC page 20.



November issue on sale 3 October

EDITOR
Phil Reed
p.reed@highburybiz.com

CONSULTANT
Ian Hickman

CONTRIBUTING EDITOR
Martin Eccles

EDITORIAL ADMINISTRATION
Jackie Lowe
020 8722 6054

EDITORIAL E-MAILS
j.lowe@highburybiz.com

GROUP SALES
Reuben Gurunlian
020 8722 6028

ADVERTISEMENT
E-MAILS
r.gurunlian@highburybiz.com

EDITORIAL FAX
020 8722 6098

CLASSIFIED FAX
020 8722 6096

PUBLISHING DIRECTOR
Tony Greville

MANAGING DIRECTOR
Roy Greenslade

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

More enthusiastic readers

I am glad to see that you readers know what you want. Yet again the mailbag was full of your comments – and I've printed a selection of them in the letters section. One reader has risen to the challenge of the Scroggie biography idea and if any reader has any information, recollections etc., I'll be happy to pass them on and put you in contact with the collator and author – Chris Jones. His introductory letter is also in 'letters'.

Certainly, the feedback I'm getting is much better than the recent reader survey, not that many of you replied. Apart from the eagle-eyed amongst you spotting various typos and my errors, there was a lot of positive feedback on what you want to see in the future. And just for the record – any mistakes in this magazine are down to me. It is my job to check everything – but sometimes deadlines and sheer blindness from reading something too many times creeps in. And quite why I found it so difficult to put the author's name in the intro to an article (as opposed to just on the contents page) I cannot fathom.

Your letters certainly tell me what you don't want. And it is interesting to note that you generally want more electronics and less computing – unless it relates directly to your interests. On that note, I'd be very interested in hearing what kind of design and emulation software you use – and also get some of you to review your favourite package.

I was quite surprised that only one reader had anything to say about the 'Conspiracy theory' (Letters, September). I know people in the medical profession that are convinced that excessive mobile phone use (when not used with a decent 'hands free' kit) can cause some nasty tumours around the head. Which is not surprising. Would you put your head into a microwave oven – of course not. So why expose your delicate parts to RF for quite long periods and expect to get away with it? It's a shame that the mobile phone manufacturers did not do more work on the effects of their products.

I must apologise to the audio haters out there as I've inadvertently turned this issue into a bit of an audiofest. What with the continuing of Cyril Bateman's 'Capacitor Sounds' series, Richard Black's 'Budget T&M' which discusses the measurement of posh loudspeaker cables, the concluding part of Michael Kiwanuka's VI protection in audio amps and Jeff Macaulay's DIY MFB speaker, audio aficionados should be pleased. The rest of you please accept my apologies and be assured that more non-audio features will be in next month's issue.

Winner of the 'Worldspace' radio competition is Kamal el Awad from Abu Dhabi

Also for future issues, I'm currently in discussions with some contributors whose names you've not seen on these pages for a while. So, look forward to a bit of controversy from EW in the not too distant future.

I am also pleased to announce that the lucky winner of the 'Worldspace' radio competition is Kamal el Awad from Abu Dhabi. Kamal was the first winning entry pulled out of the hat by my assistant, Jackie. The radio will be winging its way to Dubai shortly.

I hope you enjoy this issue – and if you don't – pick up your pen or keyboard and let me know.

***Phil Reed**, Editor.*

Electronics World is published monthly. Orders, payments and general correspondence to **Jackie Lowe, Highbury Business Communications, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey, SM3 8BZ.**
Newstrade: Distributed by COMAG, Tavistock Road, West Drayton, Middlesex, UB7 7QE Tel 01895 444055.
Subscriptions: Wyvern Subscription Services, Link House, 8 Bartholomew's Walk, Ely Cambridge, CB7 4ZD. Telephone 01353 654431. Please notify change of address.
Subscription rates 1 year UK £38.00 2 years £61.00 3 years £76.00. Europe/Eu 1 year £54.00 2 years £86.00 3 years £108.00 ROW 1 year £63.00 2 years £101.00 3 years £126
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) Englehord Ave, Avenel NJ 07001. Periodicals Postage Paid at Rahway NJ Postmaster. Send address changes to above.
Printed by Polestar (Colchester) Ltd,
Filmsetting by G&E 2000
A1 Parkway, Southgate Way, Orton Southgate, Peterborough, PE2 6YN

HIGHBURY
Business Communications
A SUBSIDIARY OF HIGHBURY HOUSE COMMUNICATIONS PLC

QUASAR ELECTRONICS LIMITED

(Dept EW), PO Box 6935, Bishops Stortford, CM23 4WP
TEL: 01279 467799 FAX: 07092 203496

ADD £2.00 P & P to all orders (1st class Recorded £4, Next day (Insured £250) £7, Europe £5.00, Rest of World £10.00). We accept all major credit cards. Make cheques/PO's payable to Quasar Electronics. Prices include 17.5% VAT. MAIL ORDER ONLY
FREE CATALOGUE with order or send 2 x 1st class stamps (refundable) for details of over 150 kits & publications.

Enhanced 'PICALL' ISP PIC Programmer

Kit will program virtually ALL 8 to 40 pin* serial and parallel programmed PIC microcontrollers. Connects to PC parallel port. Supplied with fully functional pre-registered PICALL DOS and WINDOWS AVR Software packages, all components and high quality DSPTH board. Also programs certain ATMEL AVR, SCENIX SX and EEPROM 24C devices. New devices can be added to the software as they are released. Blank chip auto detect feature for super-fast bulk programming. Hardware now supports ISP programming. *A 40 pin wide ZIF socket is required to program 0.3" devices (Order Code AZIF40 @ £15.00).

Order Ref	Description	inc. VAT ea
3144KT	Enhanced PICALL ISP PIC Programmer	£64.95
AS3144	Assembled Enhanced PICALL ISP PIC Programmer	£74.95
AS3144ZIF	Assembled Enhanced PICALL ISP PIC Programmer c/w ZIF socket	£89.95

ATMEL 89xxxx Programmer

Powerful programmer for Atmel 8051 micro controller family. All fuse and lock bits are programmable. Connects to serial port. Can be used with ANY computer and operating system. 4 LEDs indicate programming status. Programs 89C1051, 89C2051, 89C4051, 89C51, 89LV51, 89C52, 89LV52, 89C55, 89LV55, 89S8252, 89LS8252, 89S53 & 89LS53 devices. NO special software needed – uses any terminal emulator program (built into Windows).

Order Ref	Description	inc. VAT ea
3123KT	ATMEL 89xxx Programmer	£29.95
AS3123	Assembled 3123	£44.95

Atmel 89Cx051 and AVR programmers also available.

PC Data Acquisition & Control Unit

Use a PC parralell port as a real world interface. Unit can be connected to a mixture of analogue and digital inputs from pressure, temperature, movement, sound, light intensity, weight sensors, etc. (not supplied) to sensing switch and relay states. It can then process the input data and use the information to control up to 11 physical devices such as motors, sirens, other relays, servo motors & two-stepper motors.

FEATURES:

- 8 digital Outputs: Open collector, 500mA, 33V max
- 16 Digital Inputs: 20V max.Protection 1K in series, 5.1V Zener to ground.
- 11 Analogue Inputs: 0-5V, 10 bits (5mV/step)
- 1 Analogue Outputs: 0.2.5V or 0-10V. 8 bit (20MV/step.)

All components provided including a plastic case (140mm x 110mm x 35mm) with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo). with screen printed front and rear panels supplied. Software utilities & programming examples supplied.

Order Ref	Description	inc. VAT ea
3093KT	PC Data Acquisition & Control Unit	£99.95
AS3093	Assembled 3093	£124.95

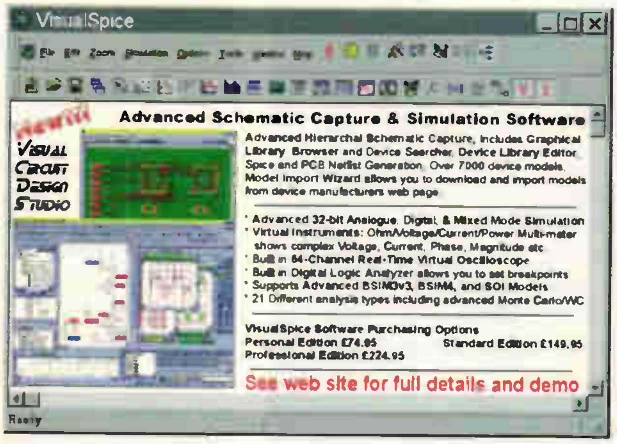
ABC Mini 'Hotchip' Board

ABC Starter Pack

Currently learning about microcontrollers? Need to do something more than flash a LED or sound buzzer? The ABC Mini 'Hotchip' Board is based on Atmel's AVR 8535 RISC technology and will interest both the beginner and expert alike. Beginners will find that they can write and test a simple program, using the BASIC programming language, within an hour or two of connecting it up. Experts will like the power and flexibility of the Atmel microntroller. as well as the ease with which the little Hot Chip board can be "designed-in" to a project. The ABC Mini Board 'Starter Pack' includes just about everything you need to get up and experimenting right away. On the hardware side, there's a pre-assembled micro controller PC board with both parallel and serial cables for connection to your PC. Windows software included on CD-ROM features an Assembler, BASIC compiler and in-system programme. The pre-assembled boards only are also available separately.

Order Ref	Description	inc. VAT ea
ABCMINISP	ABC MINI Starter Pack	£59.95
ABCMINIB	ABC MINI Board Only	£34.95

Advanced 32-bit Schematic Capture and Simulation Visual Design Studio



Serial Port Isolated I/O Controller

Kit provides eight relay outputs capable of switching 5 amps max and four optically isolated inputs. Can be used in a variety of control and sensing applications including load switching, external switch input sensing, contact closure and external voltage sensing. Programmed via a computer serial port, it is compatible with ANY computer & operating system. After programming, PC can be disconnected. Serial cable can be up to 35m long, allowing 'remote' control. User can easily write batch file programs to control the kit using simple text commands. NO special software required – uses any terminal emulator program (built into Windows). Screw terminal block connections. All components provided including a plastic case with pre-punched and silk screened front/rear panels to give a professional and attractive finish (see photo).

Order Ref	Description	inc. VAT ea
3108KT	Serial Port Isolated I/O Controller Kit	£54.95
AS3108	Assembled Serial Port Isolated I/O Controller	£69.95

Full details of these items and over 200 other projects can be found at www.QuasarElectronics.com

QUASAR ELECTRONICS Number 1 For Kits

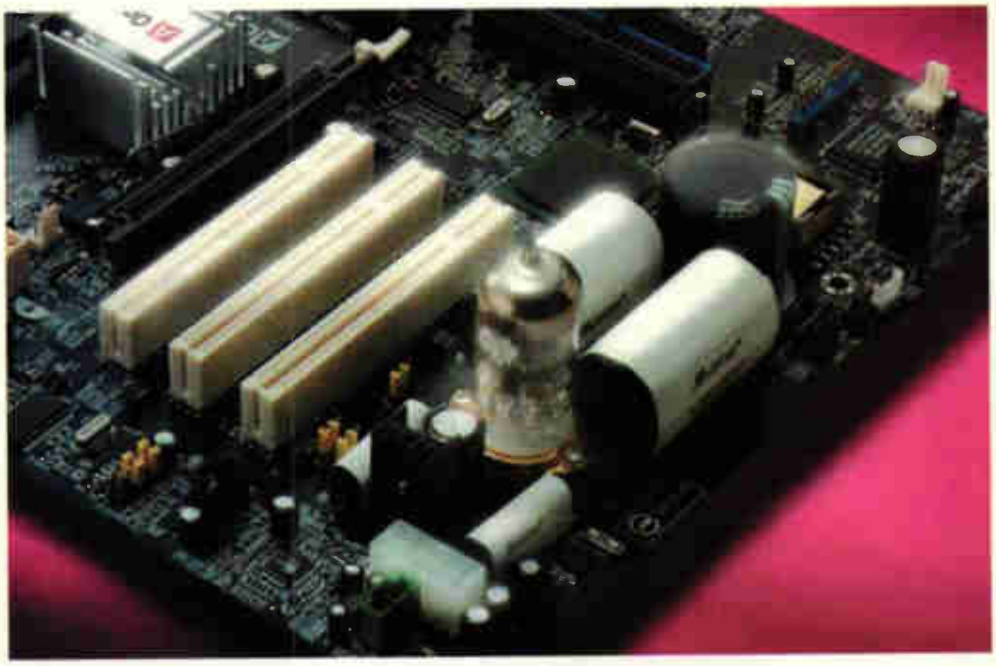
www.QuasarElectronics.com

Credit Card Sales: 01279 467799

Valve boosts PC sound

Aimed at audiophiles, Taiwanese PC maker component firm AOpen is making a motherboard with a thermionic valve sound port.

"It unquestionably is targeted to a very exclusive niche market - passionate audiophiles and extreme gamers who are interested in building their own ultimate entertaining PCs," said AOpen. "The motherboard is also certain to appeal to retailers that desire to cater to these two eccentric groups with custom-built PCs, delivered with matching speaker systems and the latest CD and DVD playback devices.



Called the AX4B-533 Tube, the sound chain on the board also includes other components frequently selected for audio quality. Alongside the Sovtek 6922 dual triode, these include: Elna and MultiCap capacitors, Cardas wires and Vishay resistors

The digital part of the motherboard is bang up-to-date with a 533MHz front-side bus for Pentium 4 Socket 478 CPUs and support for PC2100 and PC1600 DDR SDRAM.

www.aopen.com

Satellite wakes from the dead

A US amateur satellite has burst into life after orbiting lifeless for 20 years.

"Oscar 7 seems to be running on power from its solar panels. The on-board batteries failed two decades ago. One likely scenario is that a short-circuit in the batteries opened, allowing enough power to operate the spacecraft while it is in sunlight," said AMSAT, an organisation which is still making and launching satellites.

The satellite, which was launched in 1974, was spotted by Pat Gowan G3IOR who received CW telemetry and has since been found by many others. "Amateur operators have been monitoring the beacons at 29.502, 145.975, and 435.1MHz," said AMSAT.

Oscar 7 was the satellite that inspired the founders of now-successful Guildford-based Surrey Satellite Technology to first consider making their own spacecraft.

Cash for UK plastic solar cell effort

Cambridge Display Technology (CDT) is moving into plastic solar cell technology.

CDT is already one of only two companies worldwide that have saleable plastic display technology - the other is Kodak - and now it has a DTI grant to use its expertise in semiconducting polymers to develop low-cost solar cells.

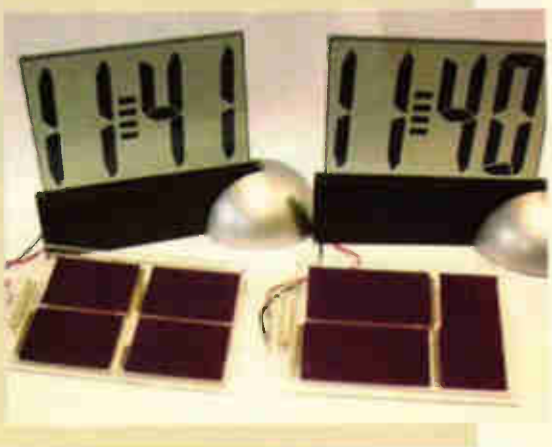
"Solar cells based on semiconductor materials such as silicon are expensive to manufacture and are limited to small area panels. The low manufacturing cost offered by polymer technology could make solar energy generated via polymer panels a viable commercial prospect," said CDT.

Belgian research organisation IMEC is already looking at organic (plastic) solar cells, as is the University of California, Berkley.

Although efficiencies so far seem to peak at around five per cent, compared with ten per cent for even the cheapest silicon solar cells, organic cells made in a continuous roll-to-roll process could be significantly less costly.

Efficiencies will also increase making plastic solar cells more desirable, but a significant problem could be ultraviolet stability as the sun's direct rays quickly alter the structure of most plastics.

CDT will be looking at indoor applications first, for instance in 'solar' calculators.



Pollution free in South Wales

South Wales students have developed some remarkable ideas for environmentally-friendly products on an industrial design course at the Swansea Institute.

Richard Clements has developed a three-wheeled scooter called PV1, his Public Vehicle for One, that could reduce traffic in city centres and is also pollution free.

"It's powered by a Stirling engine," said Clements. "I've got a powdered fuel made up from sodium, magnesium and iron."

Combining the dry powder with water results in an exothermic reaction, which provides heat for the Stirling engine.

Amazingly Clements said "there are no pollutants at all" from the reaction, in spite of the chemicals used. This fuel type is not new, but Clements said it is the first use in a Stirling engine.

PV1 has a claimed top speed of 50mph and runs for two to three hours at a time. Clements has applied for a number of patents covering the engine and tilt mechanism of PV1.

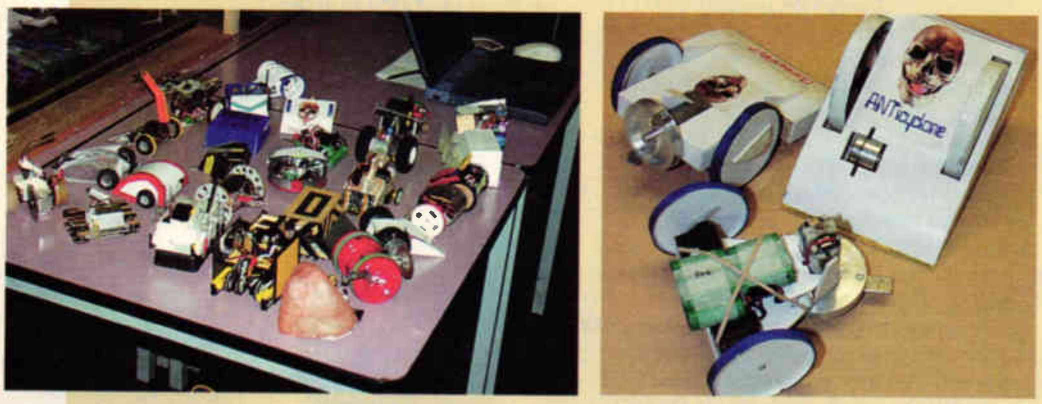
Meanwhile, John Briens designed a solar and wind-powered generator that offers a less polluting method of generating electricity.

"It's a portable, renewable energy source running off solar and wind power," he said.

Briens described the generator as looking like a golf bag. His design can deliver 12V at 1A continuously and "it can also run 240V stuff through an inverter", he added.

The unit weighs between 35 and 40kg, so would be suitable for transporting on vehicles, but can be moved to catch favourable winds or sunlight.

The environmentally friendly power source could be used in place of petrol and diesel generators on expeditions, Briens believes.



These ant-weight fighting robots took a trip to Hursley EMC recently to deal with some EMC difficulties. Creator and engineer Peter Waller had been having a few problems with interference and receiver saturation - the latter from up to six competing transmitters clustered around the tiny fighting arena. Solutions were: more suppression on his wheel motors and shorter receiver aerials. The robots pictured are: ANTicyclone, CombatANT and MilitANT. Each weighs under 150g and fits in a 100mm cube. The next ant-weight championship will be in Aylesbury in October. www.robotwars101.com for ant-weight rules.

Matlab gets speed boost

The Mathworks, based in the UK in Cambridge, has updated its Matlab and Simulink tools, including the addition of just-in-time compilation to speed up Matlab's execution.

Matlab is perhaps the most widely used piece of signal analysis software, extensively used in universities and companies across the UK. The firm is aiming to bring it up to date with modern techniques.

Many users are being forced to hand code their algorithms in C in order to speed up execution during testing, according to Jim Tung, chief market development officer at The Mathworks.

"The problem with recoding is it's time consuming and it's prone to errors. People should not have to move to C just in order to get execution speed," he said.

Thus the firm decided to use a just-in-time (JIT) compiler. "We want to deliver the speed of a compiled language in an interpreted environment," Tung said.

JIT cannot speed algorithms that are already highly optimised, such as a fast Fourier transform, but general execution speed should rise by a factor of at least 50.

The Mathworks has also extended the tools, allowing them to model mechanical systems. This would be most useful when developing automotive, aerospace or industrial control applications.

And for the first time in five years the firm is supporting Macintosh users in the latest release of the tools.

Nanotubes-to-go

Fujitsu Labs in Tokyo has developed technologies for vertical growth and diameter control of multi-wall carbon nanotubes.

Carbon nanotubes are touted as one way of connecting together future generations of on-chip components and in this development Fujitsu connected the tubes to the terminals of a mosfet.

Carbon nanotubes are usually produced using laser vaporisation and arc discharge, said the lab. However, these techniques do not offer good control over the location and orientation of the nanotubes, or the diameter of the nanotubes themselves.

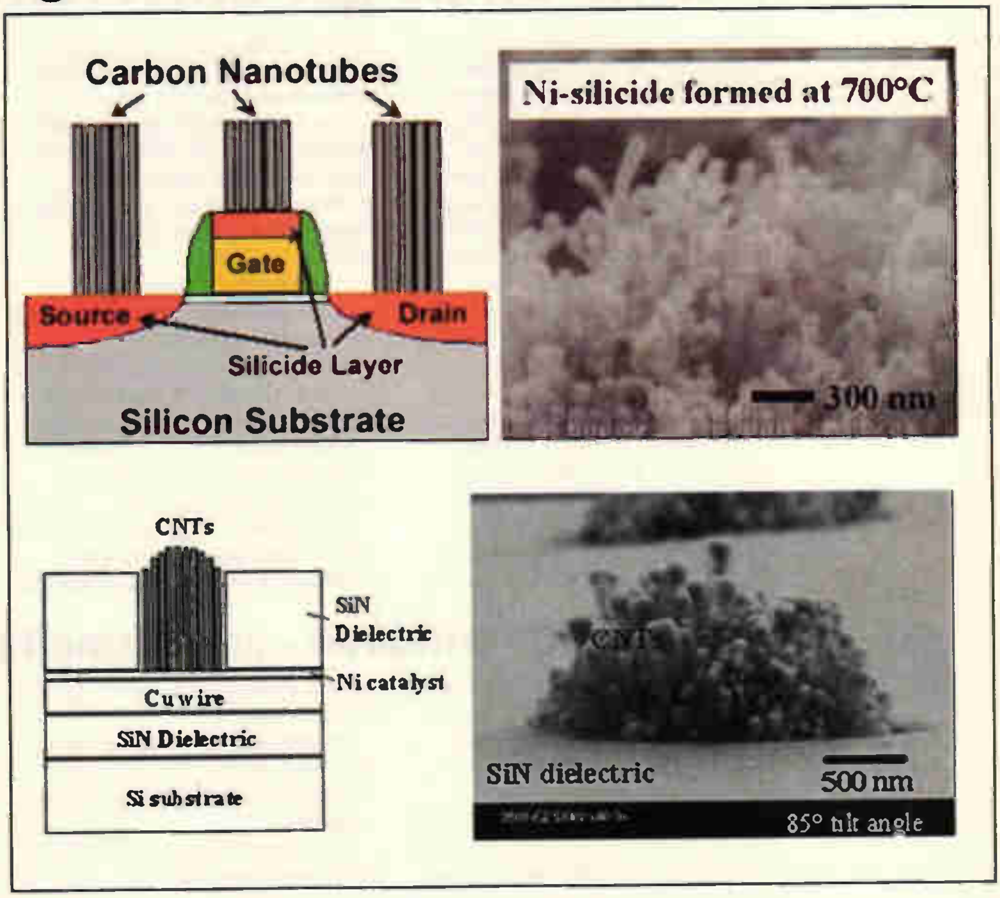
Fujitsu used plasma-enhanced chemical vapour deposition using a methane-hydrogen composite gas at the same time as applying an electrical field perpendicular to the substrate.

The field induces the nanotubes to align with the field as they grow.

Of particular note, said Fujitsu, is the tubes grow directly on the mosfet electrodes on a contact material called a silicide.

Silicides are silicon-metal alloys - in this case with nickel or cobalt.

By varying the amount of Ni or Co, the diameter of the tubes can be set.



Surrey Satellite to use Russian rockets

Surrey Satellite Technology and Rosoboronexport of Russia have signed a contract to launch 8 microsatellites on 3 Cosmos rockets from the Plesetsk Cosmodrome during 2002-2004. "Cosmos and RBE were selected due to their capabilities to achieve the necessary orbital injection accuracy into a sun-synchronous orbit within the timescales needed by SSTL and at an affordable price," said SSTL.

Seven of the advanced Earth Observation microsatellites will be injected into the same orbit by the three Cosmos rockets in order to form the first international constellation dedicated to monitoring natural and man-made disasters.

The eighth microsatellite is a demonstration high resolution Earth Observation microsatellite for the UK British National Space Centre.

Seven of the microsatellites are being constructed by SSTL in the UK in collaboration with its international partners. Cosmos has an excellent record, said SSTL, and was previously used by SSTL to launch successfully its SNAP-1 nanosatellite and the Tsinghua-1 microsatellite for China in June 2000.

The first launch for SSTL, carrying the first DMC microsatellite AISAT-1, is scheduled for autumn 2002.

Plastic chips get university backing

Polymer or carbon-based semiconductors are deemed so important that eleven UK universities have joined forces for research into the devices.

Moreover, the National Carbon-based Electronics Consortium goes further than pure research, and aims to improve the UK's record in transferring research into commercial products.

"The idea is to enable the UK to leapfrog ahead of international efforts in this area," said the group's leader, Professor Bill Eccleston from Liverpool University.

Devices using carbon or polymer circuits are increasingly finding applications, particularly in areas such as displays, solar cells and micromachines.

Sponsored by the Engineering and Physical Sciences Research Council (EPSRC), the consortium brings together the UK's leading players in carbon-based circuits.

The 11 universities involved are Bangor, Bristol, Cambridge, Heriot-Watt, Imperial College, Kings College London, Liverpool, Oxford, Surrey, Sussex and University College London.

It will hopefully improve the technology transfer of academic work to spin-off companies.

"As with liquid crystals, the UK is a leader worldwide, but unlike liquid crystals we do not intend to lose this position, and the EPSRC-funded managed programme will help to maintain it," said Eccleston.

Initial funding for the group from the EPSRC amounts to £2.7m, which should drive scientific and commercial work for three years.

Beside the universities there are around 15 companies involved in the consortium. Some of these were originally spun out of the universities themselves.

They include firms such as CRL and Epichem, which are developing products based on carbon technology, and notably CDT with its light emitting polymer displays.

Alongside the end products, the research efforts will look into growth and processing techniques and speculative research into combining carbon with other exotic materials.

The consortium also takes in 90 per cent of the academics working in the UK in the field, including Sir Harry Kroto, whose team discovered C^{60}, or buckyballs.

Sewing with Windows - and GameBoy

Sewing machine company Bernina is making what it claims to be "the first authentic sewing computer," said Martin Favre, president of the company's US arm.

Called the Artista 200E, it has more than 850 stitch options and can sew in 16 different directions - and can also browse the internet using an optional PC Card modem.

Internet connection allows users to download additional features and embroidery patterns as they become available.

A USB port allows a CD-ROM drive to be connected.

Having Windows and a touch-screen on-board means the user-guide can be stored in the machine as well as video tutorials.

Sewers amongst Electronics World readers may be interested that the Artista 200E has a 14x25cm embroidery field, averages 600 stitches per minute and offers on-screen pattern editing.

The first sewing machine with a computer? - Try Nintendo.

Bernina is claiming 'the first authentic computer', but Japanese company Jaguar got there first and has been making Nintendo GameBoy-based sewing machines for a while. Its range includes the Nuyell (which is sold by Singer as its Izek), Nuotto and Nu-Yell.

GameBoys have quite a following as embedded computers - made popular by their reliability, input-output port, built-in display and rugged buttons.

There are several websites devoted to modifying GameBoys and companies produce custom interface cartridges that plug into its gameport.

There is even a floating-point BASIC interpreter for GameBoy called GB Basic. www.devrs.com/gb/ is a comprehensive site and www.semis.demon.co.uk/Gameboy/Gbmain.htm includes a GameBoy digital oscilloscope.

Starter kit gets flash

Potential flash microcontroller users will benefit from Crossware's latest starter kit, which targets the Atmel range of devices.

The kit combines an evaluation board and development software. The board is fitted with an Atmel T89C51 controller, a 5V device containing 4kbyte of on-board flash memory. Other devices in the Atmel range include a 32kbyte chip.

Embedded code can be quickly developed, and the board is suitable for professional users, universities and hobbyists, the firm claimed.

The board can also be used as an in-circuit emulator. A header cable enables the board to be plugged into another system as the target device.

Larger prototype systems can be constructed via an IDC connector, linking the Atmel processor to other components. LEDs show activity on the various I/O lines.

Cambridge-based Crossware can be contacted at www.crossware.com

Low power radio firms under pressure

Companies whose short range devices (SRDs) operate within the unlicensed frequency bands are becoming increasingly concerned at Government plans to allow unlicensed spectrum to be used for commercial services.

The industry is worried that its SRDs - products such as car alarm fobs and garage door openers - will suffer from interference problems when commercial services start operating.

Current concerns are centred mainly around 2.4GHz. The Government has agreed to open up this licence-exempt band for public access wireless local area networks offering commercial services, which would allow the creation of internet access hot-spots.

Industry body the Low Power Radio Association (LPRA) sees the opening up of 2.4GHz as just one move which is fast eroding the spectrum allocated for its use.

"If you look at the spectrum… the amount that's actually allocated for SRDs is tiny," said Mike Brookes, chairman of the LPRA. "Yet everyone's saying 'this is the best bit of spectrum for our particular application'. The fact that it's free has nothing to do with it."

An 802.11b wireless LAN, which operates at 2.4GHz, is already being rolled out by Megabeam at a further 15 railway stations after a successful trial at London's Paddington station. Meanwhile BT started a public trial of an internet access hotspot service using 2.4GHz at the end of June and expects commercial roll-out to happen in August.

But the threat at 2.4GHz is far from the end of the story according to Brookes. Other concerns surround the introduction of HiperLAN and 802.11a, both of which operate at around 5GHz, another SRD band.

"These people have just said this is a wonderful bit of spectrum, it suits us down to the ground," said Brookes, "so we've got another hole being blasted right through the SRD allocation."

Brookes is particularly worried by the Government's spectrum review which is opening the way for this to happen. He believes the review basically boils down to "let's open up everything to everybody" and is concerned it did not thoroughly investigate the needs of the low power radio industry.

Brookes said the amount of text in the report about SRDs amounted to "about a quarter of a paragraph", from which a lot of conclusions were drawn.

"I think it's dangerous the way it's going ahead. Everyone's jumping on the little bit of SRD spectrum to use it for commercial network services," says Brookes. "The danger is it will kill the SRD market which is largely comprised of small companies."

Smart whip saves horses?

In an attempt to quantify the amount of beating occurring during horse races, Dublin bookmaker Reg Cregan has invented The Register, a smart-whip.

Proprietary sensors in its tip measure each blow and inside its handle is an 8-bit Motorola microcontroller for data-logging.

Matlab from The MathWorks is used to process the data gathered by the whip either in real time or post-acquisition. This involves recording all waveforms, storing the time and amplitude of the waveform, then graphically displaying this data on-screen.

Bike firm CAN use the bus

The increasing use of CAN-bus in the automotive industry has spread to the motorcycle industry, with Ducati choosing CAN (controller area network) for its latest machine.

The Italian manufacturer is using the bus on the Ducati 999 in order to reduce weight. The two-wire digital bus links the dashboard to the Magneti-Marelli engine management unit. This simplifies the electrics and reduces weight, the firm said.

Various sensors and electronics on the bike connect to the processor in either the dash or EMU, whichever is closest.

CAN-bus is not the only first for the bike, as Ducati has also chosen to use samarium cobalt as the rare earth magnet in the generator's rotor. SmCo is more brittle compared to the widely used neodymium iron boron. However, SmCo will operate effectively at up to 350°C, while NdFeB falls over at 130°C.

Visit our website www.distel.co.uk

THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

GIANT 10" 7 SEGMENT DISPLAYS

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

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

THE AMAZING TELEBOX

TV SOUND & VIDEO TUNER CABLE COMPATIBLE

Converts your colour monitor into a QUALITY COLOUR TV!!

The **TELEBOX** is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors or AV equipment which are fitted with a composite video or SCART input. 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**. Ideal for **desktop computer video systems** & PIP (picture in picture) setups. For **complete compatibility** - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard. Brand new - fully guaranteed.

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 signal reception Telebox MB should be connected to a cable type service. Shipping on all Telebox's, code (B)

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

HARD DISK DRIVES 2fi" - 14"

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

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

IC's -TRANSISTORS - DIODES

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

COMPUTER MONITOR SPECIALS

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

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

VGA cable for IBM PC included. **Only £129** (E) Order as CG73

External cables for other types of computers available - CALL

Generic LOW COST SVGA Monitors

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

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

Supplied in good used condition. Shipping code (D)

VIDEO MONITORS

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor **with** <u>**both**</u> **RGB and standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. Integral audio **power amp and speaker** for **all audio visual uses**. Will connect direct to **Amiga and Atari** BBC computers. Ideal for all **video monitoring / security** applications **with direct connection to most colour cameras**. High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed Dimensions: W14" x H12fl" x 15fi" D. **Only £99.00** (D)

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

INDUSTRIAL COMPUTERS

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

100's of applications inc: firewall routers robotics etc **Only £99.00** (D)

19" RACK CABINETS

Save £££'s

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

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

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

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

Call for shipping quotation

COLOUR CCD CAMERAS

BIG £ SAVER

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

Overall dimensions 66 mm wide x 117 deep x 43 high. Supplied BRAND NEW & fully guaranteed with user data, 100's of applications including Security, Home Video, Web TV, Web Cams etc, etc.

Order as LK33 ***ONLY £79.00 or 2 for £149.00*** ***(B)***

SOFTWARE SPECIALS

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

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

shipping charges for software is code B

SOLID STATE LASERS

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

Order as TD91 ***ONLY £24.95*** ***(A)***

DC POWER SUPPLIES

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

RELAYS - 200,000 FROM STOCK

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

TEST EQUIPMENT & SPECIAL INTEREST ITEMS

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

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

DISPLAY - ELECTRONICS -

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

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

ALL ENQUIRIES
0208 653 3333
FAX 0208 653 8888

Est 26 Years

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 £100. Cheques over £100 are subject to 7 working days clearance. Carriage charges (A)=£3.50, (B)=£6.50, (C)=£10, (D)=£15.00, (E)=£18.00, (F)=CALL. Allow approx 3 days for shipping - faster CALL. All goods supplied to our Standard Conditions of Sale which can be viewed at our website 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, tradenames etc acknowledged. E & O E..

Capacitor sound 3

Capacitances of 10nF and smaller.

Readers of my recent articles have seen that many capacitors do introduce distortions onto a pure sine wave test signal.[1] In some instances this distortion results from the unfavourable loading the capacitor imposes onto its driver circuit and frequently the distortion is generated in the capacitor.

When two or more signals are involved, a distorting capacitor produces a multiplicity of new frequencies. Used in an audio system, this can result in distorted sound. **Fig. 1.** Measurements are now made using a computer soundcard with FFT software, replacing the Pico ADC-100. The chosen software facilitates analysis, by calculating distortion relative to the voltage across the test capacitor.(see box Soundcard FFT Software.)

Many capacitors that distort little when sine wave tested without a DC bias voltage, exhibit much bigger distortions with increasing polarisation. With an 18 volt DC bias, the second harmonic of the capacitor in figure 1, increased by 23dB, but other harmonics hardly changed.**Fig. 2.**

Why should this be?

As a capacitor design engineer of many years, when I commenced these tests I believed that capacitor distortions would relate directly to the capacitor's measured tanδ. Dielectric absorption does not appear to significantly affect tanδ measurements, so I reasoned it should not greatly affect a capacitor's sound. I certainly was not alone in this belief.

More than 2000 distortion measurements have been made, using test signals from 0.1 volt to 6 volts AC and DC bias from 0 volt to 30 volt . Using a variety of capacitors, purchased for these tests and observing the effect of changing one measurement stimulus at a time, I was able to analyse the different distortions.

Starting in January 2002, these measurements together with their analysis, occupied many weeks. With a 30 minute warm up, my test equipment performed consistently throughout, producing exceptionally low distortion. I now realise dielectric absorption does influence measured distortions, even if the capacitor measures a low tanδ on a bridge. (See box Tanδ/ESR.)

As will be seen later in this series, when a capacitor is used with a significant DC bias, dielectric absorption becomes the dominant distortion producing mechanism. Whether these measurable capacitor distortions become audible or not, depends on the capacitor's location in the circuit. The capacitor voltage levels, any subsequent circuit gain and whether the capacitor is located inside or outside of a negative feedback loop.

Repetition.

As a result, it became necessary to repeat most of my early single frequency tests, now using two frequencies. Distortion was measured both with and without DC bias voltage applied to the capacitor. To replicate many circuit voltages without over-stressing most capacitors, for this article I standardised on an 18volt DC bias. Apart from Figure 1, the bias network was left in situ and switched to discharge for no bias measurements.

My 1kHz notch filter preamplifier was designed to attenuate 100Hz by some 55dB. A 100Hz test signal, similar in amplitude to the 1kHz signal, can be input without overloading the preamplifier or soundcard.[1]

To apply a DC bias voltage across the test capacitor, a protective 'DC Bias' network must be used. I already had one, built using 100μF and 1μF metallised PET capacitors, used to measure capacitance change with applied DC bias, of capacitances up to 10μF.

When tested with my near perfect 1μF KP test capacitor [2], this network introduced its own distortions. A new network was required. It was assembled using 11μF and 1μF MKP capacitors with a 100kΩ charge/discharge resistor. Another 100kΩ resistor to ground, protects the pre-amplifier input from charge/discharge transients, but restricts measurements to using 10kΩ and smaller sense resistors. **Fig. 3.**

This new DC Bias network permits accurate distortion measurements with dual 1 kHz/100 Hz test signals up to six volts AC and with up to 50 volt DC bias. It is quickly attached to or removed from my existing test equipment.[1] It is designed to mount in place of the test capacitor, shown in the figure. (see DC Bias Network, **Fig. 4)**

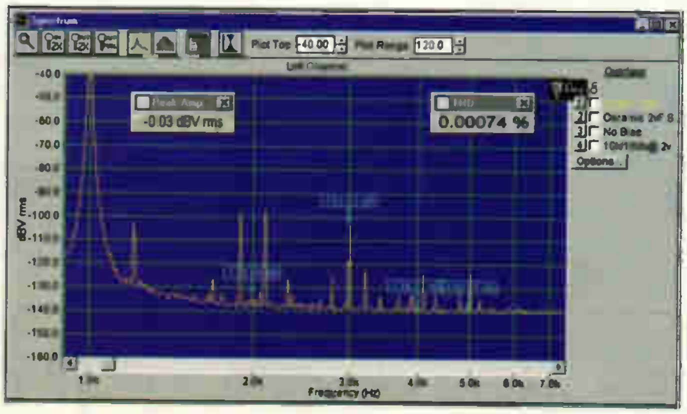


Figure 1: Y5P is a medium 'k' class 2 ceramic. Tested with two signals, 100Hz and 1kHz at 2 volts amplitude, with no bias network, it produces many new intermodulation distortion frequencies.

Capacitor Myths.

Many articles have been written about capacitor behaviour, mostly by authors having little knowledge of capacitor design and construction. As a result, many false capacitor myths have emerged.

I will try to relate some of these myths to facts:-

a) All ceramic capacitors distort.
b) Dielectric absorption causes smearing and compresses dynamic range.
c) Polypropylene is an inefficient material.
d) Capacitors are highly inductive at audio frequencies.
e) ESR of a capacitor has a fixed value.

Capacitor production tests.

In manufacture every capacitor is measured for capacitance and tanδ, usually at 1kHz. Capacitance values of 100μF and smaller are measured at 1MHz. Capacitors larger than 1μF are usually measured at 100Hz.(see box Tanδ/ESR.) Each capacitor is 'voltage proof' tested to ensure reliable operation at rated voltage. Leakage current or insulation resistance will be measured at the specified time interval or less. To expedite this time consuming measurement, leakage currents/insulation resistance are conservatively stated.

Many other tests will be performed on sample capacitors, to ensure compliance with National periodic 'Type Tests', but I know of no company that routinely tests for harmonic distortion, at realistic circuit voltages. Capacitors are not categorised for distortion, so a distorting capacitor would not be considered defective by its maker. It is the responsibility of the equipment designer to select the correct capacitor for each circuit requirement.

Tanδ measurement reflects both insulation resistance and series resistive losses. Invariably the LCR meters used include a 'tuned' detector, designed to exclude extraneous frequencies. As will be seen, dielectric absorption affects the second harmonic, so is transparent when measuring tanδ. **Fig. 2.**

Dielectric characteristics.

In essence, two major dielectric characteristics exist, polar and non-polar. By polar, I am not referring to an electrolytic capacitor, but how the dielectric responds to voltage stress. This stress relates to the volts per micron gradient across the dielectric, not simply the applied voltage.

Vacuum and air are little affected by voltage stress and solid dielectrics which behave in a similar fashion are termed 'non-polar'. Most solid dielectrics and insulators

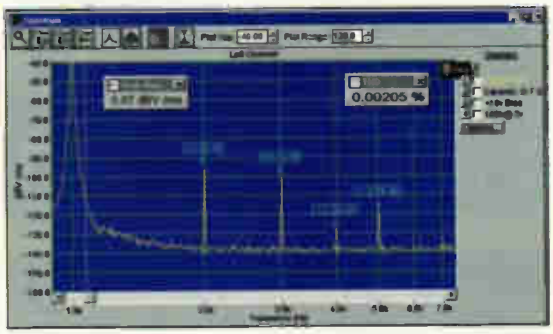


Figure 2: The figure 1 capacitor tested using 1kHz only with 18 volt DC bias. Compared to its 0 volt bias test, second harmonic has increased 23dB, a 14 times distortion increase.

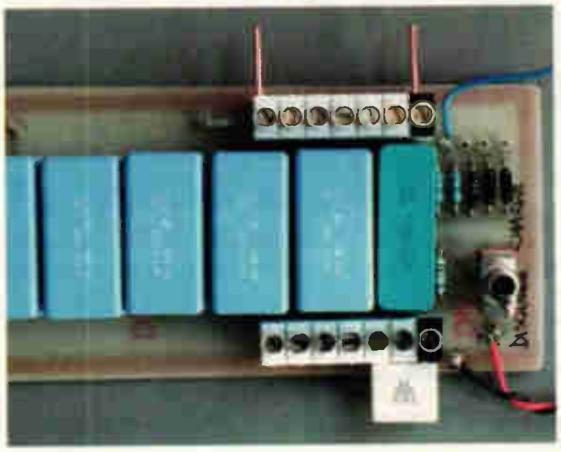


Figure 3: A fly lead connected to the hot AOT resistor terminal, a duplicate set of source resistors and five 2.2μF MKP blocking capacitors, couple the 1kHz test signal. The test capacitor output is fed to the pre-amplifier via a 1μF capacitor. A current limited 100Hz test signal may be input to the top left terminal, DC bias to bottom right.

Soundcard FFT Software

Measurements for my earlier articles used a Pico ADC-100. Many readers may wish to use a soundcard instead. A modern low cost PCI card with FFT software can provide increased dynamic range, measuring smaller distortions using my instruments, than is possible with the ADC-100. I now use the Spectra 'Plus232' software under Windows 98SE with a Soundblaster Live 1024 card, for all measurements.

With 'CoolEdit', the audio manipulation software already on my hard disc, I did try using it to measure capacitor distortions. Both 'CoolEdit' and the Pico ADC-100 software display distortion spectra but don't calculate percentage distortion. Tired of making a great many repetitive calculations, I searched internet for a better solution.

I downloaded some twenty FFT packages for evaluation. On reading their help files, many were obviously of little use. A small number looked promising, because they provided a dB scaled display and calculated distortion percentages. However few packages promised any facility to calibrate and control the soundcard gain settings.

I decided the best choice was the Spectra 'Plus232' software. Ref.6 I calibrated its input level using a known 1 volt signal. This calibration was accurately maintained from day to day. Having established a measurement set-up, it was saved as a 'config' file for re-use.

It also accepts a correction file, intended to compensate for microphone errors. Having carefully measured the output of my notch filter/pre-amp by frequency using a 1 volt test signal, I wrote a correction file to restore the much attenuated test fundamental back to level and correct for pre-amplifier gain errors. The software then automatically displays percent harmonic distortion, on screen.Fig. 12

I quickly produced other files, from 0.1 volt test level to 6 volts, by simply adding or subtracting the appropriate dB levels to the 1 volt file values. see Table. Spectra 'Plus232' can measure in real time, without first saving to disc. It can be used to cover the maximum frequency span of your soundcard, or as shown to measure over your selected frequency band.

Spectra 'Plus232' software was used for all capacitor distortion measurements, more than 2000 in all taken over several weeks, commencing with those for this article. Should you have only an older ISA soundcard, some software may not work. One that will, is FFT.EXE, a very simple, no-frills, DOS program by Henk Thomassen. This can be found on the internet and also on the Elektor 96-97 software CD-ROM.

Users having a modern PCI soundcard will find a very large variety of programs, often available as freeware, on the internet. One site that links to some of the better packages is www.pcavtech.com/links/index.htm.

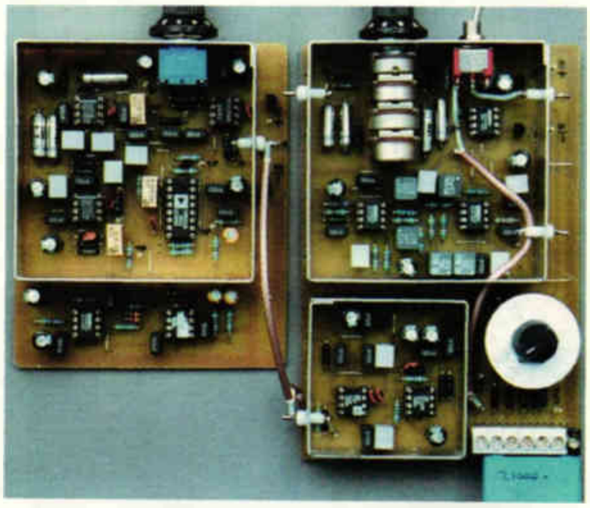


Figure 4: Low distortion test equipment measuring distortion of a capacitor with AC test signal, as described in my last two articles. To measure capacitors with DC bias, the network of Figure 3 with test capacitor attached, replaces the test capacitor shown bottom right.

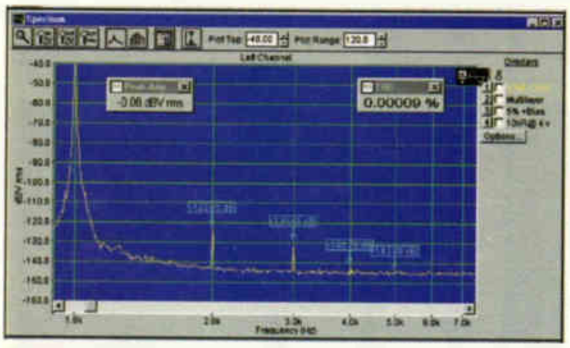


Figure 5: Distortion measurement of a Class 1 ceramic using 100Hz and 1kHz signals at 4 volts and 18 volt DC bias. With no bias this tiny 10nF 50 volt C0G multilayer capacitor measured just 0.00006%. Second harmonic was -128.5dB, the other levels remained as shown.

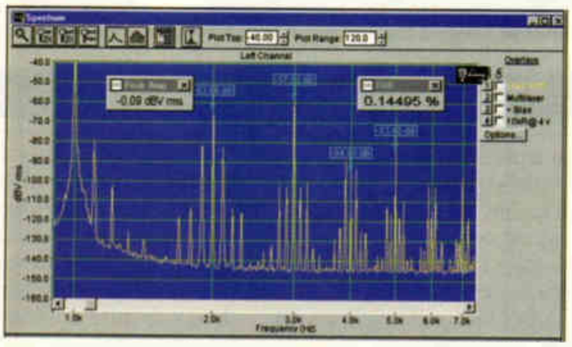


Figure 6: A Class 2 X7R 10nF capacitor from the same maker as figure 5 and tested the same. This test dramatically shows the impact an increase in both tand and dielectric absorption have on capacitor distortions.

are affected, increasing roughly in line with their 'k' value. This 'k' value is the increase in measured capacitance when the chosen dielectric is used to displace air.

Under voltage stress, electrons are attracted towards the positive electrode. The electron spin orbits become distorted, creating stress and a so-called 'space charge' within the dielectric. This produces heat in the dielectric with power loss, called dielectric loss, together with second harmonic distortion.

Non-polar dielectrics exhibit very small dielectric loss. Polar dielectrics are lossier and take longer for the dielectric to return to its original uncharged state. Polar dielectrics produce easily measured 'dielectric absorption' effects, especially apparent in thin dielectrics

Dielectric absorption is measured by fully charging the capacitor for several minutes then briefly discharging into a low value resistor. After a rest period, any 'recovered' voltage is measured. The ratio of recovered voltage to charge voltage is called dielectric absorption.

Ceramic capacitors.

'Ceramic' covers an extremely wide range of dielectrics, sub-divided as Class 1 (non-polar) or Class 2 (polar) according to the materials used to make up the ceramic. Class 1 ceramics do not use Barium Titanate and so have a low 'k' value. The best known is C0G. With its controlled temperature coefficient of zero ± 30 ppm, it was originally called NP0 by the Erie Corporation. It is non-polar and has a small dielectric absorption coefficient. From my tests, it has almost no measurable harmonic distortion. **Fig. 5.**

C0G ceramic provides the most stable capacitance value, over long time periods and temperature excursions, of all easily obtained capacitor dielectrics. It is frequently used as a capacitance transfer standard in calibration laboratories and yet as a small disc capacitor, it costs only pennies. Assembled as a multilayer, it can provide capacitances of 100nF and above, rated for 50 volts working, and can achieve higher working voltages for smaller capacitances.

Other Class 1 ceramics, sometimes called 'low k', provide increased capacitance within a controlled temperature coefficient, e.g. P100, N750 etc. in ppm. These also are non-polar and exhibit almost no measurable dielectric absorption. I have tested up to N750, sometimes called U2J, and found very low distortion.

Class 2 ceramics do include Barium Titanate. It produces a very high dielectric constant, with 'k' values ranging from a few hundred to several thousands. Class 2 ceramic is strongly polar and its capacitance varies with applied voltage and temperature. It exhibits an easily measured

DC Bias Network

Two DC blocking capacitors are needed, one to couple the signal to the test capacitor and the second to couple the test capacitor voltage into the pre-amplifier input. To minimise test signal loss, that capacitor should be ten times the value of the capacitor being tested. To not introduce distortion it should be of much higher voltage rating than the DC bias and the same or better quality, as the best capacitor to be tested. I used five 2.2μF 250 volt MKP from BC Components (Philips), type 378 capacitors connected in parallel.

To couple the test capacitor voltage to the high impedance preamplifier input, a smaller value can be used. For this a 1μF 250 volt version of the MKP capacitor would be fine. I already had a distortion tested sample of the Epcos (Siemens) equivalent, so I used that instead. Source impedance resistors, as used in the buffer amplifier, are selected and connected to the AOT 'hot' pin using a short fly lead. Two 100kΩ charge/discharge resistors and a toggle switch, completed the bias network. Fig. 3.

All were mounted on a single sided PCB size 110 x 55 mm. For convenient interconnections, I mounted two lengths of the terminal strip, one on either side of the buffer. **Fig. 13** To avoid overloading the soundcard input, the 100Hz/1kHz connections to the bias network should be completed before connecting the pre-amp output to the sound card.

Tanδ/ESR

Tanδ is used to describe capacitor quality. A textbook perfect capacitor has a phase angle of 90°, a phase angle deviation of 0°, a Tanδ of zero. Using a 6425 precision LCR meter, Tanδ of a most nearly perfect capacitor at 1kHz measured just 0.00005, a phase angle deviation less than 0.003°. These measurements were made on a Philips 10nF 1%, axial lead, extended foil and Polystyrene capacitor. Fig. 7

Some of the resistive losses which contribute to Tanδ are due to lead out wires and metal electrodes, so are relatively constant. Tanδ then increases with frequency. At 10kHz, Tanδ for this capacitor was measured at 0.00015 and just 0.0005 at 100kHz.

In past years capacitor quality was sometimes described as a 'Q' value, the reciprocal of Tanδ. 'Q' for the above capacitor was 20,000 at 1kHz, 6,666 at 10kHz and 2,000 at 100kHz.

Tanδ is measured using phase sensitive detectors, either by measuring the capacitor's impedance and phase angle, or the capacitor's resistive and reactive component vectors.

In which case,

$$\text{Tan}\delta = \frac{\text{resistive vector}}{\text{reactive vector.}}$$

This resistive vector is called ESR.

$$\text{ESR} = \frac{\text{Tan}\delta}{\text{reactive vector.}}$$

Obviously ESR must vary with frequency. At low frequencies, ESR reduces with frequency, up to the self-resonance of the capacitor. At self-resonance, the capacitive and inductive reactances have equal and opposite values, so cancel out. The capacitor's ESR is then equal to its measured impedance. For that frequency only, it can be measured using a signal generator and voltmeter. At higher frequencies, ESR usually increases. The abbreviation TSR, for True Series Resistance, is often used by capacitor engineers to describe this minimal value of ESR.

The LCR meter readings for ESR of the above capacitor, recorded 0.8Ω for 1kHz, 0.26Ω for 10kHz and 0.08Ω for 100kHz.

Self-inductance reduces the capacitor's measured reactance value. This means a capacitor's self inductance actually increases its measured capacitance value.

A fuller description of Tanδ together with a proven measurement circuit was included in my articles describing the construction of an in-circuit meter.[7] This meter was custom designed to identify good or bad PCB mounted electrolytic capacitors by measuring their Tanδ while in-circuit.

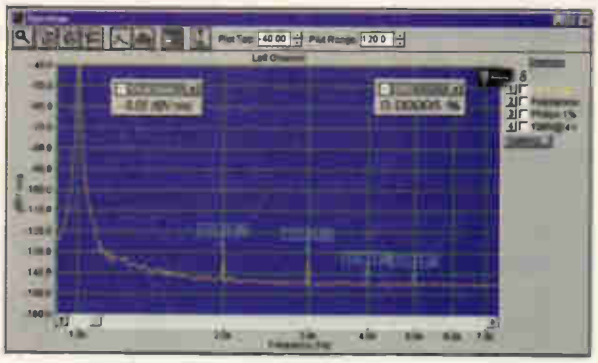


Figure 7: This now discontinued Philips extended foil/Polystyrene 1% axial lead capacitor, with 4 volt signals and 18 volt DC bias, shows negligible distortion. With test signals increased to 6 volt and DC bias to 30 volt second harmonic increased less than 4dB and distortion to 0.00007%. There was no visible intermodulation.

dielectric absorption, which increases with 'k' value.

Popular Class 2 ceramics include the X7R, W5R, BX capacitor grades and the exceptionally high 'k' Z5U. These produce extremely large measured distortions. **Fig. 6.**

Film capacitors.

Film dielectrics have smaller 'k' values, ranging from 2.2 for Polypropylene (PP) to 3.3 for Polyethylene Terephthalate (PET).[3] More significant than 'k' value is just how thin the film can be produced and used to assemble capacitors.

Perhaps the best of the easily obtained plastic film dielectrics, Polystyrene is now becoming less popular. It has an N150 temperature coefficient, a very small tanδ and the smallest dielectric absorption coefficient of all film materials. It softens around 85°C and cannot be metallised or used thinner than 4 microns, to manufacture capacitors. **Fig.** 7.

For years it was wound with solderable soft metal electrodes, producing vast quantities of 1% tolerance, high quality capacitors, with values up to several μF.

All other popular film dielectrics can be metallised. They can be used to produce small, low cost, metallised film capacitors having a limited current handling ability. Alternately, using the superior foil and film assembly to produce larger and higher cost capacitors for the same value and voltage. Foil and film capacitors survive larger

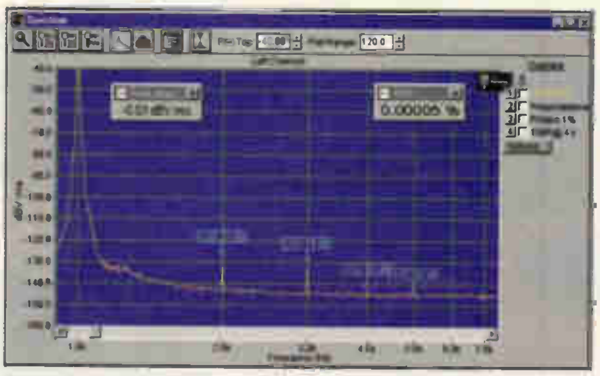


Figure 8: The makers replacement extended foil/Polypropylene shows the same 0.00005% distortion but second harmonic is 1dB worse. With test signals increased to 6 volts and DC bias to 30 volts second harmonic increased just over 5dB, distortion to 0.00008%. Again, no visible intermodulation.

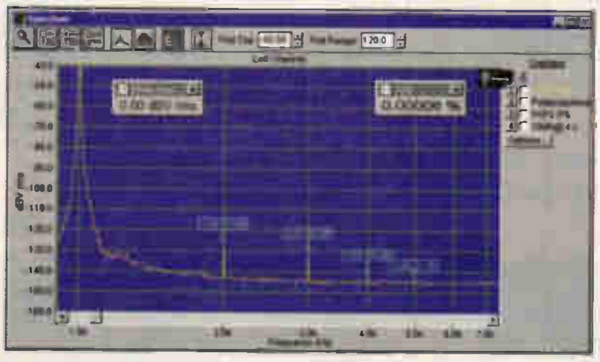


Figure 9: The small Wima FKP2 foil/Polypropylene capacitor shows similar performance except for 2dB increased second harmonic. Distortion just 0.00008% with 6 volts stimulus and 30 volts DC bias.

Table 1

Correction Table for 1 volt at 1kHz distortion measurements.

Frequency (Hz)	Value (dB)	Frequency (Hz)	Value dB	Frequency (Hz)	Value dB
100	-14.0	1005	-24.45	2100	40.0
200	-3.2	1010	-24.0	2200	40.0
300	3.3	1050	-10.0	2500	39.8
400	6.0	1100	8.2	3000	39.65
500	8.0	1200	16.2	4000	39.9
600	9.0	1300	21.4	5000	40.2
700	9.0	1400	25.6	6000	40.3
800	7.6	1500	29.2	7000	40.2
900	3.5	1600	32.4	8000	39.6
950	-10.0	1700	35.2	9000	38.7
990	-24.0	1800	37.25	10000	37.2
995	-24.45	1900	38.8	11000	`36.0
1000	-24.45	2000	39.6		

AC currents, than metallised film types.

Metallised film capacitors rely on 'self-healing' to 'clear' minor insulation faults, so can be assembled using very thin films, their metallised electrodes adding almost no thickness. Capacitance is inversely proportional to dielectric thickness, so they provide a large capacitance in a small package. Conversely, foil and film capacitors cannot self-heal, so they must be made using film of sufficient thickness to withstand the required voltage without self-healing and being wound with metal foil electrodes.

PET has very high tensile and voltage strengths and is easily metallised. Film thinner than one micron can be used in 50 volt capacitors. It is polar with 0.5% dielectric absorption and a relatively high 0.5% tanδ. Capacitance and tand are strongly temperature and frequency dependant and with up to 3% capacitance change in two years, it has poor long term stability. A metallised PET capacitor rated for 100 volt may use film perhaps one micron thick. A foil and film PET capacitor might be made using five micron thick film. With five times the volts/micron stress, we measure more distortion with the metallised film type.

In contrast, non-polar PP, has a very small dielectric absorption of 0.01% and a low tand of 0.03%. It has less tensile strength and is much more difficult to metallise. Assembling capacitors using PP film thinner than 4 micron is difficult, so PP is best suited to producing higher voltage capacitors. With dielectric losses only slighter higher than C0G ceramic or Polystyrene and usable to 105°C, PP can provide large capacitance high voltage capacitors, suited for use on AC or DC. Since its introduction more than 30 years ago, it has produced the most reliable capacitors used in the high stress line-scan circuits of domestic TV receivers. PP is one of the most efficient, low loss dielectrics.

Capacitor connections.

For the best, undistorted sound, dielectric choice is obviously all-important. But using the best dielectric materials does not guarantee a non-distorting capacitor. A poor dielectric principally influences the levels of the second and even harmonics produced by the capacitor. An internal non-ohmic connection in the capacitor however, introduces significant levels of odd harmonics, the third having the biggest amplitude.[4]

Disc ceramics use solder connections to a sintered, usually silver, electrode. Multilayer ceramics mostly use precious metal sintered end termination, with soldered wire leads. I have not found ceramic capacitors with non-ohmic end connections. All Class 1 ceramics I measured, have produced negligible and mostly second harmonic, distortions.

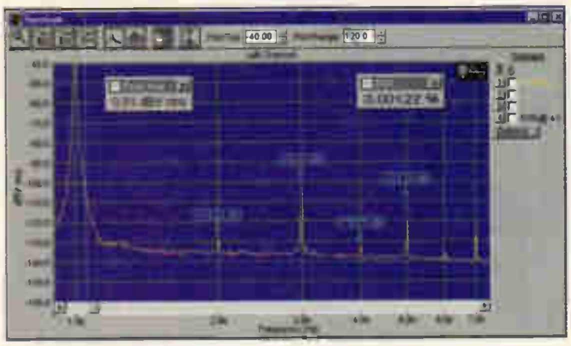


Figure 10: Despite cleaning and re-tinning its oxidised lead out wires, this 1nF Mica capacitor, tested using 1kHz only at 4 volts and no bias, clearly has an internal non-ohmic connection problem.

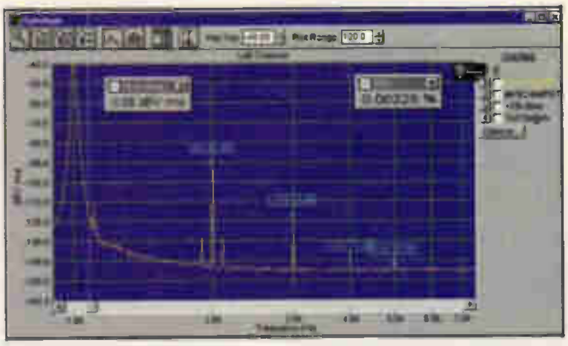


Figure 11: Tested with no bias, this 0.1mF MKS2 metallised PET capacitor measured 0.00016% with clearly visible intermodulation products. With 18 volts DC bias, the second harmonic increased dramatically, from -119.0dB to -92.9dB and harmonic distortion to 0.00225%.

From research carried out in Sweden by the Ericsson Company, a non-ohmic connection can exist in film capacitors. All metallised film and many foil and film capacitors use a 'Schoop' metal spray end connection to connect the capacitor electrodes to the lead-out wires.

I have measured many metallised film capacitors having very large third harmonic levels, frequently as much as +20dB higher than others in the same batch. I have not found this problem when foil electrodes are used with the same dielectric.

To avoid any possibility of a non-ohmic end connection we could use a solderable, soft metal foil electrode and solder it directly to the lead out wires. This is exactly the time proven assembly used by a large maker of extended foil/Polystyrene (PS) capacitors. It produces a near perfect, non-distorting, capacitor. Fig. 7.

Unfortunately, few manufacturers still make PS capacitors and many have changed their production over to extended foil/PP, retaining the soldered end connections.

Polystyrene dielectric has almost unequalled electrical properties but softens at low temperatures, so cannot be flow soldered into a circuit board. It is also attacked by many solvents, so boards with unprotected capacitors are not easily cleaned.

Self Inductance.

Each electrode turn of an extended foil or metallised film capacitor, is short circuited to every other turn, so contributes almost no self-inductance. Self-inductance of a capacitor body is then less than its equivalent length of lead wire. These capacitors have almost no self-inductance, apart from the 7nH per cm of the lead wires used to connect them into circuit.

By way of interest, I measured the resonant frequency of a 10nF 'Tombstone' capacitor.[5] A vertical mounting, extended foil, axial wound capacitor. This construction has a small footprint but increased inductance due to its one extended lead out wire. The self-resonance frequency was above 10MHz. At audio frequencies, such small self-inductances are clearly unimportant.

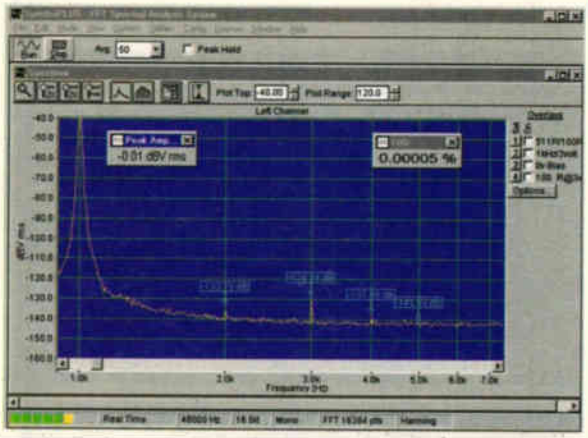


Figure 12: The Plus232 software shows a green then yellow signal strength meter, bottom left, changing dramatically to red at the soundcard overload level. My 'standard' measurement settings can be seen. Loaded with a 511Ω resistor, all harmonics are well below 0.5 ppm distortion.

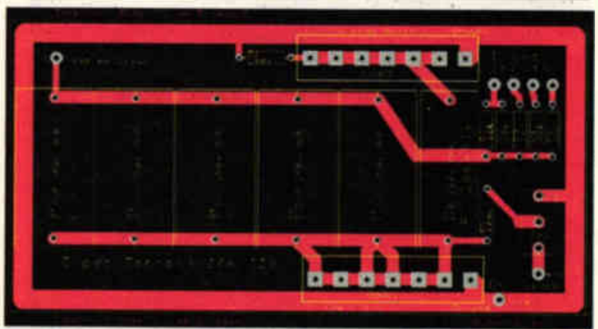


Figure 13: The 110 x 55 mm single sided PCB used to assemble Figure 3, the 1kHz DC blocking buffer network.

Low distortion choice.

For the lowest distortion I still prefer PS, however from my measurements, it proved almost impossible to distinguish between an extended foil/PS and a similarly made foil/PP capacitor. Apart from small increases in second harmonic, measured for the PP versions. Both types are easily available from mainstream distributors in values up to 10nF. **Fig. 7, Fig. 8.**

For low distortion capacitors up to 10nF, my personal choices would be C0G ceramic, perhaps also including discs up to N750, extended foil/PS or extended foil/PP, with the lead out wires soldered to the electrodes. **Fig. 9.**

Alternative capacitors.

Perhaps because of size, price, temperature range or voltage, the above small selection is not suitable. Stacked Mica is still available, but from my tests can be variable. I have some which are at least thirty years old with almost no measurable distortion. However, a small batch of 1nF, purchased specially for these measurements, distorted badly. One sample was even unstable, showing significant and variable third harmonic. **Fig. 10.**

I have measured very low distortions with Wima FKC2 foil and Polycarbonate capacitors. Bayer has discontinued production of Makrolon Polycarbonate film, so FKC2 capacitor production may cease. No doubt because of the thicker PET film used, I have measured surprisingly low distortion when testing Wima 10nF 100 volt FKS2 foil and PET capacitors. Results were almost as good as the FKP2 foil and PP of Figure 8. Tested with 30 volt DC bias, second harmonic distortion was only 2dB worse than for the PP capacitor. Unfortunately, this FKS2 style is not available in bigger values.

Having measured several hundred metallised PET capacitors, I have found many with extremely low distortions when measured without DC bias. I have also found far too many showing very bad distortions, with and without DC bias. **Fig. 11.**

For capacitances up to 10nF, low distortion, low cost capacitors are easily available, so I would avoid using metallised PET capacitors. For capacitance values above 10nF, the near perfect C0G, foil/PS and foil/PP types are not easily available. Our best options for capacitance values from 10nF to 1µF will form the subject of my next article.

Two further articles will then extend our distortion measurements to 100µF electrolytic, exploring our best options for these values. ■

Technical Support

Interested readers are free to build a system for personal use or educational use in schools and colleges. Commercial users or replicators should first contact the author.

A professionally produced set of three printed circuit boards is available for the 1kHz low distortion signal generator, the 1kHz low output impedance buffer amplifier/notch filter/pre-amplifier and the 1kHz DC bias buffer network. This set of three boards provides a complete 'with DC bias, single frequency, distortion test system'.

Supplied with component parts lists and assembly/usage notes, these single sided FR4 boards have solder resist and component legends. The set of three boards costs £32.50.

Post/packing to UK address £2.50.
Post/packing to EU address £3.50, rest of world £5.00.

Please send Postal Orders or Cheques, for pounds sterling only, to C.Bateman. 'Nimrod' New Road. ACLE. Norfolk NR13 3BD.

References.

1 Capacitor Sound parts 1&2 C. BatemanEW July/September 2002.
2 BC Components 0.47+0.47µF 250 volt type 376 KP. Farnell part 577-881
3 Film Capacitors 2000. Evox Rifa AB. Kalmar. Sweden.
4 Harmonic testing pinpoints passive component flaws. V. Peterson & Per-Olof Harris. Electronics July 11, 1966.
5 High-frequency impedance meter. C. Bateman. EW January 2001.
6 Spectra 232Plus FFT software.www.telebyte.com/pioneer
7 Check C's in situ. C. Bateman. EW May/June 1999

Budget T&M on a PC

Mention of audio cables elicits strong feelings in some quarters, huge yawns in others. Perhaps he needs to get out more, but Richard Black feels a strange fascination with the subject.

About 20 years ago a friend first demonstrated 'cable sound' to me, and ever since I have fondly believed I can hear differences between cables - both loudspeaker cables and small-signal interconnects. Millions of audiophiles across the world agree, and yet there has, to the best of my knowledge, been no convincing proof that the signal coming out of the end of Cable A is in any significant way different (within the audio band) from what comes out of Cable B given the same upstream equipment.

Several people have tried, notably Ben Duncan, whose measurements (published variously in Electronics World, Studio Sound and Stereophile) looked initially intriguing. What he claimed to have shown was variations in 'overhang' as a sinusoidal signal was gated off. Overlooking the fact that the gating, being of a transient nature, produces overtones into the stratosphere, what he actually measured was variations in the damping factor of the driving amplifier-plus-cable combination. On cutting off the signal, the loudspeaker continued to move mechanically, generating an EMF, which was damped by the low but finite impedance of the amplifier's output in series with the impedance of the cable. No surprise, then, that the higher resistance and inductance cables showed more 'overhang', and

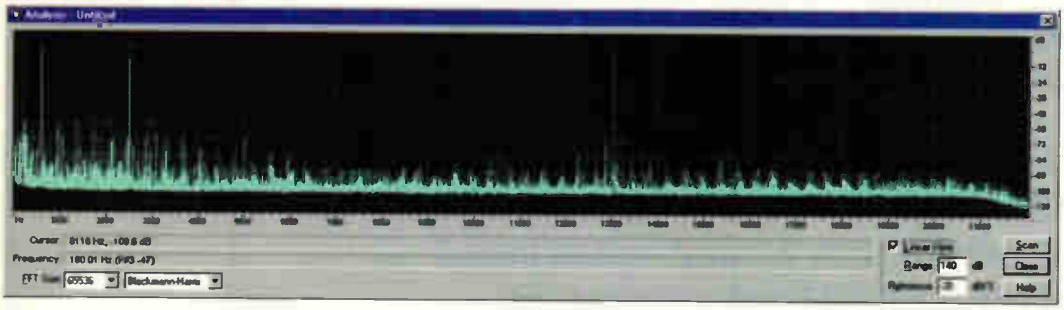


Figure 1: Spectrum at speaker terminals with Goertz M1 cable in circuit.

Cable cobblers

Many manufacturers of audio cable have a serious foot-in-mouth problem. Sales literature and 'white papers' abound with some quite remarkable claims and assertions. Here are some particularly choice brief quotes, picked from relatively recent material from various sources, mostly sales material but in one case even a patent application. I make no comment!

1 Values of capacitance and inductance, clearly stated, which taken together must imply a speed of signal propagation in the cable greater than the speed of light.

2 The return, negative or cold conductor is greater in overall cross sectional area and mass than the signal, positive or hot conductor, based on a specific ratio that balances the flow of electrons, enhances electron movement and as a result improves signal transmission.'

3 'The self-inductive related rising impedance of the conductors, sometimes referred to as the 'skin-effect'...'

4 '[our] cables .... are designed to have the lowest LCR specs and widest bandwidth on the market.'

5 'Second, the outer 'shield' is the most significant reason why the capacitance (C) and series inductance (Ls) of a 'coax' system is high and hard to reduce.'

6 'Without a proper inductive component, current cannot be stored....'

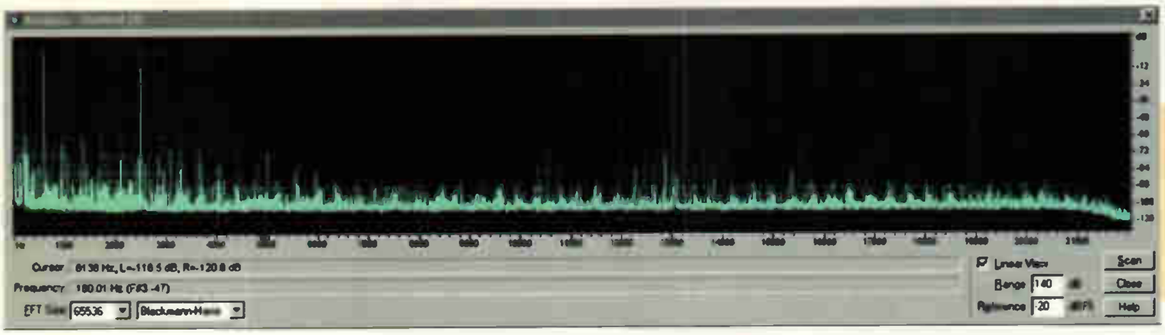


Figure 2: As Fig. 1, with Supra Ply 3.4 in circuit.

ultimately the tests did nothing but measure, by a roundabout route, the series impedance of the cable.

Even earlier, Malcolm Hawksford produced several fascinating and rather daunting technical articles in Hi-Fi News which examined audio cables from a theoretical standpoint. Unfortunately, he didn't produce much in the way of measured evidence and what little there was proved nothing more than that signals travel through cables at a finite speed (typically 0.65c), which we all knew anyway - though it's surprising at first to discover how easy it is to prove that at only 20kHz.

In the circumstances it's been easy for those who wish to rubbish cable sound to do so in print, aided not least by some of the astonishing claims made by cable manufacturers (see box). But I've always had a desire to find some kind of mechanism that can plausibly explain audible differences between cables (or perhaps comprehensively to disprove it) and the test procedures outlined in the first and second articles in this series arose from my most recent attempt. Even if you are not the least interested in audio cables, the following example shows quite nicely how one can go rooting around in a test signal for clues, using a bit of audio-based software as the analysis and processing tool.

Differences between cables?

It's trivial to prove that different loudspeaker cables give slightly different frequency responses between a given amplifier and speaker and a small difference in overall level too. Typically one might be looking at differences in the order of 0.5dB overall, plus another 0.5dB at 20kHz of HF droop, between a low-resistance, low-inductance cable and some cheap generic figure-8 flex. Under ideal conditions those changes will probably prove just about audible. But not only are the alleged sonic differences between cables greater in extent (and different in kind, arguably) than 'mere' level and frequency response shifts, it is claimed that clearly audible differences exist between cables with much closer electrical parameters.

If that's true, it surely makes sense to look for some kind of non-linear distortion mechanism, since our aural sensitivity to that is orders of magnitude greater than to level shifts, etc. Various people have proposed theoretical bases for such distortion in cables, ranging from rectification effects at crystal boundaries to the destabilising effect of the cable's shunt capacitance on the feedback loop within the amplifier driving it. Again, none of these is proven (OK, the latter is obvious in extreme cases) but that's no reason not to try!

It is fairly simple to look for non-linear distortion, since it implies that the output of the distorting device will in general contain frequencies not present at the input. It was for this reason that I wished to develop quite sensitive, yet cheap and repeatable, tests for multitone intermodulation which would readily show up any non-linear distortion within the audio band caused by cables.

Since the amplifier used in the test was bound to have distortion of its own and its interaction with the cable is certainly of interest, it seemed most sensible to perform the tests so as to compare cables. Run the test with one cable, change to another, repeat the test and compare the results. Any change in distortion spectrum could indicate that the cable is indeed having an effect.

Basic test setup

The test set-up is very simple. I prepared a CD with four digitally generated (effectively distortion-free) sinusoids, not harmonically related: their frequencies were in fact 180Hz, 590Hz, 2500Hz and 13035Hz. This was played through a Rotel CD player and an EAR (valve) amplifier, driving an ATC SCM20 loudspeaker via the cable under test. A lead connected to the speaker terminals led to a Marantz professional CD recorder that logged the signal over several seconds.

In the hope of making things fairly obvious, I started with two very different speaker cables: Goertz M1 and Supra Ply 3.4. The Goertz has very high capacitance/low inductance, the Supra quite low capacitance/high inductance, and both have low series resistance. The spectrum of each is shown in **Figs 1** and **2**. Each is an average over 8 seconds, with an FFT length of 65536 samples.

Each spectrum shows an array of distortion products, along with the stimulus frequencies, due to CD player and amplifier. But differences between the two? Next to nothing. Every distortion spike in one spectrum is there in the other, give or take at most a dB of level, and that's over a good 100dB of dynamic range.

Focusing

As discussed in my second article, it is possible to zoom in on a frequency range by means of filtering and modulation. Because it seems likely that any distortion effects due to cables should be more noticeable at high frequencies, let's examine the range around the top stimulus frequency. First, bandpass filter a narrow band, say 12.5kHz to 13.5kHz, using Cool Edit's FFT Filter with an FFT length of 24000 samples. It's a good idea to convert to 32-bit samples before doing this, so that at least the processing introduces no more noise. Then modulate by a 12.5kHz sinusoid using Cool Edit's 'Generate Tones' function. This produces a 1kHz-wide spectrum starting at 0Hz, with no increase in actual resolution but a big increase in viewable resolution using the log scaling in the frequency analysis window, **Figs 3** and **4**. The little

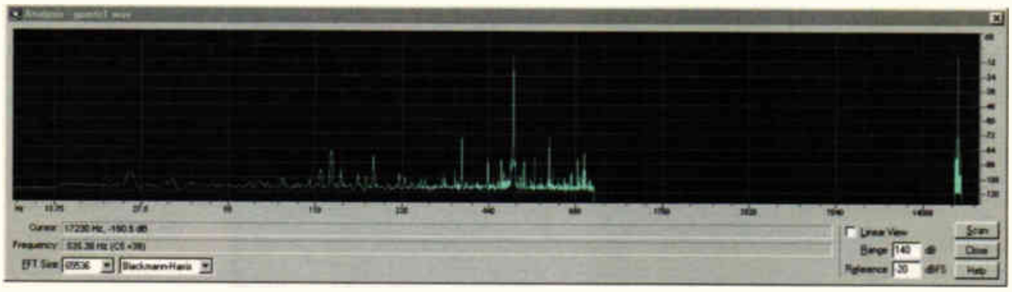


Figure 3: More detailed display of frequencies around the 13035Hz tone, Goertz.

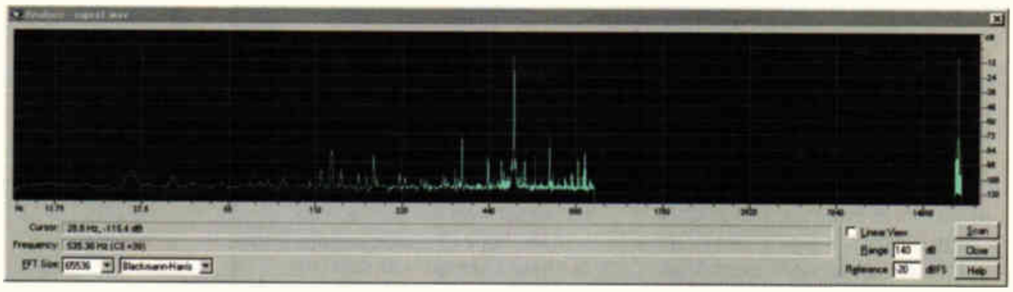


Figure 4: As Fig. 3, Supra.

outcrop of frequencies around 19kHz is the other sideband produced by modulation, which one can easily filter off by using the FFT Filter again, as a lowpass.

As you'll notice, there's still no difference - though the very consistency of the spectra proves the power of this analysis technique, resolving details at least 120dB below the overall signal level. Repeating the bandpass filter/modulate process to narrow the band to 100Hz seems to get us no further. To increase the usable resolution still further, I compressed the waveforms to one-fifth their original length, raising all frequencies by a factor of 5. As **Figs** 5 and 6 show, there's still little to choose between them, a couple of dB or so between high-order intermodulation products offset a few Hz from the original stimulus. It's hard to believe that any of this constitutes an audible difference.

The next line of attack is to subtract one signal from another. In a slight variation of the test, I added a two-sample pulse to the 4 sinusoids every 10 seconds as a marker, so that they can be synchronised after the test. Unfortunately the recorder is not running in sample synch with the CD player, so the trick is to up-sample to the maximum Cool Edit will support (2MHz), synchronise to the nearest 250ns and subtract one from the other. Having located (by ear is easiest) the clicks, copy one second or so of the signal from one cable, starting a few samples before the click.

Create a new blank audio file of the appropriate sample rate (44.1kHz if you've recorded with a CD recorder) and 32-bit depth, and paste the section you've copied to the left-hand channel. Copy a similar second-long bit of the second cable's signal and paste it to the right-hand channel. From the 'Analyse' menu choose 'Statistics' to see how the levels compare, and equalise them as well as possible (Cool Edit allows level adjustment to 0.01dB). Now, using the 'convert sample type' option from the Edit menu, up-sample to 2MS/s, 32-bit. Set the 'quality' slider to 100 or so since there's little danger of aliasing.

Zooming in to high resolution, one can easily determine how much to delay which channel by so that they line up nicely. One neat way to do this is to set displayed time format to samples (right-click on the Cool Edit time axis bar) and select the audio between two supposedly synchronised points such as zero-crossings. You can then read out the exact delay required directly. Measure a few points and average them to the nearest whole sample. After delaying, use the Channel Mixer to subtract one channel from the other. Resample to 44.1kHz since the higher sample rate is no longer any use, and look at the spectrum, **Fig. 7**. The stimulus frequencies are nulled by 30-50dB, which seems reasonable, but not all the distortion peaks are well nulled. A clue?

For a start, several of those peaks turn out to be mains harmonics which being in random phase relative to the stimulus will not null. But what of the patch around 1750Hz? Return to the original files, bandpass around 1750Hz, modulate by a nearby frequency: nearly identical spectra but presumably slightly shifted in phase, hence the failure to null. In other words, almost certainly not significant once again.

Tests with a couple of other cables produced similar results, as did high-resolution examination of other narrow portions of the spectrum.

Still no luck

This is quite a powerful test that should show up very small differences between cables, and all it has provided is evidence of level shifts, small frequency-response

Figure 5: Even more detailed display, with offsets magnified by a factor of 5, Goertz.

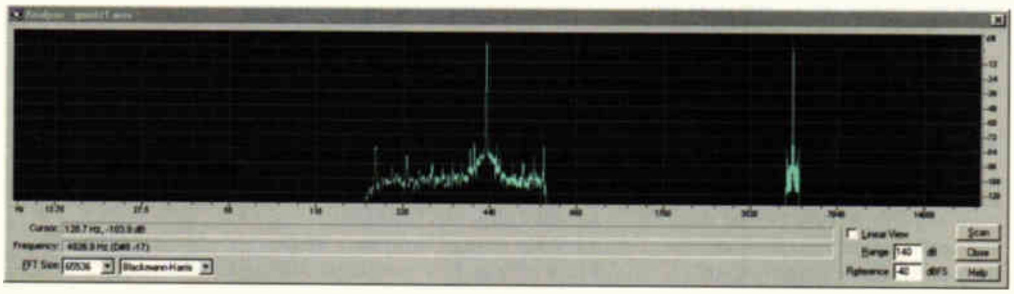
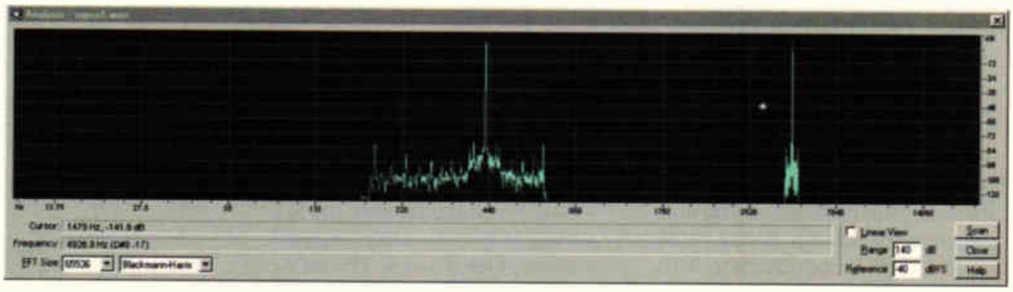


Figure 6: As Fig. 5, Supra.



shifts and phase shifts, none the least bit surprising based on the most rudimentary LCR analysis of the situation and none strong candidates for audible differences.

It is easy to advance hand-waving arguments about distortions that won't show up on test with 'steady-state' signals, or that won't show up as a voltage across the speaker terminals. None that I have seen will stand up to scrutiny, though. No, audio does not consist of pure sinusoids but given arbitrary constraints in time one can represent it to arbitrary accuracy by sinusoids and it's a very well-proven system. As for signals not showing up, why shouldn't they? Impedances are finite everywhere, so any current circulating will produce a voltage and vice versa. Even distortions due to noise pickup on the cables must eventually manifest as an AF voltage if they are to produce audible effects. I did actually try repeating the measurement with a microphone capturing the acoustical output of the speaker while it was driven through different cables, but as one would expect background noises were too high to allow really high resolution analysis.

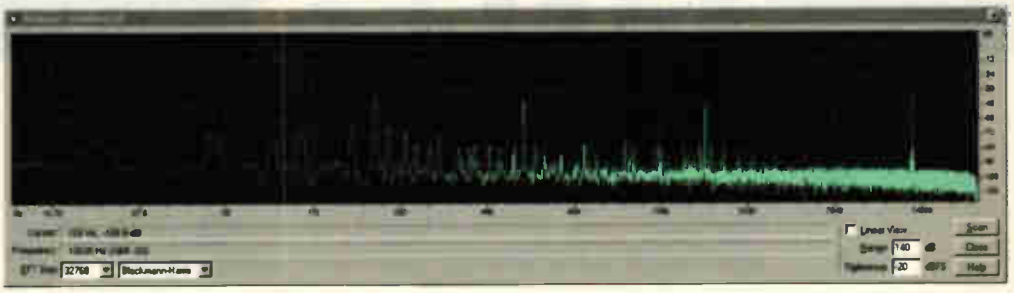


Figure 7: Spectrum of the difference between the signals via Goertz and via Supra, nulled within 250ns and 0.01dB overall level.

It does start to look as if cable audibility comes down to a combination of level and frequency response changes and suggestibility (which is most certainly a strong factor in hi-fi comparisons). Lots of tests have been done on human sensitivity to those, and to phase shifts, which tend to suggest that cable changes should introduce only borderline-audible changes at most. However, the most sensitive tests I can think up so far show no evidence for any non-linear distortion. ■

References

Ben Duncan, Loudspeaker Cables, Case Proven, Proc. The Institute of Acoustics, UK, Nov '95: also published in Studio Sound (UK); and Stereophile (USA) - both Dec '95.

Ben Duncan, Modelling Cable, Electronics World (UK), Feb '96.

Ben Duncan, Measuring Speaker Cable Differences, Electronics World (UK), June/July '96.

Malcolm Omar, Mawksford, The Essex Echo, Hi-Fi News, Aug '85: Aug & Oct '86 & Feb '87.

Fred E. Davis, Effects of Cable, Loudspeakers & Amplifier Interactions, JAES, June '91.

LETTERS
to the editor

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

Storm scope

I enjoyed reading Joe Carr's article on lightning in the July 2002 issue of Electronics World. The "Storm Scope" described in the article looks like a very interesting device for monitoring lightning discharges at a distance. However, I wish to correct one statement in this article.

Mr. Carr seems to indicate that when Benjamin Franklin performed his kite experiment, a bolt of lightning struck the kite. This is a commonly held belief, which I have seen stated in several books. Franklin's survival of this event is usually attributed to his use of a dry silk ribbon to insulate him from the lightning discharge.

However, historical accounts of the kite experiment do not describe an actual lightning strike. The best accounts are a general description of a kite experiment by Franklin himself, and a description of Franklin's actual experiment, written by Joseph Priestly, read in manuscript by Franklin, and presumably verified by him[1]. The kite had a "sharp pointed wire" attached, and the kite was to be flown "when a thunder-gust appears to be coming on." The pointed wire collects the static charge of a thundercloud without actually being struck by lightning. The purpose of the dry silk ribbon is to insulate the kite string from the person holding the kite, so that the electric charge can accumulate on the kite and string, and not immediately discharge to ground.

Priestly describes Franklin seeing the loose filaments of the kite string sticking out as they became charged and repelled one another. Franklin then produced an electric spark by bringing his knuckle near the metal key attached to the string. Clearly this is a case of a static charge building up on the kite and string, rather than a terawatt of power flowing through the apparatus.

The distinction between a build-up of static charge on the kite and an actual lightning strike is important, and not just for historical accuracy. One must realise that the reason Benjamin Franklin was not harmed in the kite experiment was not because of the electrical insulation of the silk ribbon. It is doubtful that the ribbon would have provided any significant protection if the kite had been struck. He survived because he was fortunate that the kite was never struck by lightning. He avoided a strike by flying the kite before there were actual lightning strikes in the vicinity. However, lightning is unpredictable, and he could easily have been killed, like others who attempted this experiment.

Although Mr. Carr's article clearly emphasises the danger, I fear that many of the other accounts of this famous experiment inadvertently downplay the danger by misrepresenting the role of the silk ribbon, and by claiming that the kite was actually struck by lightning. The kite experiment was pioneering, and important in the development of modern electrical theory, but there is no need to repeat it in the twenty-first century. And, as Mr. Carr points out, there is certainly no justification for the risk involved.

Joe Borrello
Portage, Michigan, U.S.A.

Ref 1: Van Doren, C., "Benjamin Franklin", The Viking Press, New York, 1938, p. 164-166.

EMC

I have been reading the piece on EMC (EW August.) What a muddle of ideas I read. I have worked in many areas of electronics, and have had to deal with EMC issues on several occasions. Star earthing is a vital tool in solving many situations. In audio amplifiers it gets round many earth loop problems. In RF it is a different story where ground planes are much used. In power engineering Star earthing can be a lifesaver. I know there are some occasions were it may cause problems, but these are very rare.

The basic idea, as most readers will know, is to limit separate earth currents from interacting, and causing noise to be spread around the circuit. The problem is that it is often misunderstood as to just how this really works. It can be explained in terms of a power amplifier were there are two parts the low power input, and the much higher power out put stage. In order to prevent unwanted modulation of the low power input stage by the high power output stage. Separate supply lines should be used with a star earthing arrangement to prevent the re-circulation of ground currents. A ground plane here would be a good way to produce much hum.

Balanced plus/minus power rails also help to eliminate noise. Screening is also useful, if it is clearly understood just what is being screened out. Not all metals are of use in killing unwanted noise and several different means may be required to solve all the problems encountered in modern circuits. Stray circuit capacitance, or inductance can be a very difficult problem to cure.

Several years ago I was working for a then well known electronics test equipment manufacturer. They were part of what was then GEC. Because work was scarce they took on an order for traffic control systems including the Pelican system. These units were being assembled and wired when a young charge hand decided it would be quicker and look neater if the wiring was put into a nice loom rather than a point-to-point assembly. So several dozen of these were made up and fitted. The testers were surprised to find that the previously working units were now reporting strange errors. The upshot of this was that signals that had been posing without coupling now had plenty of way to do this. The units had to be completely rewired as before on a point-to-point basis. This shows that neat wiring does not always mean good wiring. It nearly scuppered the whole order because of the extra time it took to change the wiring back to the correct layout. It can be that what looks wrong is in fact correct, I know from experience you can't always improve on an idea. The wheel still works rather well for me.

Ian Johnson
By email

Here's a recollection to add to the July 2002 article by Joe Carr on "Observing Lightning". I grew up in Drumheller, Alberta, Canada in the

1950s and the closest AM radio station was in Calgary about 100 miles away. Drumheller is in a deep valley and to get better reception on my poor performing cat whisker crystal set I decided to build a bigger antenna. I had over a 1000 feet of No. 20 shot wire left by an oil seismic exploration crew and decided to use it to for an antenna going up the side of a hill. I used a post-hole auger to drill about 7 holes and installed some 10-foot poles using the finger hole of inverted glass wine jugs for insulators. My hobby space shared the basement with the coal furnace. I installed the antenna leading along a floor joist and brought a ground wire in along an adjacent floor joist that were on 16-inch centres. The crystal set worked much better on the long antenna and my attempts to improve it included making a bigger coil that took me below the BC band. I started listening to modulated CW aircraft beacons. As summer storms approached I could hear weird, strange whistling sounds and assumed that these sounds had something to do with the storm. Many times the noises were so loud that they and the static crashes were hard on the ears so I'd leave the basement. One afternoon my mother went into the dark basement and immediately came running out yelling that my apparatus was going to start the house on fire. I went to investigate and saw sparks jumping between the feed and ground wires. The parallel wires 16 inches apart were insulated but the charge was strong enough to break through and make a colourful display in the dark basement for the entire length of about 20 feet. My mother insisted that I stop the sparking before the house caught on fire. I grounded the antenna lead and my mother was satisfied but a few days later when my dad saw the sparks I had to take the antenna down. That led me to make a regenerative receiver that worked well with my 25 foot stub antenna. The article has rekindled my interest and I think I'll build some VLF equipment and listen but with a shorter antenna unless I can find a nice hill and a dark basement.

73

Henry Kolesnik

WD5JFR Tulsa, Okalahoma, USA.

Your thoughts

I thought I would e-mail you after reading your comment on "reader enthusiasm" in the September 2002 edition of EW.

I would like to see more circuits and articles in the area of microprocessing, and micro controllers, this seems to be the current area of electronics and one that personally interests me. I've started to program PIC Micro controllers and am fascinated by their capabilities.

You may be interested to know that I am only 15 years old, and have been reading EW for a bit over a year now. Although it has progressed over time with a few more micro controller circuits, but they are not very frequently occurring.

Danny Schofield

By email

I am quite anxious about the future of EW as it is the only remaining Electronics magazine worth reading: full of original articles and ideas and innovative projects (I'm mainly interested in audio and analogue circuits).

Considering the August issue, I was disappointed that the name of some authors was omitted, that the second part of C. Bateman's distortion meter was not present and the Tony Meacock's circuit idea was already published in the previous issue.

I also have a request - more than twenty years ago, P.J. Baxandall started a series on the design of power amplifiers in the then called EWWW.

Six parts were published but the series was never finished. I would love to read the remaining parts if they were written.

Sébastien Veyrin-Forrer

France

Do any readers know the answer? - Ed

I've noticed in the last couple of months that something like 50% of authors' names have disappeared from their Electronics World articles - it's necessary to refer back to the index page to get this information. Is this intentional? If so, it's not helpful, particularly when it comes to 'selective archiving' of past articles of special interest.

Otherwise, keep up the good work.

Joe Graham.

By email.

My fault entirely - Ed

Just read your editiorial for September issue. Am now worried as to where the mag may be going. Been reading the thing for 33 years now and have watched on as it has changed form, content (and spine thickness), during this time. From what you are suggesting as a potential new direction, I can see the mag resetting itself to a situation about 6-7 years ago when I stopped buying it.

I'm a freelance electronics design engineer who lives and breathes the subject. In 33 years I've never met another reader of the mag, yet I'd be willing bet money that most of your readers (who pay cash for it), are of similar motivation.

What I want to see in it, is electronics, electronics and yet more electronics.

"Computer articles, small networks, software reviews, enabling technologies, digital imaging, video and audio compression, Bluetooth, Lans" etc, are not 'electronics'. They are purely the guff of marketing departments and programming companies. I'd also include WAP, mobile phones, the internet, connectivity, multi-media, broadband, switching power supplies, digital busses, ASICs, PLAs, Digital and terrestrial TV, 'personality' interviews, any marketing department press releases and unfortunately, "Tackling interference problems on 433.92MHz" and "Spectrum pricing's uncertain future".

I want to see stuff from the likes of Ian Hickman, Cyril Bateman Doug Self etc. I want to be amazed as to what Kamil Kraus can do with a single op-amp a C and an R. I want to see lots and lots of circuit ideas and readers letters. I'd like to see some general technical comment from masters of the art. I'd like to read discussion of the technical fine details of classic test and instrumentation kit. Articles on oddball aspects of some unusual circuit arrangements. Some of the interesting historical aspects of our industry. More of the weird science stuff and a lot on product design philosophy. Some items on 'neat' methods of getting a particular

Spring conundrum

Can you help me - I keep having a nightmare where I am bouncing on a spring mattress and my thoughts are rather over the top for a man of 77 years who has read Wireless/Electronics World for around 60 of them. The mattress has sets of two springs connected by string with the separate springs slackly restrained with further strings.

I am worried that if I bounce up and down too much and the connection string breaks, will I shoot through the ceiling or be smothered in a collapsed mattress and I hate to think what would happen if the restraining strings also break.

Or alternatively would Hot Electron tell me the answer to his spring conundrum (July White Noise). I calculate that the springs P & 0 are originally in series but if the string X is cut they would be in parallel and the weight would go up - No! Too easy. Well, it seems to depend on several variables so back to the mattress.

N.L.Smith

Stoke-on-Trent, UK.

result and some case studies of equipment design.

I want to be educated and informed in all things electronic and not feel I'm being patronised by some moronic marketing gobshite.

If you move in the direction you have indicated then yes! the advertisement revenue will return, yes! the mag's financial future will be more secure. It will never ever gain the respect of Wireless World as was. It will never be mentioned as a point of reference. It will never reside in the pocket of bright-eyed young engineers as they make their way in the world. It will be just yet another glossy, trade, advertising mag. An accountant's revenue stream or business resource? Electronics people like me will not be paying cash for it, nor will any electronics authors be writing material for it.

The reason the electronics publishing world is falling apart in the U.K and has been for many years now, is that no one (especially young 'uns) is any longer interested in making the effort to acquire the considerable body of knowledge and skills needed to earn a decent living in this particular industry. Why bother when the trivial effort involved in web site design, or the media or money markets etc, brings vastly greater reward? It's a cultural problem with no particular end in sight. Just look at the endless queues of wannabee's for the 'pop idol' series. From Electronics World's POV and in line with no doubt, its accountant's driving for financial return. I reckon it should be aiming itself precisely at those readers who have stuck with it for god knows however many years.

Ask 'em how long they've been reading it and why. You'll find most of 'em are born engineers who are compelled to read it just like smokers are addicted to the weed. Remove the nicotine and you will not be selling the product.

The captive market of existing and incoming electronics enthusiasts will still be reading something of general value. Let it be EW.

To hell with the accountants! Take the risk! Aim for a reverence and respect within the real electronics industry. God knows we need something to point to. (Not the transient flim flam of the marketing world). Grab the real engineering people and hold them. They'll see you through thick and thin year in and year out. The book world has "The art of electronics" the mag world has zilch. Wireless World lost it when it started to take the trade shilling. Don't send EW further down that same path.

Personally the only mags that have ever really caught my attention have been the first few issues of 'ETI'. most of the 'Electronic Engineerings' and WW's from the sixties and every single priceless issue of the 'Ambit International' house magazine run by Bill Poel.

The biggest most significant and improving change that can be quickly made to the present mag is to get all those shite, amateurish, author? supplied circuit diagrams, redrawn into a pleasing, uniquely styled, EW standard format. (Costs £ though!).

John Jardine.
By email

It certanly does cost - but I'll see what I can do. - Ed

It's good to know from your Electronics World editorial that you're employed in the electronics industry!

Just a little feedback: the readership of Wireless/Electronics World has dropped from 60,000 copies per month twenty years ago to something like 15-20,000 now. The editorial department twenty years ago was a half-dozen strong, including technical editorial assistants and layout designers.

Electronics applications have blossomed during the last twenty years, so why the factor of 3 or 4 decrease in readership?

Competition has not increased, since the number of electronics titles then was just as plentiful as today.

It seems that successive publishers have sought to tailor the magazine to a core readership, progressively losing news-stand sales. If you ask subscribers, they will tell you that they want electronic design features. But if you ask the casual buyer in the newsagent, they will tell you that something in particular caught their attention while browsing.

What happens is that catering for a common core of readers trims off the casual browsers, and loses 40,000+ readership.

If you look back in the archives to the heyday, you will see that the magazine has become progressively more focussed on technical and theoretical topics, and has lost the wider focus.

I hope that you will try to broaden the sales pitch - if your publisher allows you - by widening the territory of Electronics World to include computer developments, wireless networking, and that old favourite - the 'build your own' series. Circuit ideas and design hints are fine fodder for the expert, but to draw in new readers and student engineers you should be publishing instalment articles on how readers can cheaply build their own modern electronics gear from components.

I reckon that 'build your own top-spec laptop with instant boot up every time' (by having the operating system in flash memory, instead of on the hard disc) would be worth a try.

Nigel Cook
By email

I would most strongly advise against going down the path of all things computer orientated. This would lead to the loss of at least one reader, myself being that one. There are plenty of other publications dealing with all things computer, whether hardware or software. Elector and EPE, to name but two. Electronics Today International failed for this very reason.

Your readership requires a good mix of electronics articles, covering everything from simple audio circuits, up to more complex RF circuits. Ok, if there is a special demand or some particular reason why computer related circuits should be included put it to the readership. They will vote with their wallets won't they?

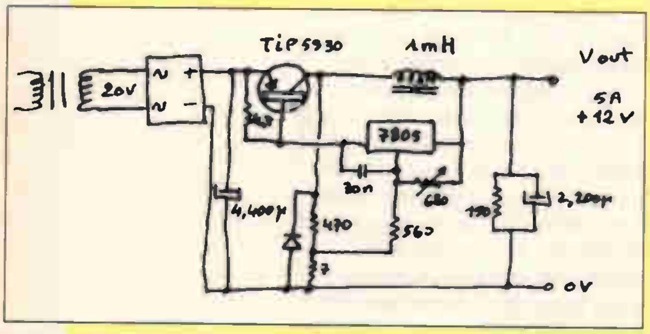
At one time far too many audio related circuits of doubtful value were published and I for one gave up buying Electronics World for about a year until it went back to a better mix of subjects.

I would like to see more on unusual electronics, or the out of the ordinary type of things, something to exercise my brain. Why follow in others

Circuit idea re-visited

Fernando Garcia's article in the December 2001 issue on hysteretic regulators reminded me of the May 1976 issue of Wireless World in which a circuit idea from V. R. Krause appeared. It contained a non-conventional use of a 7805 to realise a ripple regulator. I think that it would be worthwhile to repeat it.

Jean-Marc Brassart
Saint-Laurent-du-Var, France



footsteps when you can lead the field?

Try to keep the unnecessary pages of maths to a minimum, it fools nobody when an article is simply several pages of theoretical equations. I was never much good at this highbrow stuff.

I have always been a very practical person, developing my own circuits, in thirty years I have never built any magazine based design. The thing is they never cover my requirements. I repair electronic equipment for a living. I have most test equipment and many thousands of components.

The one thing I would like is a simple design for a good RF spectrum analyser. There have been one or two but they were far too expensive, using so special semiconductors that were very soon obsolete.

That is the crux of the matter - finding parts that will be around for more that a few months and that don't cost the earth. Well some food for thought.

As I write this a big thunder storm is nearly over head so I will have to terminate my writing here before that fateful stroke of lightening crashes over and kills this machine and me with it. Bye for now.

Ian Johnson
By email

I am very pleased with the latest editions of EW. Recently, I was talking to the owner of a electronics shop, one of very few left here in Denmark. He was complaining that so few were interested in real construction activities nowadays, so his main source of income was PC odds and ends, batteries and lamps.

I found a wealth of inspiration reading WW and its successors, and competitors like ETI and Elektor. My first issue of WW is from 1971, and I still keep it. This interest later became my livelihood, working for the audio recording industry for many years, and these days I'm designing 'High End' audio equipment for OEM manufacturers in several countries. Although I do have a very respectable set of measuring equipment, the wonders of an Audio Precision set-up is still out of my reach.

In a correspondence a while back I asked for more constructional articles and practical articles about the new inexpensive measurement and simulation techniques, within reach of so many readers with access to PC hardware.

I find that the subjects are now being treated in the present and future issues, especially delightful is the article on capacitor sound, that may well put in a sense of reality among the subjectivists - and Mr. Bateman both demonstrates the constructional ingenuity of a modern day Linsley-Hood using PC measurement and simulation, and builds a low cost high class measurement system to prove his points. I for one will be duplicating his designs as soon as possible. Please forward my respect and praise to Mr. Bateman, for writing a great many useful and entertaining articles over the later years.

And since the June 02 issue, Mr. Richard Black is taking us the budget route to advanced electronics analysis, again with inexpensive PC soft- and hardware.

A suggestion: I would very much like to see a practical article about low cost intermodulation distortion measurement using PC hardware for analysis of audio equipment. So much has been written on THD measurement, but so little about of IMD, TIM etc. Could you ask Mr. Black, please?

And Mr. Black and Mr. Bateman could perhaps work together, making a synergy of their work, if possible and a broader, more practical approach for Mr. Black? He is going through a very interesting field much too fast, surely a more in-depth approach is due?

In the past, some of your contributors have seen fit to present simulation results as the infallible gospel, along with some hand waving.

In the future, please ask them to present the simulation net lists, conditions and models on an internet site, so we all may look over their shoulder, learn from their wisdom and duplicate the result.

So now I only miss a good series of educational articles on the ins and outs of PC simulation, by someone who will cover the subject thoroughly. In the past, there have been several articles on the subject but mainly for a specific purpose. What I (and maybe others) do need is a roadmap and a progression of simulations using real world designs as the object, and demonstrating the tricks, pitfalls and advantages of such programmes.

I am aware that a great number of simulation packages at widely varying prices exist, so for the proposed series, a shareware or freeware package with schematic entry should be used as the demonstration software to allow as many readers as possible to participate.

I am certain that a commercial software vendor will jump at the chance of this kind of exposure.

While I understand that a source of income for your writers may be found in selling readymade printed circuit boards, I would very much like to see a way of downloading these layouts, for example in the form of a 300dpi windows bitmap file, or other generic graphic format that will allow the necessary detail to be printed out. Maybe a modest fee per download could be set as a compensation for the authors that will also serve as a popularity indicator for the magazine?

For a quick prototype, following the DIY methods of Mr. Bateman and others is not too difficult.

Michael Edinger,
Denmark

Scroggie help

I noticed a letter in your most recent issue regarding M.G. Scroggie, with the suggestion that a biography of him should be written. This is the sort of thing I could do, based on contributions from those who were close to him or his work. I remember reading his articles in (what was then) Wireless World; his "Foundations of Wireless" was my 'bible' in my formative years and is still on my bookshelf! I seem to remember my father telling me of meeting Mr. Scroggie while working on radar in the RAF during WW2, but I can't confirm this because my father died some years ago.

My background is in electronic engineering, specifically in the broadcast industry. For the last 12 years I have been working as a technical author in this field, creating instruction manuals, user guides, test procedures etc. for a wide variety of equipment and systems and would be only too pleased to help.

Chris Jones
Langport, Somerset, UK

Any readers interested in contributing, please e-mail me with your details -Ed.

A warm welcome to the "Electronics World" editorial position! Your name is familiar to me from the IBE magazine, (I too have been in the broadcast industry for many years) and I look forward to reading your 'worldly wise and cutting' comments in the future in EW.

I have been regularly reading Wireless/Electronics World for several years - more then I would like to mention..!, and by chance I recently stumbled on my copy of Wireless World from the Queen's Silver Jubilee year (June 1977). The first thing that was obvious was that the occasion was marked by a special front cover for the 25th Jubilee together with a short column looking back to the state of affairs then 25 years ago in 1952. Very fascinating stuff!

A photo of a WW from June 1952 was shown on the Jubilee front cover, at the time costing 2 shillings (10p)!! In 1977 the price is 40p and today £2.95.

On looking through the copy from 1977, I think you might agree that the change in the electronics industry is much less marked in the last 25 years leading up to the Queen's Golden Jubilee then the previous quarter century. In 1952, semiconductor devices and microprocessors were still yet to come and the valve reigned king. By 1977 the situation was reversed and already firm/software based electronic devices were becoming common. Silicon integrated into digital and analogue "chips" were and still are fundamental building blocks for the industry. Looking back from 2002 however, some of the most significant changes in recent years include information and data transfer via internet, the use of a PC for design, simulation and testing electronic systems, and gradual loss of the ability to repair modern circuitry down to a component level. (It's just getting too small to see!!) I wonder what the next 25 years will bring?

Sorry, I forgot to mention that the editorial article in the June 1977 WW was about "Radio and Air Safety" That is something which is still very much in the public focus in 2002 - some things just don't change do they!!

Peter Sullivan
By email

Good luck with the new job from a WW/EW subscriber of very many years, although with a break some years ago when the magazine seemed to have lost its way.

An issue on which it might be worth commissioning an authoritative article is the controversy now being aired in RSGB's RadCom (May 2002 p28 and subsequent issues) about whether the Crossed-Field Antenna does anything more than any other bit of metal put up in the sky.

Authoritative but also comprehensible to self-taught dummies like me, please. The late, great Scroggie could have done it. Hickman, perhaps, or Bateman?

Can I suggest a little more care with final proofing? (I expect someone has mentioned already the desirability of not publishing the same item in consecutive issues, so I shall not labour that point.) For example, the article on p46 of the September issue seems to start at the second paragraph. The letter "Exposure" on p57 refers to " brackets on which a polycarbonate carrier simply rests on." Perhaps this error was in the original email, but it should not have been published. And your editorial: whose, not who's.

I wonder if there should be either more careful scrutiny of Circuit Ideas or a disclaimer of the "Untested - you're on your own" variety on the page: I think more may be needed than the disclaimer on the editorial page. For example, R1 in the first item on p30 is at best a bit under-specified, if that is the term, and possibly a source of fire risk, especially if replaced as suggested in the text with a 47K resistor. And what purpose does C1 serve?

Should it be necessary to go to the 'Contents' page to identify the authors of articles?

Some of these points are rather trivial; but easily avoidable mistakes create an impression of scruffiness and more importantly may engender thoughts in the reader along the lines that "if they can't get simple things like that right, can I rely on them in more complicated matters?"

Pleased to see that there will be no more long software listings. Please do not let EW become yet another computer magazine.

John Compton
Southampton UK

Spellign or Grammer?

You really ought to fire the staff-member who let out your editorial with "who's" instead of "whose" in it.

If he or she does it again we'll see "it's" for "its" in your learned journal. It's bad enough re-naming it "Electronics World", but now there's electronic speling chequers, and grammar cheques even, there ain't no excuse for it, know wo' I mean?

T. R. Mortimer

Double sided PCBs

When making printed circuit boards I went through most of the stages described by Cyril Bateman in the May and June issues of Electronics World. But I have a few points that may still be of interest.

1] Transparencies. As Mike Harrison, I use tracing paper in A4 pads. With REt on 'dark' the Density on '5' and the paper routing through the back, my Laserjet 4L printer gives good results with 65 GSM paper.

2] Registration. My PCBs are limited to 160 x 100 mm. If more is needed I use more boards. The printed transparencies are cut to 120 mm width. The sheets have more then 60mm free on each end. The top and bottom sheets are put together and exactly aligned. Light through small 0.6 mm holes in the isles shows whether alignment has been reached. If so, the transparencies are glued together at the 120mm outer rims. The registration can be checked and corrected if needed. The sheets are now placed between two plates of 6mm Perspex, each 210 x 145 mm, see sketch. They can be screwed together with six M4 bolts and have two alignment pins along the outer rim, glued in the hole of one plate. The 145 mm ends of the Perspex plates get a bit of water-soluble glue on the inside before the sheets are clamped between the plates. The sheets stick out of the Perspex plates, whose ends are cut off. If you take the plates apart each transparency sticks to its plate. You now may put the photosensitive material in place and screw the second plate on top. The alignment pins make sure the registration stays correct. Making double sided ICBM, single or multiple, is no problem any more.

3]. Etching. I changed from ferrichloride to ammonium- or sodiumpersulfate to avoid yellow stains. I do not premix the etching chemical but use about 20 grams of persulfate per 100 square centimetre of copper (35mu) to be removed. A digital kitchen scale with a 1 gram resolution was bought for this purpose. The chemical is diluted with 5ml water per gram. The water used is initially at 55 degrees Centigrade and is kept above 45 degrees by rocking the plastic etching container in a hot water bath. After 5 minutes the first copper is off and another three minutes are needed to remove all of it. The amount of liquid is rather small, however complete coverage of the PCB surface has not been a problem. The etching container should be some 200 x 110 x 60 mm and be slightly deeper in the middle, to avoid scratches. This method gives the same results each time and avoids crystallisation of partly used chemical solution. The spent etching chemical is retained and accepted by our local chemical removal service. This liquid may create a bit of oxygen gas, so do not completely close the storage container until after some time.

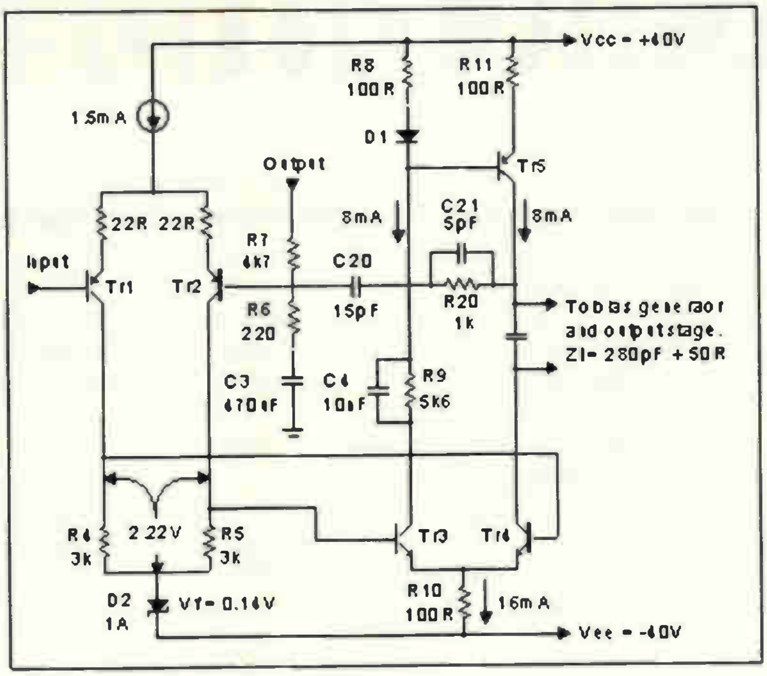
4]. PCB design. Until recently I removed all copper from a PCB that was not needed for its electronic function. This is environmentally unfriendly. The present aim is to leave all copper on the PCB that does not interfere with its function. Connecting tracks are isolated from each other by 0.5 to 1 mm wide openings in the copper. The amount of chemical used is a lot less than what was needed the old way! Maybe I have to return to premixing and reusing chemical solution in order to wet all copper surfaces.

Georg H.Lindner
Vlissingen, the Netherlands

MOSFET compensation

In his letter in the April 2002 issue, Mr. Kessler brought up, quite rightly, the way the Miller compensation was applied to the original Hitachi MOSFET amplifiers. Regarding the first design, one of the capacitors must have been unintentionally omitted from the diagram, because otherwise this amplifier is definitely unstable. Regarding the second design, he wonders why the compensation capacitors on both halves of the second long-tailed pair are rated at different values, in fact 36pF and 10pF. Presumably, it's an attempt to equalise the currents trough both capacitors. As pointed out by D. Self[1], this matters, as the two signal paths from input stage to the next stage must have the same bandwidth. However, I'm afraid this cannot be achieved at all, since the voltages across these capacitors are completely different.

There is a way around this problem by omitting both capacitors and compensating by means of a single capacitor that also includes the input stage, (see figure). This scheme is based on a design by Linsley Hood[2] (whose name is strikingly absent from the list of references, why?) The advantage is that most of the current from the first stage is available as input for the next stage, rather than being consumed by the compensating capacitors, hence a higher slew rate and lower transient intermodulation distortion. Furthermore, the unity-gain frequency of the global feedback loop is almost exclusively defined by R7 and C20. The internal loop (via C20) is stable due to the loading by the MOSFET output stage (for a IRF240/IRF9240 pair, typically 280pF) and gate series resistors (typically 100Σ). So inserting drivers between second stage and output stage or using MOSFETs with a much lower input capacitance may impair the stability. To improve the phase margins, C21 and R20 are added. Note that R20 x C20 roughly equals the time-constant of the gate series resistors and effective input capacitance of the output stage (50Σ x 280pF). According to my simulations, the internal loop has an unity-gain frequency of 16MHz and a phase margin of 83°, while the global feedback loop has an unity-gain frequency of 2MHz and a phase margin of 85°. The slew rate has improved to 100V/s. Apart from this, I added Schottky diode D2 to make the quiescent current of Tr3 and Tr4 less temperature dependant.



With regard to the two-terminal current source, I have no reason to doubt it has excellent characteristics. However, Mr. Kessler did not explain how to apply this circuit to the amplifier, although the article[3] he referred to, is concerned with current sources in the second stage. Therefore I assume he suggests applying the circuit the same way as Dr. White did: as a replacement of R9 and C4. In my letter of January 2002, I disapproved of this kind of practice. Dr. White replied, but missed my point* and also apparently Mr. Kessler, as he proposed an even better current source, where essentially a short ought to be. So I take the opportunity here to clarify my objections. My concern was not how the current source was implemented, but why was it put there anyway and so robbing the second stage from its ability to sink and source quite large amounts of current (>30mA). In principle, one can tie the collector of Tr3 directly to Tr5/D1 (see also ref.2, fig.9). As stated in my previous letter, the only reason why R9 is present is to reduce the power dissipation of Tr3 and to provide protection in case of overloading. C4 is added to avoid loss of AC gain. Replacing R9/C4 by a current source not only cripples the second stage, but creates instabilities as the output of Tr3 shows such a high impedance, that it can be considered as a current source too. I'll repeat, connecting two current sources in series is not done. Moreover, it could be dangerous. Suppose the current source is rated slightly higher than the current Tr3 can sink, then the current source becomes saturated and Tr3 is exposed to almost the full supply voltage, thereby (possibly) exceeding the maximum power dissipation. If the current source is rated slightly lower, then Tr3 collapses. This kind of instability has already been described (and cured) by Linsley Hood (ref.2, fig.12).

Dr. White replied that neither Tr3, nor the current source was saturated. With careful adjustments not impossible, at least under quiescent conditions, but certainly not when the second stage is spurred to action. He claims a distortion of 0.005% at 1kHz and 1W. Again, not impossible, as my Spice simulation, that shows a tendency to flatter results, indicates 0.002%. However, at 20kHz and 1dB below full power, simulated distortion rises to 0.16%, sixteen times more than he claims. Slew-rate was claimed at 35V/s, while simulation reveals a meagre 12V/s.

It is not my intention to criticise Dr. White and Mr. Kessler, because they are seeking methods to improve performance. Instead, I strongly recommend using a simulator, as this is the easiest way to explore new ideas and to reveal potential shortcomings that are otherwise hard to detect. As a starting point, the demo version of Micro-Cap[4] suits this application well, because it has sufficient numerical precision for thd analysis, and it is free. Appropriate Spice models must be obtained from other sources.

Edmond Stuart
Amsterdam, The Netherlands.

* Perhaps, because he was asked to reply on publication deadline day! (private communication).

References

1. Self, D., 'Distortion in power amplifiers, the voltage-amplifier stage', EW+WW, Oct. 1993, p. 822.
2. Linsley Hood, J.L., '80-100W MOSFET Audio Amplifier' WW, Aug. 1982, pp. 28-32 and July 1982, pp. 63-66.
3. Cherry, E.M., 'Ironing out distortion', EW, July 1997, pp.577-582
4. www.spectrum-soft.com

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

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

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

Clear hand-written notes on paper are a minimum requirement: disks with separate drawing and text files in a popular form are best – but please label the disk clearly.

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

Experimenter's pendulum timer

We needed an experimental set-up to check the acceleration of a pendulum due to gravity. The circuit we devised starts with a 555 configured as a monostable, **Fig. 1**. Its trigger input is fed by a light-dependent resistor. A pulse caused by the pendulum bob briefly interrupting the light impinging on the LDR triggers the monostable.

Output from the monostable forms a clock to two bistable devices. Output $/Q_1$ of the first JK bistable device clocks the second.

Output Q_2 from the second bistable device feeds a 555 timer configured as an astable multivibrator with a period of 0.01s. While Q_2 is high, pulses from the astable multivibrator pass through to the decade counters. These counters are followed by decoder/drivers and displays for indicating units, tens and hundreds, **Fig. 2**.

To take readings, the pendulum the bob is taken to extreme right, i.e. point N on **Fig. 3**, and then released. **Figure 4** shows the pendulum and sensor set-up. The pendulum passes the LDR three times each period, **Fig. 5**.

Heights of the LDR and

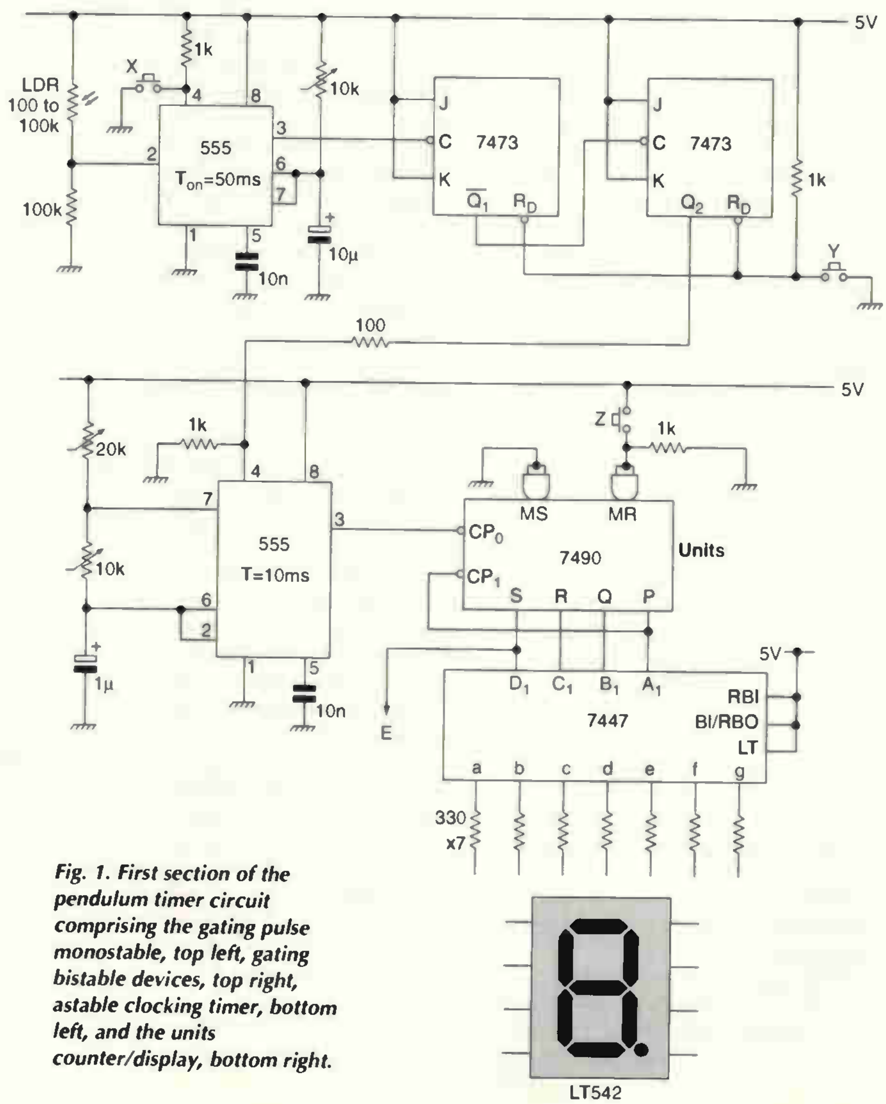


Fig. 1. First section of the pendulum timer circuit comprising the gating pulse monostable, top left, gating bistable devices, top right, astable clocking timer, bottom left, and the units counter/display, bottom right.

lamp relative to the bob can be made adjustable using pillars.

Figure 5 shows the pendulum pulses from monostable relative to output from the two bistable devices. Knowing the period t, the velocity of pendulum swing, g, can be evaluated.

The relationship of the pendulum is given by:

$$t_p = 2\pi\sqrt{\frac{l}{g}}$$

$$t_p^2 = 4 \times \frac{\pi^2 \times l}{g}$$

Therefore,

$$g = \frac{4 \times \pi^2 \times l}{t_p^2}$$

To illustrate, l=40cm=0.4m and the time period of the astable device is 0.01s. The display count is 127 so t_p is the period of the pendulum, which is 127×0.01s, i.e. 1.27s.

On substitution in the above relationship for g:

$$g = \frac{4 \times \pi^2 \times 0.4}{(1.27)^2} = 9.791\,\text{m/s}^2$$

Switches X, Y and Z are initialisation resets. Normally, the astable is in its reset condition. By momentarily pressing Y and Z several times after the pendulum passes point N in Fig. 3, fresh counter readings can be obtained. Several readings can be obtained for different lengths of pendulum and an average taken.

V. Gopalakrishnan
Bangalore
India

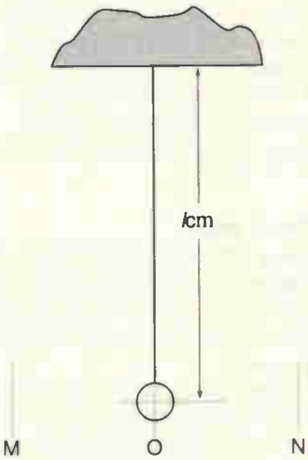


Fig. 3. Illustration showing the positions of pendulum points M and N.

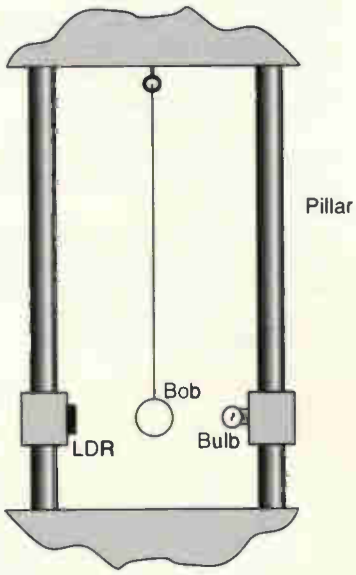


Fig. 4. Outline of the set-up showing how the pendulum interrupts the light source.

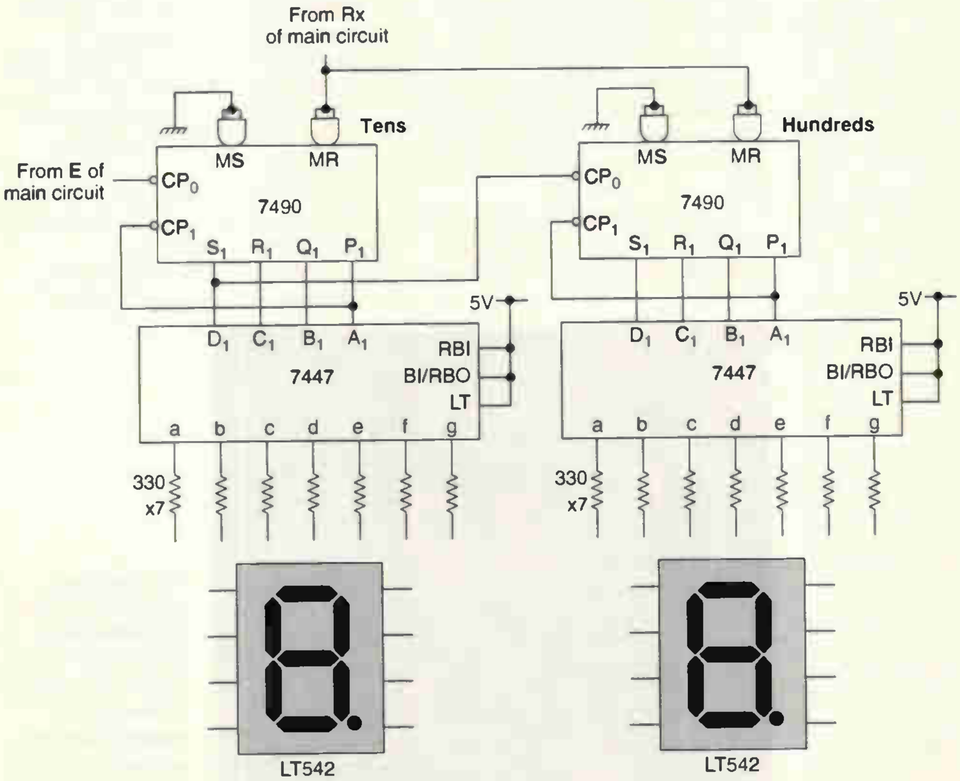


Fig. 2. Tens and hundreds display section of the pendulum timer.

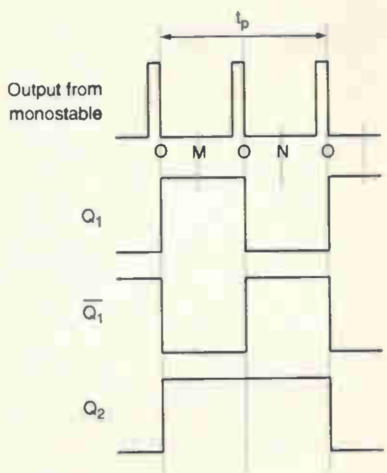


Fig. 5. Key waveforms. Top is output from the first monostable, while bottom is the final gating pulse for the astable-configured 555.

Speaking clock with an educational display

This clock is unusual. Seconds are displayed in binary, minutes with decimal numbers and hours via an LED "analogue" pointer. Last but not least – the clock can speak.

To make sure that this design was accessible to those involved in education, the circuit was put together using traditional components. The design's purpose is to demonstrate binary digits, gates, counters, display units, decoders, etc. Seconds are displayed in binary-coded decimal format and minutes using seven-segment LEDs. Hours are shown with a 'pseudo-analogue' LED-pointer.

Voice output is implemented using an ISD memory chip, which can store one minute of voice recorded via the microphone. The chip is binary addressable. When triggered, it outputs the recording starting from the active memory address.

In this design, I have recorded declarations of full and half hours to various addresses so that as time proceeds, the active address contains the message related to that time. Voice output is triggered by the minute counter when reaching value '00' or '30'.

How it works

Timing reference IC_1 contains frequency dividers so that exact 1Hz signal are available from pin 14. Higher frequencies can be taken from other pins.

One second cycles are taken to a decade counter, IC_2, the status of which is displayed in binary using LEDs. Counter overflow triggers count to six counter, IC_3, whose count is displayed in binary as well. Thus the seconds are indicated in BCD with two rows of LEDs.

Minutes, handled by IC_4, and tens of minutes, IC_5, are counted in the same way, but their statuses are taken via decoders IC_7 and IC_8 to seven-segment displays.

Hours are counted with a count-to-twelve counter, which comprises four-bit binary counter IC_6. This chip is reset back to zero with a positive pulse to pins MR_1 and MR_2 when the counter reaches its maximum. Thus the clock face has normal 12 hour increments, without day and night separation.

The hour counter output causes one of the BCD-to-decimal decoder, IC_9, outputs to fall to zero, activating the hour-pointer LED. These LEDs are spread around a circle, as on a clock face.

As the decimal-decoder only has ten outputs, extra decoding via IC_{11} is needed to display hours from 10 and 11.

The binary value feeding hour counter IC_9 is also taken to address lines $A_{5\text{-}8}$ of the voice chip, IC_{13}. Address line A_4 is fed with a signal indicating full hour (0) or half hour (1). The lowest address lines, $A_{0\text{-}3}$, are grounded, so the storage is divided into 32 slots of 5 bits. Of these, the first 24 are used.

Speech triggering requires a negative going pulse to pin 23 (CE), which is generated when output from IC_{12} (pin 8) goes to ground. This happens when the output from the tens of minutes decoder, IC_{10}, achieves the value "0" or "3". When that happens, loudspeaker L outputs the message from the memory slot pointed to by address bits $A_{4\text{-}8}$.

Message recording

Using five address bits, the memory is divided into 32 parts, the length of each of which is about 2 seconds (60/32). In this design, only the first 24 are needed. Other memory slots thus have 2 seconds of time, but the last one can use up to (32–24)×60/32 = 15 seconds.

Declarations of time, e.g. "it is half past five" or "it is ten o'clock" must thus fit into 2 seconds, but at 11.30 there is lots of time to explain that "it is half past eleven now"

Recording is performed by speeding up the clock using S_3 (IC_1, pin 10) to the desired time, 6.30 for example, and stopping there by taking S_3 to its neutral position. Note that all values between 6.30...6.39 will do, because single minutes are not included in the chip address formation.

Push button S_1 and speak the desired message, e.g. "it is half past six". After recording S_1 is immediately released and thus the end-mark is generated. You can

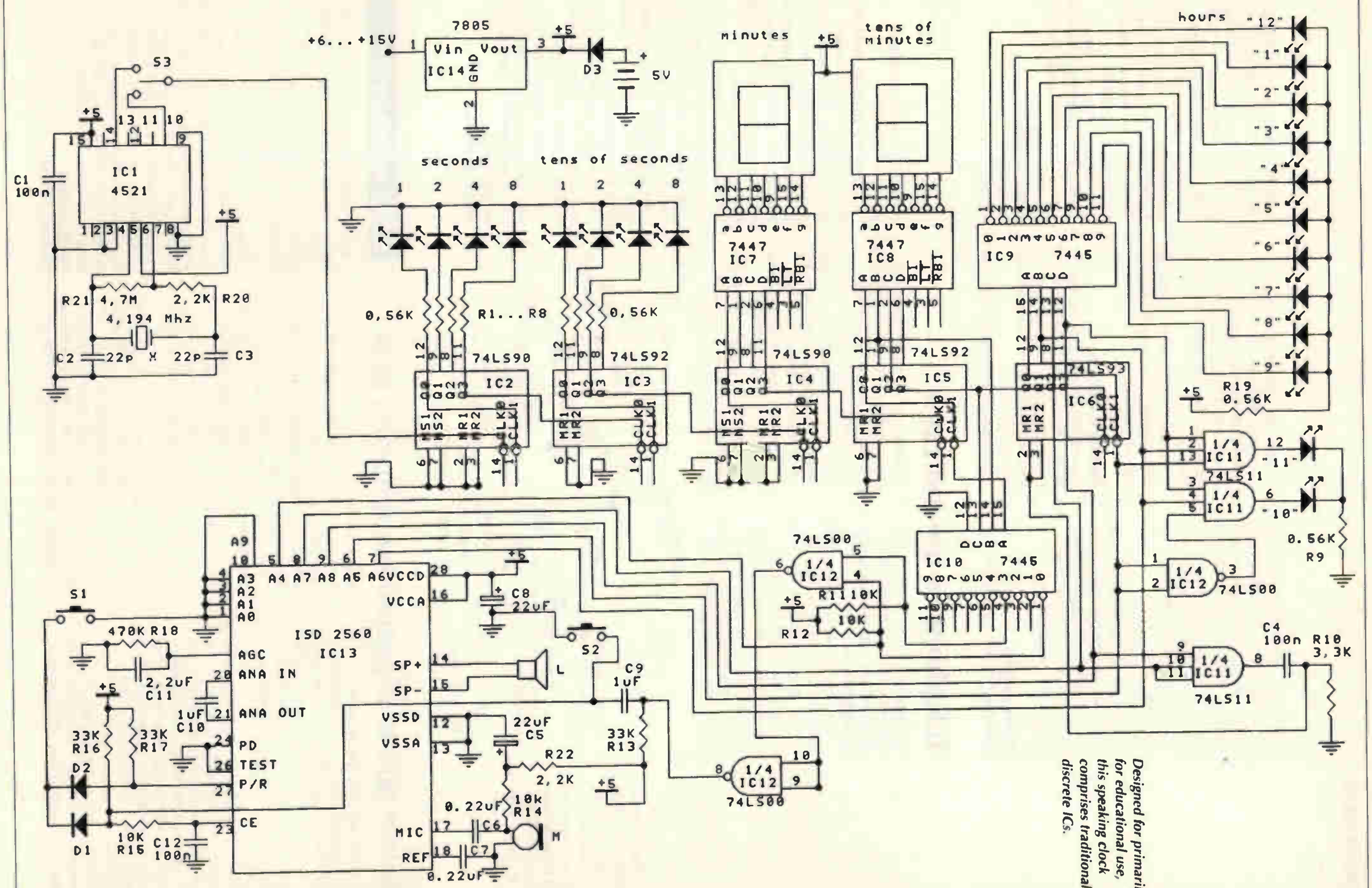
Parts list

Resistors (1/4W)	
$R_{1\text{-}9}$, R_{19}	0.56k
R_{10}	3.3k
R_{11}, R_{12}, R_{14}, R_{15}	10k
R_{13}, R_{16}, R_{17}	33k
R_{18}	470k
$R_{20,22}$	2.2k
R_{21}	4.7M
Capacitors (16V)	
C_1, C_4, C_{12}	100n
C_2, C_3	22p
C_5, C_8	22µ
C_6, C_7	0.22µ
C_9, C_{10}	1µ
C_{11}	2.2µ
Integrated circuits	
IC_1	4521
IC_2, IC_4	74LS90
IC_3, IC_5	74LS92
IC_6	74LS93
IC_7, IC_8	7447
IC_9, IC_{10}	7445
IC_{11}	74LS11
IC_{12}	74LS00
IC_{13}	ISD2560
IC_{14}	7805

Miscellaneous:
20 red LEDs for seconds and hours
12 small green LEDs for hour marks
2 7-segment displays for minutes (common anode)

$D_{1\text{-}3}$	Small-signal diode, e.g. 1N4001
X	4.194MHz crystal
S_1, S_2	Push-button switch
S_3	Switch with middle neutral position
M	Electret microphone
L	Loudspeaker, >15Ω

The speaking clock's face. Hours are indicated by the red LEDs while the seven-segment display shows minutes. Seconds are indicated in BCD using further red LEDs



Designed for primarily for educational use, this speaking clock comprises traditional discrete ICs.

immediately verify that the recording was successful. Briefly push S_2 and the speaker should output the stored message. If also now other messages are heard, you have exceeded the two-second limit before releasing S_1. No problem. Simply repeat the operation.

Note that recordings and their contents can be changed at any time, if the old ones start to sound boring.

When all time slots are recorded, drive the clock to right time and switch S_3 to normal position.

Power supply

Provided that there are no power failures, the clock keeps time accurately. Normally, power is supplied from a small adapter via regulator IC_{14}, but it is supported by a battery to overcome possible mains failures.

As battery voltage does not exceed 5V, D_3 keeps it disconnected under normal operation.

Putting it together

I assembled my prototype on two PCBs. Display components were soldered to a vertical board (clock face) and others to a horizontal board joined to the other.

Switches are in the back panel. The front panel of the box is darkened Plexiglass, through which only the active LEDs are visible. To make the clock face visible, hours are marked with small green LEDs that are permanently turned on. These are not shown in the circuit diagram. Red LEDs indicate the latest full hour. Minutes and seconds are indicated in the middle of the display.

The whole device, including speaker and microphone, is built into a wooden box measuring 10cm by 10cm by 15cm.

Heikki Kalliola
Helsinki
Finland

Telephone in use indicator

I designed the circuit described here to provide an indication of a busy telephone line when another family member is on the phone.

A ringing indicator is also provided that lights a second LED when AC ringing voltage is present. The circuit is simple, draws less than 150µA from the line and around 10µA from the battery in its idle state. About 4mA is drawn from the battery when the line is busy. The circuit is also isolated from the mains supply and input overload protection is provided.

In the idle state, line voltage is around 50V, dropping to around 20V in the busy condition. Zener ZD_1 acts as a simple comparator switching Tr_1 off when the line is busy, allowing Tr_2 to conduct through the high value resistor R_5 and lighting LED_2.

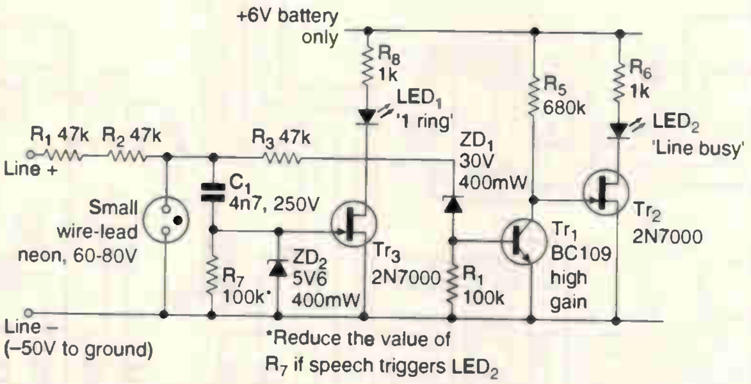
A high-gain transistor – one with a gain of more than 250 – should be used for Tr_1. In addition, a low current LED should be used to preserve battery life.

Ringing current passes through C_1 and the negative half cycles are removed by ZD_2. The resulting signal causes Tr_3 to conduct, lighting LED_1. Diode ZD_2 also provides protection for Tr_3 and R_7 allows the gate/source capacitance of Tr_3 to be discharged between ringing pulses.

Resistors $R_{1,2}$ and the neon lamp provide input overload protection of up to 350 volts, AC or DC. The neon lamp can be replaced with two 68V 1.3W zener diodes connected back to back. Capacitor C_1 should be rated at 250V DC minimum.

I have had the circuit running for over a year on the same set of AA alkaline batteries. A Darlington optoisolator or a low-current reed relay can be used in place of the LED if you need to drive external devices with the circuit.

Alistair Borthwick
Edinburgh



Plugged into a phone socket, this activity monitor indicates if a phone connected to the same line, but elsewhere in the house, is in use.

Mobile phone triggered combination lock

£50 winner

This electronic combination lock is unlocked when the circuit recognises a unique valid sequence of four tones from a mobile phone. This unique code is easily changed if need be. Note that the phone is used 'off-line' so no phone expenses are involved.

One great benefit compared to a traditional code lock is that no door keypad is required. Installing is thus cheaper and simpler and there are no visible targets for vandalism.

The door to be locked needs only a small hole for a microphone, which can be very small. It is not essential to locate the microphone near to the lock.

In addition to forming the basis of a combination lock, this circuit can be used to operate anything that runs off electricity.

How it works...

Pressing a mobile phone button generates a so called dual-tone multiple-frequency, or DTMF, code whose frequencies depend on which key is pressed.

The circuit receives DTMF tones via its microphone and is set by the user to respond to a unique four-digit code using switches. After amplification, the DTMF signal received at the microphone is directed to a DTMF-receiver, IC_2, which converts it to 4-bit binary format.

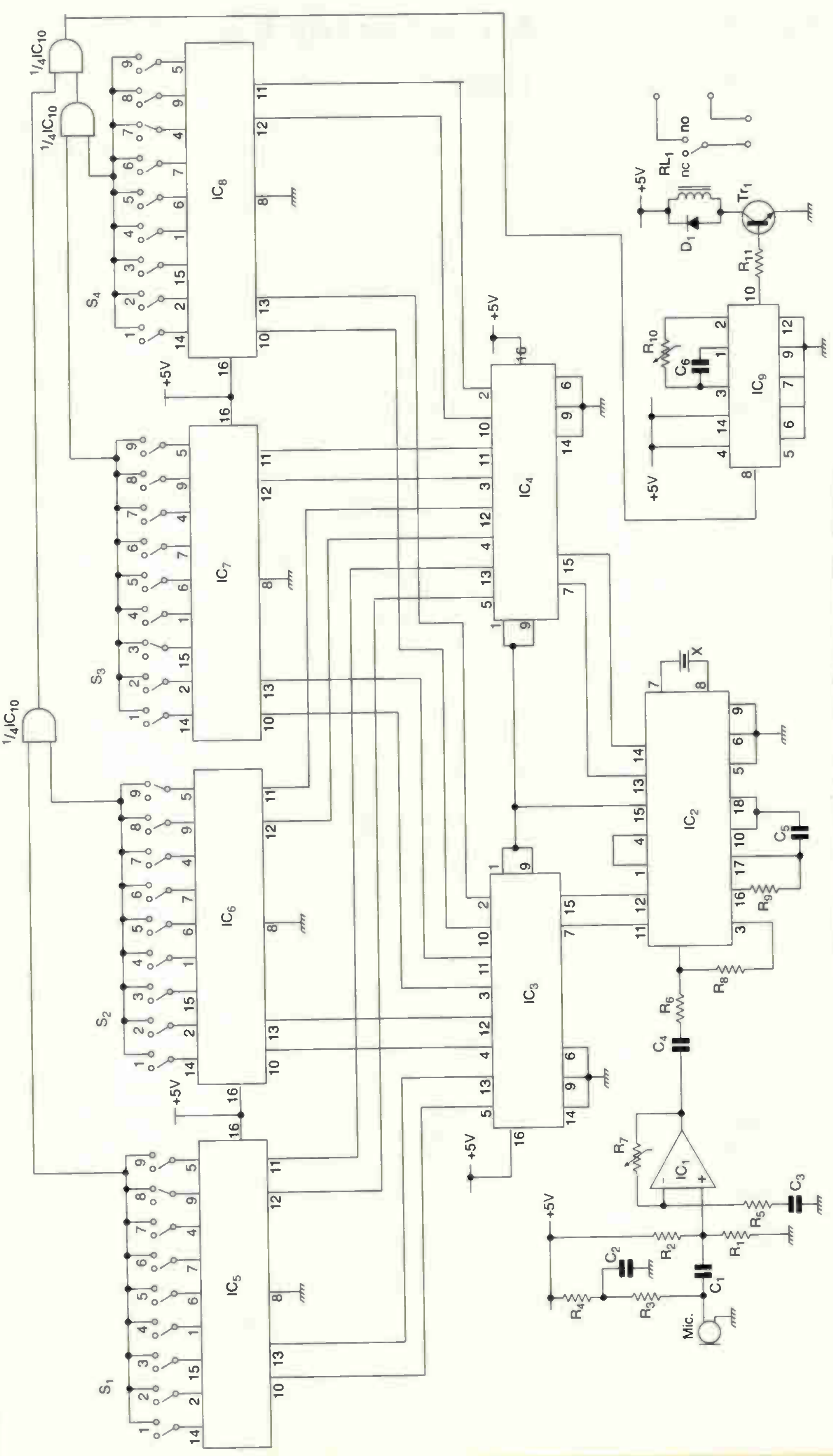
Received digits are stored as four, 4-bit words in the 16-bit register formed by $IC_{3,4}$. The digits are converted to decimal using BCD-to-decimal-decoders IC_{5-8}. When a new digit is keyed, the previous ones are shifted forward. In the diagram, the last entered digit is in the left.

If four digits in sequence match with the code set by the switches, output from the AND gates IC_{10} goes high and triggers the monostable circuit, IC_9. Output from IC_9 goes high for a moment, adjustable via R_{10}, and activates the lock relay via Tr_1.

Four, nine-way DIL switches set the code. With the settings as shown, the relay is powered with digit combination 7398. Digit 0 is not used because the DTMF code for zero is not the same as the BCD code for zero.

Sensitivity of the microphone amplifier can be adjusted via R_7. Maximum operating distance is about 20cm. If there's a lot of ambient noise, it is best to set the phone's speaker sound level to maximum.

Heikki Kalliola
Helsinki, Finland



This combination lock is triggered by a unique set of four DTMF tones produced by pressing the keys on a mobile phone. The combination code is set using four 9-way DIL switches.

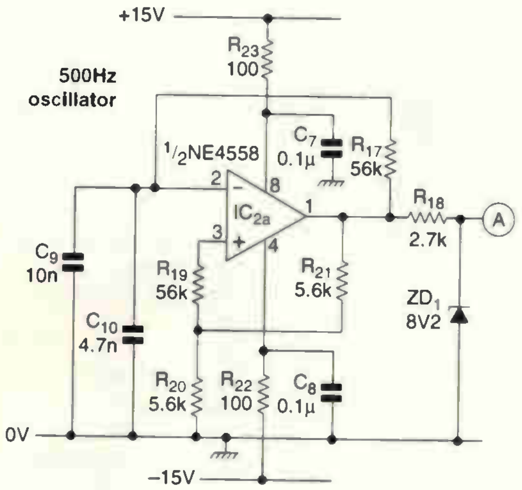
Parts list

Resistors (0.25W)	
$R_{1,2}$	47k
R_3	1.5k
R_4	330
R_5	1k
R_6	33k
R_7	5M trimmer
R_8	100k
R_9	380k
R_{10}	200k trimmer
R_{11}	10k
Capacitors (16V)	
C_1	0.47µ
C_2	47µ
C_3	1µ
$C_{4,5}$	100nF
C_6	6.8µ
Semiconductors	
IC_1	LF357
IC_2	8870
$IC_{3,4}$	4015
IC_{5-8}	4028
IC_9	4047
IC_{10}	4081
Tr_1	2N2222
D_1	1N4001
Miscellaneous	
M	Electret microphone
RL_1	Relay (5V)
S_{1-4}	DIL-switch (9 way)
X	3.579545MHz crystal

£50 winner

0-5mV to 4-20mA converter based on chopper stabilisation

This oscillator is used to drive the chopper transistors in the main circuit.



Here is a circuit that has industrial uses. I built it to amplify a 0-5mV input signal – in my case from a transducer in a Wheatstone bridge – and convert it as accurately as possible to 4-20mA form.

I developed the circuit to help me carry out some research into thermal conductivity, but it has many other potential uses. The equation of this converter is simply:

$$Output(\text{mA})=4\text{mA}+3.2V_{in}$$

Here, V_{in} is expressed in millivolts (0-5). To make this equation work, you need a stable voltage gain of 800, or 58.1dB.

My converter owes its accuracy and 140dB open-loop gain to the classical chopper amplifier. This amplifier comprises IC_{1a} and IC_{1b}, with IC_{1a} producing about 60dB of gain and integrator IC_{1b} providing about 80dB of gain.

Total open-loop gain amounts to 140dB. This is controlled globally by $1+R_{15}/R_{16}$. The total gain available is the product of that produced by IC_{1a} and IC_{1b}.

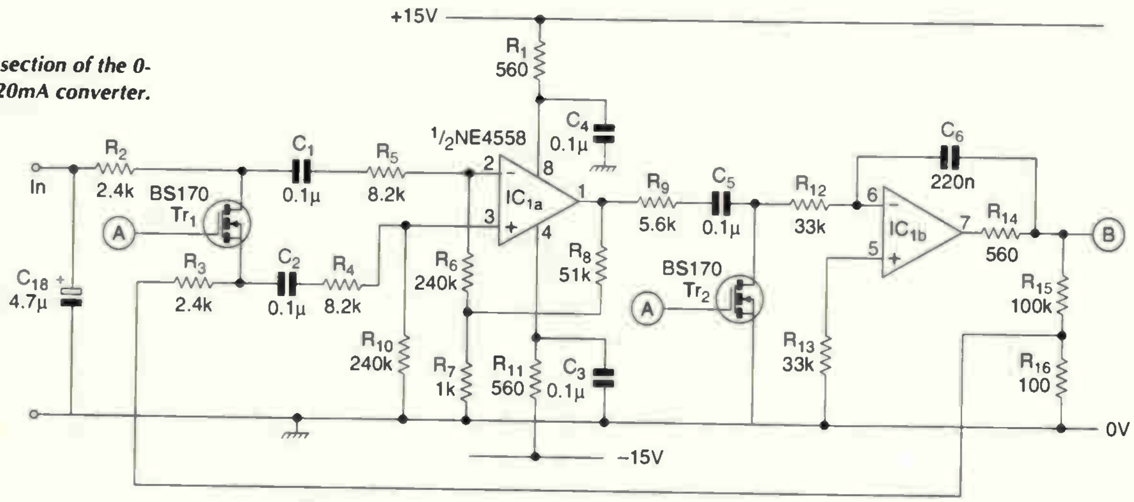
Since the open loop is so high, it is possible to obtain 60dB amplification while still leaving 80dB spare for the closed loop. This results in incredible amplification accuracy. As shown, the circuit is set to 60dB which equates to a voltage gain of 1000.

Both zero and span are accommodated, allowing for a two-point calibration. Calibrating the converter to the above linear equation is relatively simple. Once it is correctly calibrated, a quick linearity test can be carried out: adjust the input voltage test source to 2.5mV and the circuit should yield exactly 12mA output.

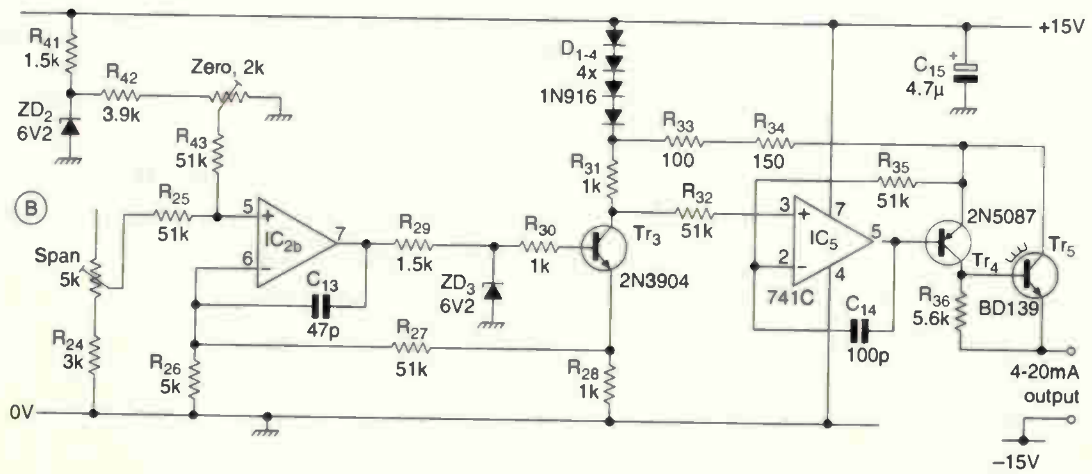
Oscillator IC_{2a} operates at around 500Hz. It drives the two FET switches, Tr_1 and Tr_2, which commutate synchronously. Since IC_{1a}'s signal path is isolated by way of C_1, C_2, and C_5, ambient temperature drifts have negligible effect.

Next, IC_{2b} converts the signal from voltage to current. This allows level shifting to take place. The signal then

Chopper amplifier section of the 0-5mV to 4-20mA converter.



After amplification, the signal voltage passes through this voltage-to-current converter to turn it into 4-20mA form.



appears across R_{31} and equally across R_{33} and R_{34}.

In conjunction with Tr_4 and Tr_5, IC_5 forms a variable 4-20mA current source. The range of the output-termination resistance of the 4-20mA signal spreads from zero to in excess of 1000Ω.

If you prefer a voltage output then simply terminate the 4-20mA signal with a 250Ω, 0.1% resistor for 1 to 5V output.

Normally, the input signal will be from the output of a wheatstone bridge with one of the arms being the transducer. In order to maximise CMRR from the bridge, the bridge should have an isolated supply. This not only knocks up the CMRR to around 150dB, but also accommodates the classical chopper's single-ended input (reference ground 0V) very nicely.

While most transducers are very slow – they can take minutes to respond – the converter has an adequate bandwidth of about 20Hz. This can be altered by changing *RC* time of R_{12}/C_6.

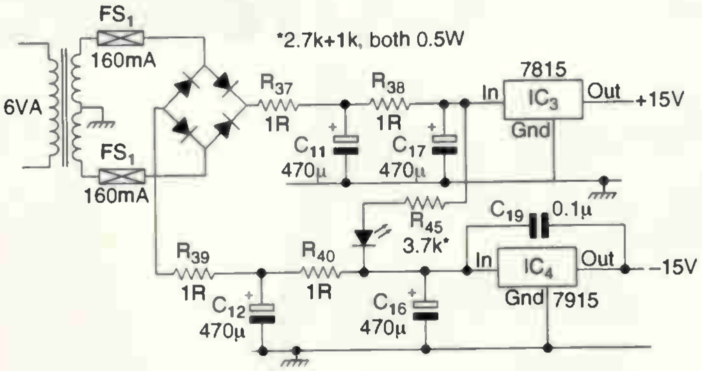
Since the converter is mains powered, there is a small residual 100Hz signal riding on the final output. Obviously, increasing the speed of the integrator will increase this residual. This unwanted signal comes about because the bridge rectifier acts as a mixer, generating many low frequency components in the supply.

After building this design, I tested the ICL7650S. This is a complete chopper on a chip, but it has a drastically different architecture from that of the classical chopper shown here.

I found that the 7650S works extremely well. At a guess, I would say both schemes work equally well. However, my converter is extremely low cost and has supply and low output impedance (wide swing) advantages over the ICL7650S. Most importantly, it is nice to know that there are alternatives to using the 7650S.

I built the whole converter – including mains supply – on a 100 by 160mm Eurocard size PCB.

Darren Heywood
Buckley
Flintshire



As the input signal to the converter is only a few millivolts, the power supply needs good regulation.

Since finalising this design, Darren has found that reducing the oscillator frequency to 80Hz gives a significant increase in performance.

Circuit CAD on a shoestring

Needing a means of drawing circuits in a presentable fashion and in such a way as they could be easily modified using existing software, I decided to have a look at PC Paint. A few hours of practice mixed with some frustration resulted in my building a small component library that makes the job of drawing circuit diagrams much easier and provides quite acceptable results – importantly, at no extra cost.

First, open the symbol library in one PC Paint window and then start the circuit drawing in another. It is a simple matter to 'copy' from the symbols window and 'paste' to the drawing. Once a symbol is used in the drawing, it may be copied and pasted from within that window.

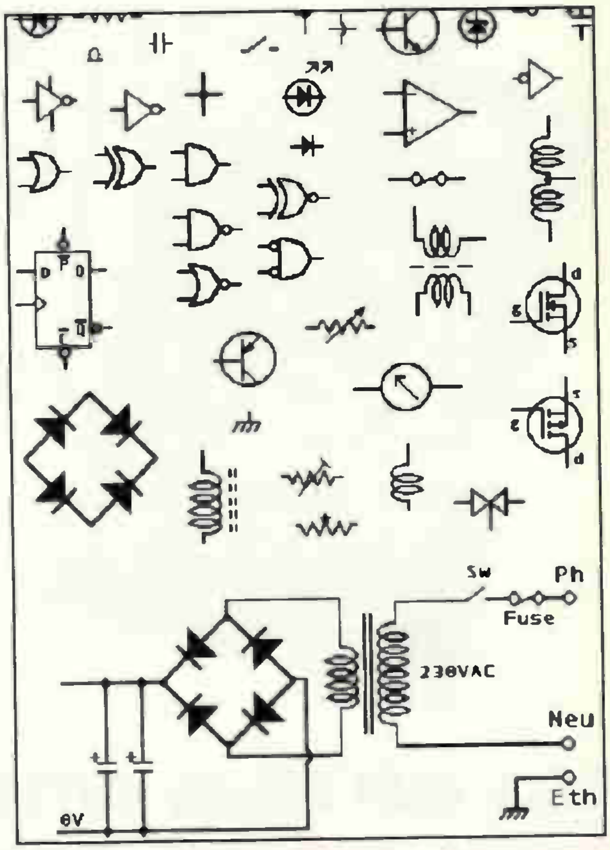
I've found that most drawing operations are fairly easy to perform with a 200% magnification. PC Paint gives three levels of 'undo' in case you make a mistake. You can select between the circuit and symbols windows by clicking the appropriate icon on the task bar at the bottom of the screen.

The library contains all the components I have used to date, but there is room for plenty more to be added. I suggest creating them at 400% magnification so that fine details can be drawn. This magnification is the highest that PC Paint will allow.

With practice comes proficiency. For me, this method has turned PC Paint from being an unfriendly monster into a useful tool. 'Flips' and 'Rotates', available by selecting the symbol and right-clicking on it, allow components to be orientated as required.

Minimum file space for saving drawings is attained by reducing page size to just fit the drawing (Image. Attributes menu) and saving the work as a monochrome bit map. Remember to save the work frequently, just in case your computer crashes or there's a power cut.

Malcolm Watts
Wellington
New Zealand



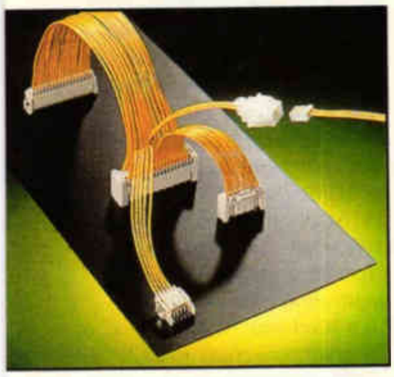
Section of the author's bitmap file. For a copy of the file, e-mail j.lowe @highburybiz.com using the subject heading CAD file.

NEWPRODUCTS

Please quote *Electronics World* when seeking further information

Wire harness saves 45% PCB space

The 1.25mm (0.049in.) pitch Mini Mill wire harnessing connector system from Molex is designed to save about 45% of PCB area compared to similar 2.00mm (0.079in.) pitch versions for applications such as printers, home appliances and automotive telematics. The system can carry 1.5A and is available in wire-to-board and wire-to-wire configurations in 2 to 20 circuits for single row and 10 to 40 circuits for dual row. It features a common single-row IDT receptacle that provides mass termination of discrete wires. The receptacle has guide slots to facilitate wire placement.



Side ribs provide polarisation and lock into a clip for dual-row configurations. Header options include single or dual row, SMT or through-hole, and vertical or right-angle.
Molex
Tel: +44 (0)1252 720720
www.molex.com

36 Mbit quad data rate SRAM

Samsung Electronics has announced its first 36Mbit Quad Data Rate II (QDRII) SRAM memory device designed for high performance telecoms applications. The device is compliant with the recently approved JEDEC specification for QDRII SRAM architectures. It has a 250MHz bandwidth and 1.8V operating voltage. Unlike the conventional synchronous SRAM, QDRII memory device has two data ports that run independently at Double Data Rate (DDR), resulting in the transmission of four data words per clock cycle, allowing it to process four times as much data as conventional networking SRAM. In addition, it offers a wide data-valid window of 65% of the clock cycle, facilitating ease of system design. The device is available in a 15 x 17mm 165-pin FBGA package, recently standardized by JEDEC.
Samsung
Tel: +44 (0)49 6196 663514
www.samsungsemi.co.uk

DSL modems get low voltage switch ICs

A family of low-voltage analogue switches and multiplexers introduced by Siliconix Vishay are pin and function compatible companions to higher voltage CMOS devices. The family includes five monolithic quad SPST analogue switches (DG411L, DG412L, DG441L and DG442L), two single SPST analogue switches (DG417L and DG418L), a single SPDT analogue switch (DG419L) and two precision analogue multiplexers: the 8-channel DG408L and the dual 4-channel DG409L. Typical turn-on time for the switches is 20ns and insertion loss is 3dB at 280MHz. All devices are specified for 2.7V to 12V single supplies or ±3V or ±6V dual-supply operation. The devices provide a logic interface, break-before-make switching action, ESD protection to 2000V, and are available in SOIC-16 or TSSOP-16 packaging.
Vishay
Tel: +44 (0)191 5144155
www.vishay.com

Quarter brick with dual voltages

SynQor is offering a dual output voltage quarter-brick sized isolated DC-DC converter. The DualQor series is capable of delivering up to 60W of total output power at +12V and −12V, without the need for an attached heatsink. The converter module employs synchronous rectification and a patented topology to achieve efficiencies up to 92%. The converter has a 48V nominal input (35 to 75V range) and meets input voltage transient requirements up to 100V for 100ms.
SynQor
Tel: +44 (0)49 9621 784322

Power resistor rated to 1500W

Designed for applications where traditional heatsinking is not practical, the BPR series high power resistors from Tyco

Mobile processor with camera

Hitachi's second version SH-Mobile application processor, the SH37294 incorporates a SH3-DSP CPU core with an operating frequency of 120MHz, and features enhanced camera support and display functions. The device is intended to support the development of next-generation mobile phone systems with built-in cameras. Working alongside the baseband chip of the mobile phone, the device performs dedicated processing of multimedia applications such as audio and moving pictures. It has its own development platform and middleware, including face-authentication and fingerprint-authentication software, as well as more typical applications such as MPEG-4, JPEG, and MP3.

Camera support functions enable direct connection of a VGA-size (640 x 480 pixels) camera. According to the supplier, this is expected to be the standard camera for next-generation mobile phones as it enables capture of high-definition images and electronic zoom display. The SH7294 is available on its own and as part of the HJ93D1705BP Multi Chip Module (MCM), which incorporates 1Mbyte SRAM, stack-mounted. The package used for the SH7294 and the MCM is a 10 mm x 10 mm x 1.4 mm, 0.5 mmpin pitch, CSP-225 package.
Hitachi
Tel: +44 (0)1628 585163
www.hitachi-eu.com

Please quote *Electronics World* when seeking further information

Electronics are available in power ratings from 500 to 1500W. Designed for dynamic braking, snubbing, motion control and capacitor charging and discharging, the resistors deliver up 1500W continuous power or up to 14,000 joules at 1Ω. Low ohmic bulk foil versions are available to order as are custom designs. The resistors incorporate an internal heatsink and the devices are environmentally sealed to IP64 for use in industrial conditions. They are offered in three versions, BPR 500 with continuous rated power of 500W and 1Ω to 25k resistance range, BPR 1000, rated to 1000W with 1Ω to 47k range, and BPR 1500, rated to 1500W continuous over a 1Ω to 60k range. There is ±10% resistance tolerance and –55 to 350°C operating temperature.

Tyco Electronics
Tel: +44 (0)20 8954 2356
www.tycoelectronics.com

Wireless LAN chipset for 54Mbit/s

Intersil has introduced a dual-band 802.11a and 802.11g wireless LAN chipset capable of transmitting high-speed video, voice and data at speeds of up to 54Mbit/s while remaining backward compatible to the 802.11b WLAN standard. The chipset features baseband processor and medium access controller based on direct down conversion (ZIF) architecture. Its dual-band OFDM-based (Orthogonal Frequency Division Multiplexing) technology communicates with both 2.4GHz and 5GHz WLAN devices.

Intersil
Tel: +44 (0)1276 686886
www.intersil.com

16-bit flash micro has boosted program speed

Hitachi has introduced its first microcontroller to incorporate its fourth generation flash technology. The H8/3069F is a 512kbyte flash microcontroller supporting faster programming, on-chip firmware for simplified handling and a user boot program area. It is aimed at industrial and consumer applications. The H8/3069F combines 512kbyte flash with 16kbyte SRAM on-chip. At 2.5s for 128kbytes, the flash write

speed is approximately three times faster than current Hitachi products. The on-chip firmware is designed to shorten development time by eliminating the need for a user-written control program and making software more reliable and future-proof, said the supplier.

Hitachi
www.hitachi-eu.com

C/C++ compilers for PowerPC, Xscale and MIPS

Wind River has released version 5.0 of its Diab C/C++ compiler suite which includes optimisations for specific microprocessor architectures including PowerPC, Intel Xscale and MIPS. It allows software developers to create an executable program by taking application code written in a high-level language such as C or C++ and converting it into machine language that runs on the target application. It supports PowerPC, MIPS, Motorola 68K and ColdFire, ARM, Intel xscale/StrongARM, M CORE, Hitachi SH, Mitsubishi M32R, SPARC, SPARClite processor families. Host support includes Windows 95/98/NT/Win2000, Solaris, HP-UX and Linux host machines. The next release of Tornado II/VxWorks platform for which Diab 5.0 has been integrated will be available later this summer.

Wind River
Tel: +44 (0)121 6281888
www.windriver.com

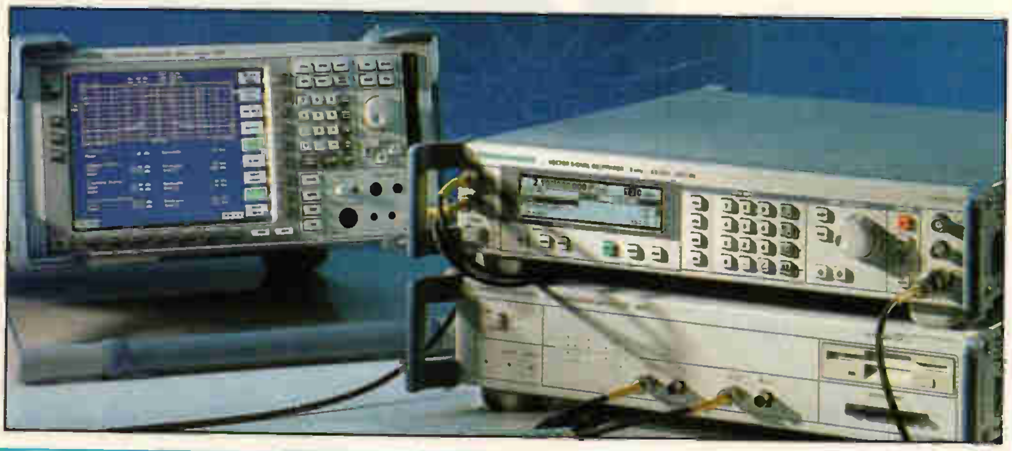
72Mbit SRAM has no bus latency

Ramtron is sampling its 72Mbit no bus latency burst enhanced SRAM (ESRAM), which uses a

Vector generator has 100MHz modulation bandwidth

The latest vector generator from Rohde & Schwarz includes amongst its RF characteristics, an RF modulation bandwidth of 100MHz. The SMV03 is a vector signal generator which offers comprehensive vector and analogue modulation modes as well as fast frequency and level setting. With a frequency range from 9kHz (analogue modulation) and 5MHz (vector modulation) to 3.3GHz, the instrument covers many important frequency bands for mobile radio, WLAN and Bluetooth applications as well as for EMC measurement. Frequency synthesis based on a tried and tested DDS (direct digital synthesis) concept makes for an SSB phase noise of typically –128dBc (at 1GHz, carrier offset 20kHz, 1Hz measurement bandwidth). Frequency settings are performed with a crystal controlled resolution of 0.1Hz.

Rohde & Schwarz
Tel: +44 (0)1252 818888
www.rohde-schwarz.com



Please quote *Electronics World* when seeking further information

one-transistor SRAM design. The products are organised 2 Mbit x 36, operate at up to 166MHz clock speed and deliver 100 per cent bus bandwidth during four-word read-write transactions. The products are available with 2.5V or 3.3V power supply options and 100-pin TQFP and 119-pin PBGA packaging options. It is pin-compatible with existing 18Mbit no bus latency or ZBT SRAM products.
Ramtron
www.ramtron.com

BGA/flip-chips get reworkable underfill material

Loctite is supplying reworkable underfills for flip-chip, BGA (ball grid array)

and CSP (chip scale package). Although designed for use without underfill, CSPs and BGAs can experience mechanical and thermal shock and the use of an underfill material can provide a stable interface between the package and the PCB. The Loctite underfills can be rigid or flexible at operating temperatures and heating the material will allow it to be reworked.
Loctite
Tel: +44 (0)1442 233233
www.loctite.com

Auto microcontrollers get a roadmap

Infineon Technologies has announced a roadmap for its next generation of microcontroller chips for engine and transmission control systems.
The AUDIO-NG family of 32-bit microcontrollers is based on the firm's TriCore unified processor architecture, which incorporates a digital signal processor in the core.
The family will initially comprise three 32-bit microcontrollers; The TC1766 and the TC1796, both of which are based on the TriCore 1.3 architecture, and the TC2700, which uses the TriCore 2 architecture and will be capable of clock speeds up to 400MHz. An extended peripheral set includes a MultiCAN module with up to four CAN (controller area network) nodes and Time Triggered CAN(TTCAN) functionality, a fast analogue-to-digital converter module operating at ten times the conversion speed of previous models. A multiprocessor interface is geared to the requirements of power train applications. This interface enables a number of AUDIO-NG microcontrollers to exchange data streams and is an essential prerequisite for the development of future drive systems with intelligence distributed over multiple processors. The TC1766 offers clock speeds in the 80MHz range. The TC1796 operates at clock speeds up to 150MHz.
Infineon Technologies
Tel: +44 (0)49 89234 22767
www.infineon.com

Mezzanine connector supports 10Gbits/ data

Providing differential and single-ended electrical connection between parallel mounted PCBs, the GIG-Array mezzanine connector handles signal data rates up to 10Gbit/s. This BGA receptacle and plug system

accommodates up to 392 signals per connector. High-speed performance is supported by the connector's 100Ω differential pair matched impedance design. The resulting cross-talk performance of less than 2 per cent ensures signal integrity is maintained across the signal frequency range, said the supplier FCI. Multiple stack heights range from 15mm to 35mm and connector sizes support between 104 and 392 signals.
FCI
Tel: +44 (0)33 13949 2082
www.fciconnect.com

Low gate voltage Mosfets have low RDS(on)

Fairchild Semiconductor has introduced low RDS(on), N-channel, 20V Mosfets which are designed for DC-DC converter applications, with low gate voltages down to 1.5V. The FDS6572A and FDS6574A N-channel devices are designed to replace 30V parts in point-of-load power supplies and other low voltage power management applications, especially where low gate drive voltage is a requirement. The first 20V parts produced using a new manufacturing process, the FDS6572A/6574A feature lower RDS(on) in the same or smaller die size as common 30V devices. Low threshold voltage is 0.6V for the FDS6574A and 0.8V for the FDS6572A which allows low RDS(on) to be achieved with low gate voltage. According to the supplier this is important for secondary side regulators where the available gate drive voltage can actually be below the output voltage, which in some cases is as low as 1.5V. These SO-8

packaged devices offer RDS(on) for the FDS6574A of 9mΩ at 1.8V (VGS) and both parts specified at 6mΩ at 4.5V.
Fairchild
Tel: +44 (0)49 8141 61020
www.fairchildsemi.com

2.5kV solid-state relay is 5mm wide

Finder's first solid-state relay is a version of the company's 34-series electromechanical PCB-mounting part. Designated the 34.81, the relay is initially available in two models. One has the part-number suffix 9024 and is designed for switching up to 2A at 24V DC. Its partner - suffixed 7048 - can switch up to 100mA but at 48V DC. Each can be specified for 24V or 60V DC control input. Featuring silent operation, the 34-series solidstate relay has a footprint of 28mm by 5mm and measures 15mm high. It mounts on the PCB via its

Please quote *Electronics World* when seeking further information

solder pins. Dielectric strength between the input and output of this relay is 2.5kV.
Finder
Tel: +44 (0)1785 818100
www.findernet.com

2.4GHz spread-spectrum technology

AeroComm has published brochures which are intended to expose a number of what the 2.4GHz spread-spectrum wireless system supplier calls 'Wireless Myths'. Aimed at those involved with the selection, purchase or design of wireless systems for use in a wide range of OEM applications, the four literature pieces offer advice concerning equipment selection, standards, interoperability and approvals. For example, one brochure deals with the 802.11 standard which the company claims is somewhat erroneously known as the industry standard. Another looks at single frequency radios. Finally, Bluetooth comes in for a pasting.
AeroComm
Tel: +44 (0)1908 326342
www.aerocomm.com

Channel device for DS3 access systems

TranSwitch has an IC plus software for next generation channelised DS3/DS1/E1/DS0 communications network applications targeting wireless access, multi-service access platforms, time division multiplexing (TDM) over packet, and echo cancellation. Called TEPro, it is a Risc processor-based device with embedded DD-AMPS firmware and host API supporting the requirements of next-generation channelised DS3 access systems. Supporting either one DS3, 28 DS1, or 21 E1 line interfaces, the device can be configured for different operating modes. It integrates an M13/G.747 multiplexer including a DS3 framer with full C-bit functionality to support clear-channel DS3; a 28-channel EI framer, and a 28-channel DS1/E1 cross-connect.
TranSwitch
Tel: +44 (0)32 1660 7538
www.transwitch.com

CAN controller can be pre-qualified

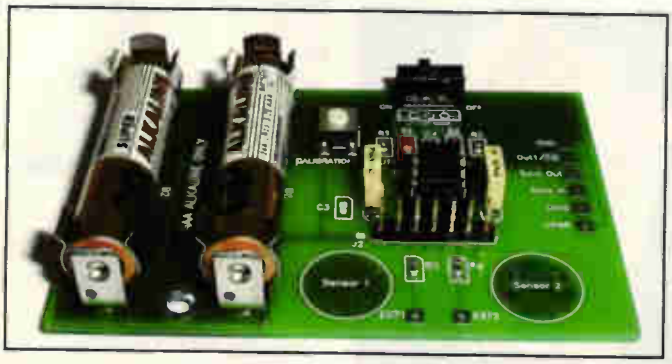
Atmel has announced pre-qualification of its CANary microcontrollers for automotive temperature ranges. The devices implement self-programming code flash memory and data EEPROM. By executing the C51 code located in the boot flash memory, one can update the code or data in flash and EEPROM in-application, after system deployment. The changes may be handled either through the UART or the CAN bus or any tailored customer interface at any step of the end-product's life cycle.
The CANary microcontrollers are available with different flash memory sizes and packages for diverse automotive applications. For embedded target applications, Atmel's embedded CAN microcontrollers are fully compliant with specification levels 2.0A and 2.0B. Additionally, they can handle from 4 up to 15 message objects independently and dynamically assign them to the reception, transmission or reception buffers in case of multiple CAN frames. To complete the full capability line-up of the CAN product family, these devices also support a variety of possible secure applications by supporting industry requirements such as, for example, time triggering and time stamping.
Atmel
www.atmel.com

Cases for horizontal PCBs

The 1455 series of extruded aluminium instrument cases from Hammond Electronics are primarily designed to house PCBs, mounted horizontally into internal slots in the body of the case; they can also be used to house any small electronic, electrical or pneumatic components. The units are available with silver or black anodised finish for good resistance to wear and tear. Two types of end panels are available; either a flat aluminium panel, retained to the case body by a plastic bezel, or a one-piece moulded plastic panel. There are seven sizes in the family ranging from 80x54x23mm to 220x103x53mm; the two largest sizes have a removable cover on the case body to allow access to the PCB when it is in situ; these units will accept a standard 100x160mm or100x220mm Eurocard respectively.
Hammond Electronics
Tel: +44 (0)1256 812812
www.hammondmfg.com

Programmable virtual button IC

Quantum Research Group has released a programmable touch sensor IC. The 8-pin part is based on the UK firm's proprietary Qprox charge-transfer technology. It is based on a Risc processor core and has two sensing channels. It can be used to create 'virtual buttons' through glass, plastic, stone, ceramic, and even wood. It can also turn small objects into touch controls. The QT320 is designed specifically for human interfaces, for example in appliances, lighting controls, computer peripherals or anywhere a mechanical switch or button may be found. According to the supplier, the price per channel represents a 33 per cent reduction per sensing channel over its previous product family. The device uses signal processing techniques to tackle 'stuck sensor' conditions and drift. The chip's EEPROM and communications port let the user program the device from a PC using Quantum-supplied software and adaptor. All operating parameters can be user-loaded into the part's internal EEPROM to configure sensitivity, drift compensation rate, response time, and output polarity. The part also features user-configurable automatic recalibration and output toggle mode. Power consumption and speed can be traded off depending on the application; drain can be 60mA, allowing battery operation. Both 8-pin DIP and SOIC packages are available; the temperature rating is –40°C to +85°C.
Quantum
www.qprox.com



TCP/IP Modules
PageSwitches
GPRS Modems
GSM Modems
Connect "anywhere everywhere" with plug & go solutions
2.4 GHz Solution (Modules, Bridges, Routers)
Serial - Ethernet Controllers
Radio Modules
Radio Modems

WATCH SLIDES ON TV MAKE VIDEOS OF YOUR SLIDES DIGITISE YOUR SLIDES

(using a video capture card)

"Liesgang diatv" automatic slide viewer with built in high quality colour TV camera. It has a composite video output to a phono plug (SCART & BNC adaptors are available). They are in very good condition with few signs of use. For further details see www.diatv.co.uk ....£91.91+ vat = £108.00

Board cameras all with 512x582 pixels 8.5mm 1/3 inch sensor and composite video out. All need to be housed in your own enclosure and have fragile exposed surface mount parts. They all require a power supply of between 10 and 12v DC 150mA.

47MIR size 60x36x27mm with 6 infra red LEDs (gives the same illumination as a small torch but is not visible to the human eye)....£37.00 + vat = £43.48

30MP size 32x32x14mm spy camera with a fixed focus pin hole lens for hiding behind a very small hole....£35.00 + vat = £41.13

40MC size 39x38x27mm camera for 'C' mount lens these give a much sharper image than with the smaller lenses....£32.00 + vat = £37.60

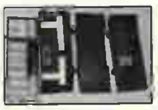
Economy C mount lenses all fixed focus & fixed iris

VSL1220F 12mm F1.6 12x15 degrees viewing angle....£15.97 + vat = £18.76
VSL4022F 4mm F1.22 63x47 degrees viewing angle....£17.65 + vat = £20.74
VSL6022F 6mm F1.22 42x32 degrees viewing angle....£19.05 + vat = £22.38
VSL8020F 8mm F1.22 32x24 degrees viewing angle....£19.90 + vat = £23.38

Better quality C Mount lenses

VSL1614F 16mm F1.6 30x24 degrees viewing angle....£26.43 + vat = £31.06
VWL813M 8mm F1.3 with iris 56x42 degrees viewing angle....£77.45 + vat = £91.00

1206 surface mount resistors E12 values 10 ohm to 1M ohm 100 of 1 value £1.00 + vat 1000 of 1 value £5.00 + vat



866 battery pack originally intended to be used with an orbitel mobile telephone it contains 10 1.6Ah sub C batteries (42x22dia the size usually used in cordless screwdrivers etc.) the pack is new and unused and can be broken open quite easily....£7.46+vat = £8.77

Please add 1.66 + vat = £1.95 postage & packing per order

JPG ELECTRONICS
Shaws Row, Old Road, Chesterfield, S40 2RB
Tel 01246 211202 Fax 01246 550959 Mastercard/Visa/Switch
Callers welcome 9:30 a.m .to 5:30 p.m. Monday to Saturday

TYING THE KNOT

We are pleased to be able to offer both the Morel drive units and the amplifier component kits for the Jeff Macaulay designed motion feedback loudspeaker project, as featured in the September and October issues.

Drive units and amplifier component packs can be bought individually, but we are offering a special saving to Electronics World readers if all items are purchased together.

Morel MDT29-
£34.00 each *(total 2 required)*

Morel MW265-
£69.00 each *(total 4 required)*

Amplifier component pack - £210 (includes components for 2 amps excluding IEC lead)
All prices include VAT.

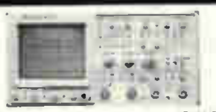
Total cost including postage within the UK - £562.00 including VAT
Special offer price - £520.00 including VAT and postage within the UK.

We also have a comprehensive range of drive units, components, capacitors (Ansar, SCR & Hovland), inductors, cable, damping and grille materials all available from stock.

The UK's largest supplier of kit loudspeakers - all on demonstration.
Phone today for your FREE catalogue or check out our Website.

WILMSLOW AUDIO
50 Main Street, Broughton Astley, Leicester LE9 6RD.
Tel: 01455 286603 Fax: 01455 286605
Website: www.wilmslowaudio.com

SPECIAL OFFERS



TEKTRONIX 2445A 4 Ch 150MHz Delay, Cursors etc. Supplied with 2 Tektronix probes — ONLY £425

TEKTRONIX 2232 Digital Storage Scope Dual Trace 100 MHz 100m/s with probes....£525
H.P. 54501A Digitizing Oscilloscope100MHz, 4Ch £425
H.P. 3312A Function Gen 0.1Hz-13MHz AM/FM Sweep/Tri/Gate/Burst etc....£300
FARNELL Dual PSU XA35-2T 0-35V 0-2A Twice OMD LCD Display....£180
CIRRUS CRL254 Sound Level Meter with Calibrator, 80-120dB, LEQ....£150
EDDYSTONE 1002 Receiver 150kHz-30MHz + Broadcast FM....£125
FARNELL AMM255 Automatic Mod Meter 1.5MHz-2GHz Unused....£300
FARNELL DSG1 Low Frequency Syn Sig Gen 0.001Hz to 99.99kHz, Low Distortion TTL/Square/Pulse Outputs etc....£95
FLUKE 8060A Handheld True RMS DMM 4½ digit As new £150 Used £95
BECKMAN HD110 Handheld 3½ digit DMM, 28 ranges with battery, leads and carrying case....£40

H.P. 3310A Function Gen 0.005Hz-5MHz Sine/Sq/Tri/Ramp/Pulse....£125
FARNELL FLM4 Sine/Sq Oscillator 10Hz-1MHz low distortion TTL Output, Amplitude Meter....£125
H.P. 545A Logic Probe with 546A Logic Pulser and 547A Current Tracer....£90
FLUKE 77 Multimeter 3½ digit Handheld....£60
FLUKE 77 SERIES II....£70
HEME 1000 LCD Clamp Meter 0-1000A in Carrying Case....£60

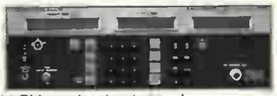
Racal 9008 Automatic Modulation Meter AM/FM 1.5MHz - 2GHz — ONLY £95

Datron 1061 High Quality 5.5 Digit Bench Multimeter True RMS/4 wire Res/Current Converter IEEE — £150

Datron 1061A High Quality 6½ digit Bench Multimeter True RMS/4 wire/Current Converter — £225

Racal Receiver RA1772 50KHz - 30MHz LED Display Basically Working — £250

MARCONI 2019A



AM/FM synthesised signal generator 80kHz - 1040MHz
NOW ONLY £400

MARCONI 893C AF Power Meter, Sinad Measurement. Unused £100 Used £60
MARCONI 893B - No Sinad....£30
MARCONI 2610 True RMS Voltmeter Autorangin 5Hz-25MHz....£195
GOULD J3B Sine/Sq Osc. 10Hz-100kHz Low distortion....£75-£125
AVO 8 Mk6 in Ever Ready Case, with leads etc....£80
Others Avos....from £50
GOODWILL GVT427 Dual Ch AC Millivoltmeter 10mV in 12 Ranges Freq 10Hz-1MHz....£100-£125
SOLARTRON 7150 DMM 6½ digit True RMS - IEEE....£95-£150
SOLARTRON 7150 PLUS....£200

HIGH QUALITY RACAL COUNTERS

9904 Universal Timer Counter, 50MHz....£50
9916 Counter, 10Hz-520MHz....£75
9916 Counter, 10Hz-560MHz, 9-digit....£50
WAYNE KERR B424 Component Bridge....£125
RACAL/AIM 9343M, LCR Databridge, Digital....£200
Automeasurements of R C L Q D
HUNTRON TRACKER Model 1000....£125
MARCONI TF2015 AM/FM sig gen, 10-520MHz....£175
FLUKE 8050A 4.5 Digit, 2A True RMS....£75
FLUKE 8012A 3.5 Digit, 2A....£40

SOLARTRON 7045 Bench Multimeter 4.5 Digit Bright LED with Leads ONLY £30

Portable Appliance Tester Megger Pat 2 ONLY £180

H.P. 6012B DC PSU 0-60V, 0-50A 1000W....£1000
FARNELL AP60/50 1KW Autoranging....£1000
FARNELL H60-/50 0-60V 0-50A....£750
FARNELL H60/25 0-60V, 0-25A....£400
Power Supply HPS3010 0-30V, 0-10A....£140
FARNELL L30-2 0-30V, 0-2A....£80
FARNELL L30-1 0-30V, 0-1A....£60
Many other Power Supplies available.
Isolating Transformer 240V In/Out 500VA....£40

GOULD OS 300 OSCILLOSCOPE

DUAL TRACE 20MHz TESTED WITH MANUAL £95

OSCILLOSCOPES

TEKTRONIX TDS350 Dual Trace 200MHz 1G/S unused....£1500
TEKTRONIX TDS320 Dual Trace 100MHz 500M/S £1200
TEKTRONIX TDS310 Dual Trace 50MHz 200M/S £950
LECROY 9400A Dual Trace 175MHz SG/S....£1500
HITACHI VC6523 Dual Trace 20MHz 20M/S etc unused....£600
PHILIPS PM3092 2+2Ch 200MHz Delay....£800 As New £950
PHILIPS PM3082 2+2Ch 100MHz Delay etc....£700 As New £800
TEKTRONIX TAS465 Dual Trace 100MHz Delay etc £750
TEKTRONIX 2465B 4Ch 400MHz Delay Cursors etc £1500
TEKTRONIX 2465 4Ch 300MHz Delay Cursors etc £900
TEKTRONIX 468 Dig Storage Dual Trace 100MHz Delay....£450
TEKTRONIX 466 Analogue Storage Dual Trace 100MHz....£250
TEKTRONIX 485 Dual Trace 350MHz Delay Sweep £550
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep £400
TEKTRONIX 465B Dual Trace 100MHz Delay Sweep £325
PHILIPS PM3217 Dual Trace 50MHz Delay. £200 - £250
GOULD OS1100 Dual Trace 30MHz Delay....£150
HAMEG HM303 Dual Trace 30MHz Component Tester....£275
HAMEG HN203.7 Dual Trace 20MHz Component Tester....£200
FARNELL DTV20 Dual Trace 20MHz Component Tester....£125

MANY OTHER OSCILLOSCOPES AVAILABLE

MARCONI 2022E Synthesised AM/FM Sig Gen £525 - £750 10KHz - 1.01GHz LCD Display etc
H.P. 8657A Syn 100KHz - 1040MHz Sig Gen....£2000
H.P. 8656B Syn 100KHz - 890MHz Sig Gen....£1350
H.P. 8656A Syn 100KHz - 990 MHz Sig Gen....£995
R&S APN62 Syn 1Hz - 260KHz Sig Gen....£425 Balanced/Unbalanced Output LCD Display
PHILIPS PM5328 Sig Gen 100KHz - 180MHz with 200MHz Freq Counter IEEE....£550
RACAL 9081 Syn AM/FM Sig Gen 5KHz - 1024MHz £250
H.P. 3325A Syn Function Gen 21MHz....£600
MARCONI 6500 Amplitude Analyser....£1500
H.P. 4192A Impedence Analyser....£5000
H.P. 4275A LCR Meter 10KHz - 10MHz....£2750
H.P. 8903A Distortion Analyser....£1000
WAYNE KERR Inductance Analyser 3245....£2000
H.P. 8112A Pulse Generator 50MHz....£1250
MARCONI 2440 Freq Counter 20GHz....£1000
H.P. 5350B Freq Counter 20GHz....£2000
H.P. 5342A 10Hz - 18GHz Freq Counter....£800
H.P. 1650B Logic Analyser 80 Channel....£1000
MARCONI 2305 Mod Meter 500KHz - 2Ghz....£750

RADIO COMMUNICATONS TEST SETS

MARCONI 2955/2955A....from £1500
Rohde & Schwarz CMT 0.1 - 1000MHz....£2000
Schlumberger 4040....£900

JUST IN

H.P. 6063B DC Electronic Load 3-240V/0-10A 250W....P.O.A.
H.P. 66312A PSU 0 - 20V/0-2A....£400
H.P. 66311B PSU 0 - 15V/0-3A....£400
H.P. 66309D PSU Dual 0 - 15V 0-3A/0-12V 0-1.5A. £750
H.P. 6632B PSU 0 - 20V/0-5A....£500
H.P. 6623A PSU Triple Output ranging from 0-7V 0-5A to 0-20V 0-4A....£850
H.P./Agilent 34401A DMM 6½ digit....£400/£450
H.P. 3478A DMM 5½ digit....£275
FLUKE 45 DMM Dual Display....£400
KEITHLEY 2010 DMM 7½ digit....£950
KEITHLEY 617 Programmable Electrometer....£1250
H.P. 4338B Milliohmmeter....£1500
RACAL Counter type 1999 2.6 GHz....£500
H.P. Counter type 53131A 3GHz....£850
H.P./Agilent 33120A Function Gen/ARB 100microHz - 15MHz....£900/£1000
SONY/TEKTRONIX AFG320 Arbitary Function Gen. £1250
H.P. 8904A Syn Function Gen DC - 600KHz £1000/£1250
BLACK STAR JUPITOR 2010 Function Gen 0.2Hz - 2MHz with Frequency Counter....£140
H.P. 8116A Pulse Generator 1mH-50MHz....£1950
H.P. 8657B Syn Signal Gen 0.1-2080MHz....£2500
CO-AXIAL SWITCH 1.5GHz....£40
IEEE CABLES....£10

SPECTRUM ANALYSERS

H.P. 8561B 50Hz - 6.5GHz....£6500
H.P. 8560A 50Hz - 2.9GHz Synthesised....£5000
H.P. 8594E 9KHz - 2.9GHz....£4500/£5000
H.P. 8591E 1MHz - 1.8GHz 75 ohm....£3500
H.P. 853A with 8559A 100KHz - 21GHz....£2250
H.P. 8558B with Main Frame 100KHz - 1500MHz £1250
H.P. 3585a 20Hz - 40MHz....£3000
H.P. 3580A 5Hz - 50KHz....£800
ADVANTEST R4131B 10KHz - 3.5GHz....£3500
EATON/Ailtech 757 0.001 - 22GHz....£1500
MARCONI 2382 100Hz - 400MHz High Res....£2000
MARCONI 2370 30Hz - 110MHz....from £500
H.P. 182 with 8557 10KHz - 350MHz....£500
H.P. 141T Systems
8553 1KHz - 110MHz....from £500
8554 500KHz - 1250MHz....from £750
8555 10MHz - 18GHz....from £1000
TEKTRONIX 491 10MHz - 12.4 GHz....£500
H.P. 8443 Tracking Gen/Counter 110MHz....£250
H.P. 8444 Opt 059....£750
B & K 2033R Signal Analyser....£750
H.P. 5372A Frequency & Time Interval Analyser....£2250
H.P. 8754A Network Analyser 4MHz - 1300MHz....£1250
H.P. 3577A Network Analyser 5Hz - 200MHz....£3000
H.P. 53310A Modulation Domain Analyser Opt 001/003....£5000
ONO SOKKI Portable FFT Analyser....£1500

STEWART OF READING
110 WYKEHAM ROAD, READING, BERKS RG6 1PL
Telephone: (0118) 9268041 Fax: (0118) 9351696
www.stewart-of-reading.co.uk
Callers welcome 9am-5.30pm Monday to Friday (other times by arrangement)

USED EQUIPMENT - GUARANTEED. Manuals supplied.
This is a VERY SMALL SAMPLE OF STOCK. SAE or telephone for lists. Please check availability before ordering. CARRIAGE all units £16. VAT to be added to total of goods and carriage.

Full kit details can be found in the Wilmslow Audio ad on page 45 in this issue.

TYING THE KNOT 2

This month sees the practical implementation of Jeff Macualay's ideas of a full range motional feedback speaker system

Last month I described how, by using the back emf generated by a speaker and a dose of positive feedback, the Q of the bass resonance could be reduced. I also explained the relationship between this idea and standard T/S design theory. Now it's time to roll up my sleeves and produce a design based on this principle. Before doing so however I must discuss the influence of the voice coil inductance upon the performance of such speaker systems.

As you would have noted from the equivalent electrical circuit of a speaker shown in last month's sidebar, the voice coil inductance is in series with the tuned circuit equivalent of the bass resonance. Like the voice coil resistance, this inductance is not constant but varies with the voice coil's position in the gap. It has an influence on the high frequency response of a driver because it forms a series resonant circuit with the reactive components representing the bass resonance. If this is not compensated for in the circuit it will seriously reduce the bandwidth of the system.

The cure is to place a small proportionally sized inductance in series with the sense resistor in the positive feedback circuit. This appears as a negative inductance at the amplifier's output, thus cancelling the voice coil's inductive effect on the circuit. The net effect is to restore a flat overall frequency response to the circuit.

In order to design a successful speaker system we must first define what the objectives are, in other words a specification. In this case I want to produce a small to medium sized monitor speaker capable of 25Hz –3dB. Of course, just as much attention must be paid to the entire frequency range as well as just the bass. As I have to design a modified power amp for the bass section, it makes sense to make the design active and self contained. In this way you only need a signal source and you have a complete audio system. These thoughts lead naturally towards the first design choice, which drivers to use.

For good bass output a large diameter driver with good linear excursion range is indicated. Unfortunately 12" drivers, the logical choice, have a limited piston range and tend to die above 1kHz or so, making crossover design difficult. Just as importantly a wide cabinet would be required leading to poor horizontal sound dispersion and stereo imaging problems. The choice made here is to use a pair of 8" drivers in parallel. These have as great a radiating area as a 12" speaker but fit into a slimmer enclosure. In addition they provide an extra 6db worth of acoustic output, compared to a single driver.

As far as the tweeter is concerned I have chosen to use a Morel MDT29. This is a high quality soft dome unit with a very smooth extended response, high power handling and a low resonant frequency. After perusing a few catalogues and some further thought the bass units chosen were the Morel MW265. These 8" drivers were chosen for their 8mm pk-pk excursion and flat response in the midrange.

Having decided upon the drivers the design work can commence. First to be determined is the required enclosure volume and this means choosing the power amp rating. Since we are designing a domestic system a peak output of 104dB/W/m was designed for. If my neighbours are to be believed this is more than enough output. With a 88dB/W/m sensitivity per driver this is not an arduous task. Two drivers connected in parallel will give 94dB/W/m so the power amp needs an power output of 10db. This works out at 20 watts into 4Ω!

This is convenient because the output amps can be designed around op-amps working at normal supply voltages. Since the rest of the circuitry is op-amp based the circuit can be implemented fairly easily.

Having chosen the drivers the next task was to determine the enclosure size. Using the data sheet information and the method outlined in my previous article this was computed to be 26 litres.

As I had decided to use two woofers, the dimensions of the cabinet were dictated by the need to mount all three drivers on the front panel. I chose to use the MTM (Mid-Top-Mid) layout. This configuration has been used to circumvent phase shifts in odd order crossovers and is popular in the US where it is known as the 'D'Appollitto' configuration.

The design was started by building a prototype enclosure and measuring the frequency response of the drivers in situ. **Figure 1** shows the nearfield response of the MW265. This is measured with a microphone mounted a few millimetres from the cone. No signal gating is used. The response clearly shows the bass resonant peak and rolloff. Measuring the impedance curve showed that the system was operating as a hi-pass 2nd order filter with a turnover

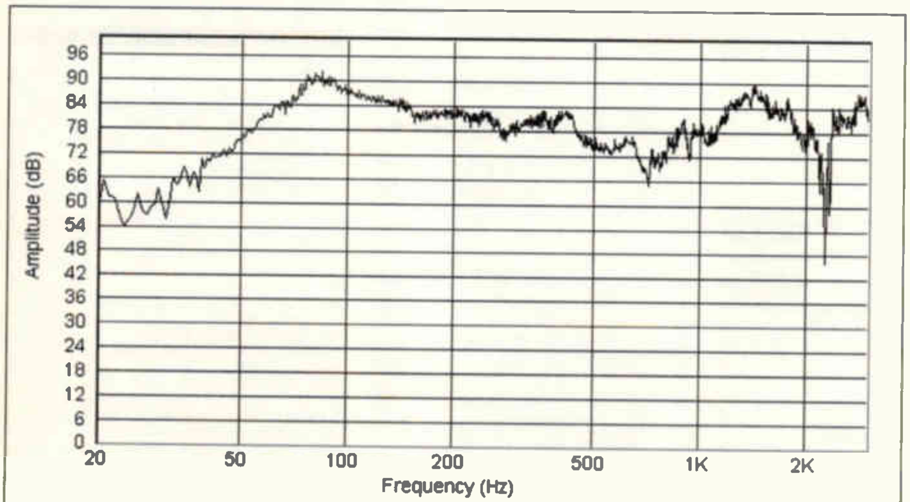


Figure 1: MW265 nearfield response

frequency of 80Hz .This was in accordance with initial T/S calculations.

Next, the speaker was driven from an amplifier modified to give a negative output impedance of –2.1Ω. This was the value calculated to reduce the bass resonant Q to 0.4. **Figure 2** shows the resulting near-field measurement. As you can see, the bass resonant peak has been suppressed but the response resembles that of a band-pass filter centred around 200Hz. This is, of course due to the voice coil inductance resonating with the moving mass as described earlier.

When considering this project I had in mind an active speaker with separate amplifier channels for the woofer and tweeter fed from an active 4th order crossover network. Consequently I set to work breadboarding the necessary circuitry. After a fortnight of work on the project it became clear to me that there must be an easier way. I ended up with 4 quad op-amps per channel. Although it sounded fine it was difficult to obtain a flat enough measured response. At this point I went back to basics. Why not forget about the crossover unit and concentrate on simplicity?

Let me explain. Crossover units are more of a necessary evil than anything else. Even the best of them introduce excessive phase shift that tends to ruin the stereo image. This is especially true around the crossover frequency, as this is usually between 1 and 3kHz, slap bang in the middle of the vocal range, where the ear is at its most sensitive. Only first order crossovers are free from this defect. Unfortunately the frequency range of the drivers needs to be extremely wide for such a crossover to be viable.

The other problem hardly ever addressed in crossover design is the natural rolloff and phase shift introduced by the drivers themselves. Interestingly, the easiest way to minimise phase shift problems is to use crossovers with a large overlap region. That is to allow both drivers to radiate together over an extended range. It was with these thoughts in mind that I looked again at the overall response of the system without a crossover.

The response of the unequalised system rises at 6dB/octave below 2kHz, levelling out at 200Hz before falling in the bass. However most of the woofer's response irregularities have been smoothed out by the applied motional feedback. I reasoned that the response could be rendered sensibly flat by a simple shelving filter. After some bread-boarding, a response within ±4dB between 100Hz and 18kHz was obtained. **Figure 3** shows the overall response obtained by the equalised system.

More importantly was that the sound was now right. Unless you knew better you wouldn't believe that there was no crossover unit. Some might question whether the dome tweeter would be capable of handling the power. Well, the tweeter itself does a good job of rejecting low frequencies as its response drops at 12dB/octave below 900Hz. The addition of a series 10μF capacitor adequately protects this driver from low frequencies. In

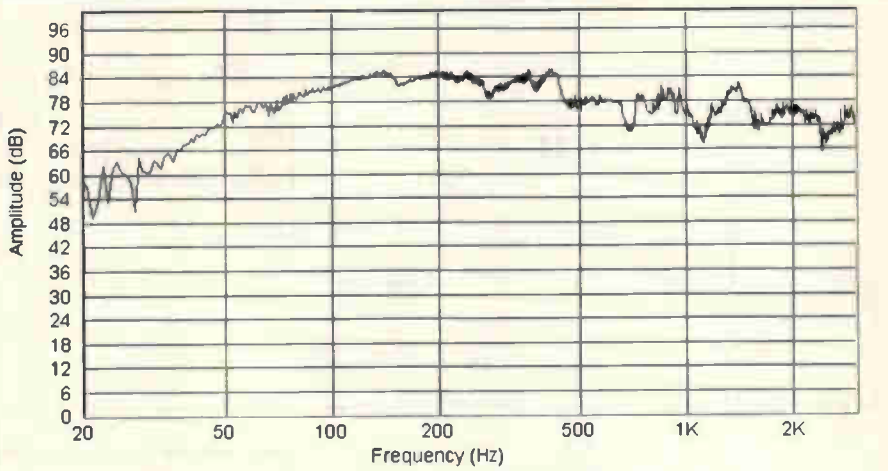


Figure 2: MW265 nearfield response @ -2.1R

fact the acoustic response of the driver/cap combination is >60dB down at 100Hz. I didn't bother to include the tweeter in the motional feedback loop though. There are two reasons for this. Firstly, the acoustic response of the tweeter is that of a critically damped second order hi-pass filter. There would be no advantage in reducing the Q even more. Secondly, the driver tweeter would effectively damp out the impedance of the woofers leading to unpredictable results.

However, the use of a full range speaker system without crossover is not unique. I would like to quote P.J.Baxendall's 1968 Wireless World article, 'Low Cost High Quality Loudspeaker' as an inspiration for this system. In the above mentioned article the author described using equalisation to a small full range driver to obtain a 100Hz to 15kHz flat response. The equaliser consisted of a pair of closely coupled LC circuits. These days op-amps are ubiquitous and very complex transfer functions can be simply obtained by their use.

The bass response was equalised with a separate circuit. The full circuit is shown in **Figure 4a**. Here input signals, at line level, are fed into the non-inverting input of A1 via the volume control VR1. A1 is used as a low gain buffer to provide a low impedance drive for the active filter circuitry. The shelf filtering is done with a passive network comprising C1,R3,R4 and R5. From here the signal is fed into the bass equaliser circuitry built around A2. This equaliser is half passive half active. It consists basically of two near identical low pass, first order filters. The passive part consists of R6, C2 and R9. The signal from the output of the filter is then taken directly to the non-inverting input of A2. The active part of the filter comprises C3,R7 and R8. Both these sections boost the bass response in the 10-40Hz range.

The next stage of the bass equalisation consists of the shunt feedback amplifier built around A3. This applies gentle bass boost between 50-200Hz. The filter consists of C4,R11 and R12. The gain of the circuit, about 6.5dB and the gain of the A1 stage, are necessary to compensate the insertion loss associated with the passive filter sections. Finally the bass response below 20Hz is deliberately curtailed by the hi-pass filter comprising C5,C6,R13 and R14. If this isn't done valuable cone excursion could be wasted unnecessarily, excursion that could be more usefully employed generating bass! The response of the equalisation circuit is the

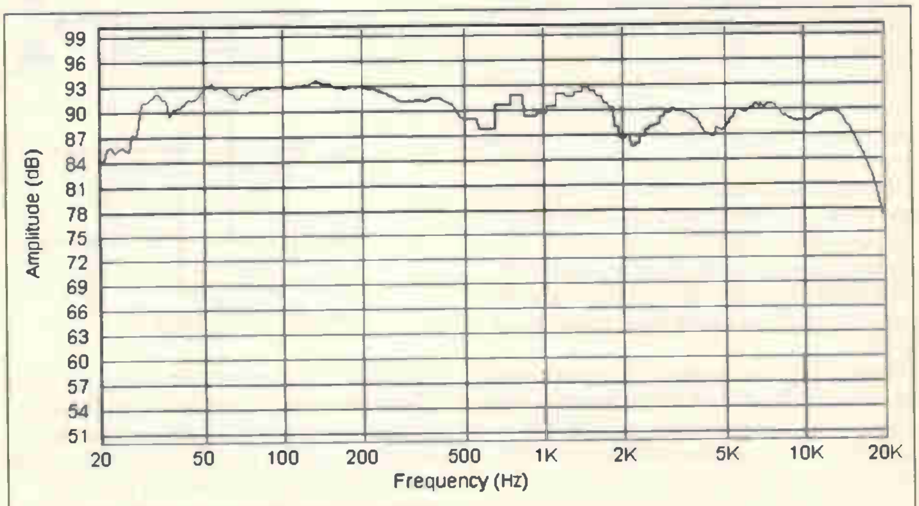
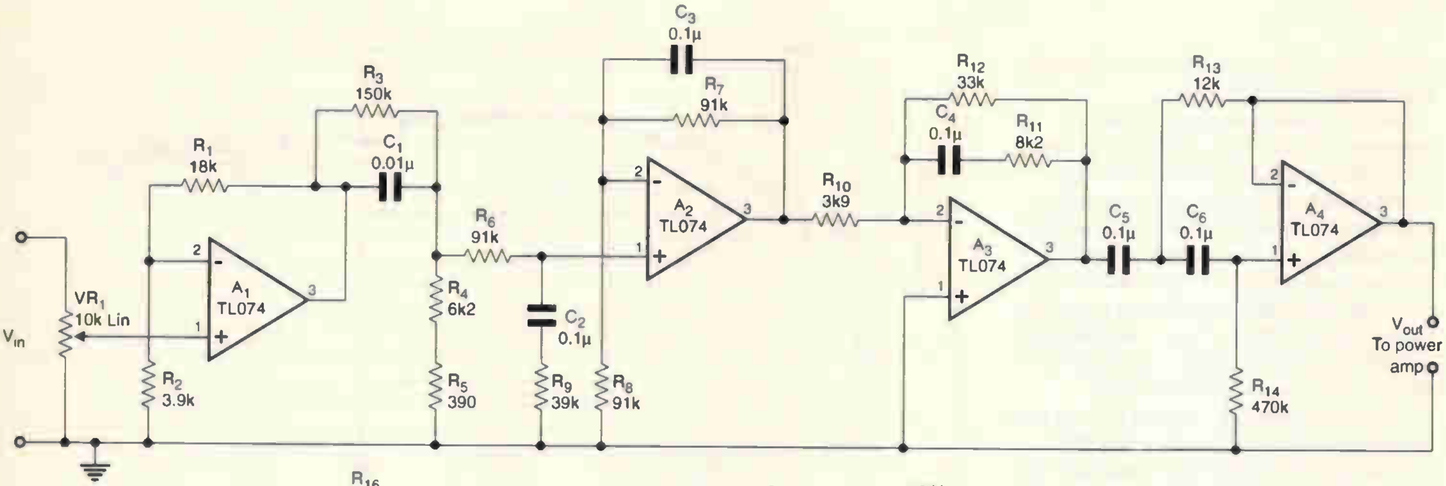


Figure 3: Overall system frequency response



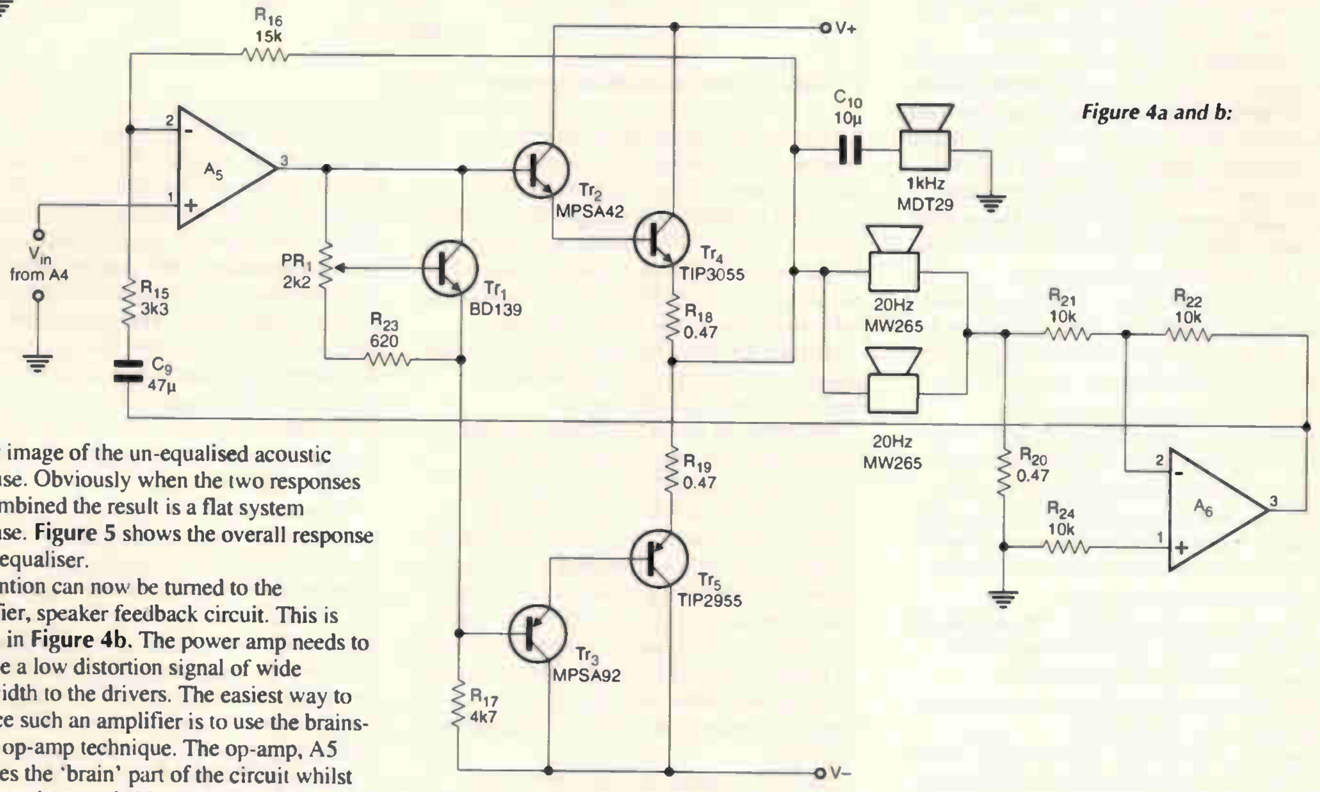


Figure 4a and b:

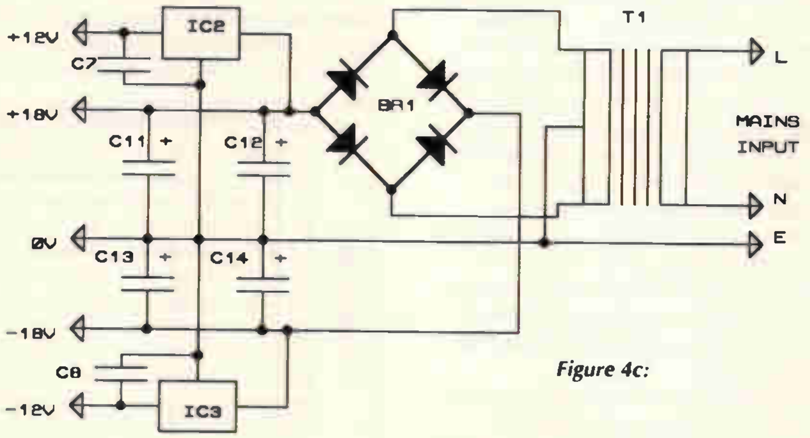


Figure 4c:

mirror image of the un-equalised acoustic response. Obviously when the two responses are combined the result is a flat system response. **Figure 5** shows the overall response of the equaliser.

Attention can now be turned to the amplifier, speaker feedback circuit. This is shown in **Figure 4b**. The power amp needs to provide a low distortion signal of wide bandwidth to the drivers. The easiest way to produce such an amplifier is to use the brains-brawn op-amp technique. The op-amp, A5 provides the 'brain' part of the circuit whilst the brawn is provided by the output stage. Specifically the input signals, supplied from the output of A4 are fed directly to the non-inverting input of A5. The output from A5 is applied to the output stage via the biasing network. This comprises a Vbe multiplier, Q1.PR1,R23 and the biasing resistor R17.

The output stage proper comprises a pair of discrete complementary Darlington pairs. Q2 and Q4 comprise the NPN Darlington and Q3 and Q5 the PNP Darlington. Plastic power transistors are used both to simplify mounting and allow easy mounting of Q1. To remove the possibility of thermal runaway Q1 is mounted directly on the mounting tab of Q4. R18 and R19 are also incorporated to provide linearisation of the output stage at low signal levels.

Overall negative feedback is applied around the circuit by R16 and R15. C9 acts as an open circuit to dc whilst passing ac signals. The amplifier's output is thus stabilised by 100% dc feedback through R16.

Tweeter signals are ac coupled via the 10µF cap C10 whilst the woofers are connected in parallel to the junction of R18 and R19. Signal current through the woofers is sampled as a voltage drop across R20. A6 is used as an inverting amplifier that phase shifts the signals across R20 by 180° to provide a positive feedback signal. Positive and negative feedback signals are mixed together at A5's inverting input via C9, R15 and R16. The amplifier as a whole produces < 0.01% THD at 1kHz and at any level below clipping. Note that the drivers are connected in reverse polarity to compensate for the phase inversion caused by A3.

Finally the PSU. This is shown in **Figure 4c** and is very conventional. The mains voltage is stepped down by T1, full wave rectified by the bridge, BR1. The resulting ± supplies are smoothed by C11 to C12. Parallel capacitors were chosen since they are easier to obtain than 10,000μF types and are somewhat smaller. Stabilised power supplies are used for the equaliser circuit. Voltage regulators IC2 and IC3, de-coupled by C7 and C8 providing the necessary rail voltages.

Having described the circuit operation attention can be turned to the construction of the system. Assembling the circuit requires little comment. As long as the polarised components are correctly orientated no problems should result. Before applying power though it is important to ensure that PR1 is turned fully anticlockwise so that the base and collector of Q1 are shorted together. Naturally the power transistors need to be mounted on a heatsink in the normal way with insulating washers and mica bushes. The heatsink need to be of the 'flat' type rated at 2°C/W or less so that it can be mounted flush with the enclosure rear panel. Note also that Q1 needs to be mounted on the heatsink in a similar way.

Component list

R1	18k	2
R2/10	3k9	4
R3	150k	2
R4	6k2	2
R5	390R	2
R6/7/8	91k	6
R9	39k	2
R11	8k2	2
R12	33k	2
R13	12k	2
R14	470k	2
R15	3k3	2
R16	15k	2
R17	4k7	2
R23	620R	2
R21/22/24	10k	6
PR1	2k2	1
VR1	10k LOG	
R18/19/20	0.47R. 3W	6
C1	10nF	2
C2/3/4/5/6/7/8	100nF	14
C9	47μF 35V NP	4
C10	10μF 35V NP	2
C11/12/13/14	4700μF 25V	8
A1	TL074	2
A2	78L12	2
A3	79L12	2
A4	TL072	2
Tr1	BD139	2
Tr2	MPSA42	2
Tr3	MPSA92	2
Tr4	TIP3055	2
Tr5	TIP2955	2
PCB	PCB	2
BR1	400PIV 3A	2
T1	12-0-12VAC SEC	2
MT1	TO3P	4
SK1	PHONO SKT	1
SK2	PHONO SKT	1
IEC SKT	IEC SKT	2
HEATSINK		1

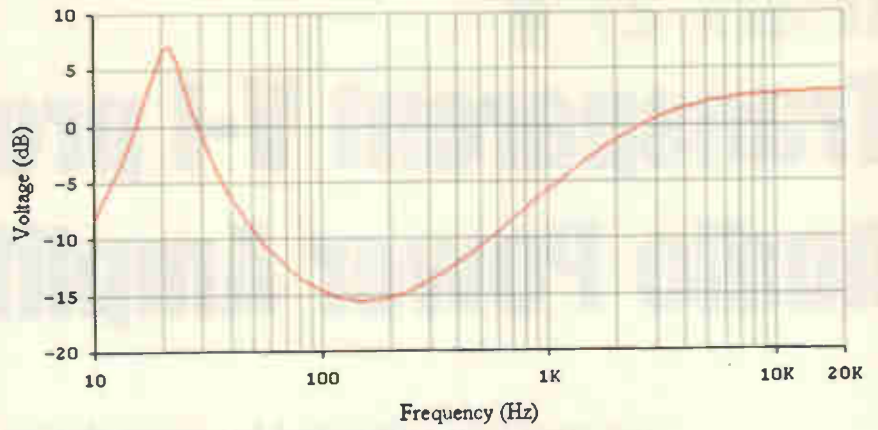


Figure 5: equaliser overall response

The prototype enclosure was built from 15mm thick melamine faced chipboard although there is no reason that equal thickness MDF couldn't be used. The mechanical details are shown in **Figure 6.** It's a good idea to get your timber merchant to cut it to size. There's nothing worse than trying to make enclosures with wrong sized pieces! The main requirement of the enclosures is that they are airtight when assembled. Epoxy rapid is an excellent glue for this purpose. However, it pays to run some interior Polyfilla down the seams to be sure. You will notice that the enclosures contain nothing more complicated than butt joints. This is deliberate. I hate woodwork and there is a requirement to make the back panel removable to allow mounting of the electronics. Notice the internal partition behind the tweeter cut-out. Don't fit this at this stage.

Having glued and screwed the front and sides together the drivers can be mounted. A jigsaw makes short work of this. To ensure an airtight fit, the drivers need to be mounted on a sealing gasket. A strip of draught excluder foam strip is ideal for this purpose. For the speaker wiring nothing exotic is required. 5A domestic mains lead is more than adequate, especially as a length of 50cm on each driver will be ample.

Now the internal partition. This is necessary to stiffen the cabinet and thus eliminate panel resonances. A recess needs to be cut behind the tweeter aperture to avoid fouling it. The dimensions here are not critical. Glue the partition into place.

Now the assembled electronics can be mounted on the back panel. A slot will need to be cut to accommodate the heatsink which is screwed to the outside. Having mounted the electronics on the panel the quiescent current can be set. For your own safety at this stage I would suggest that you bind any live terminals with insulating tape. The quiescent current is set by monitoring the voltage drop across the emitter resistors R18 and R19. First connect the drivers, adjust VR1 to minimum and switch on. Nothing should happen. If you get a loud hum you have a fault, switch off immediately and rectify. Assuming all is well, monitor the voltage drop between Q4 and Q5

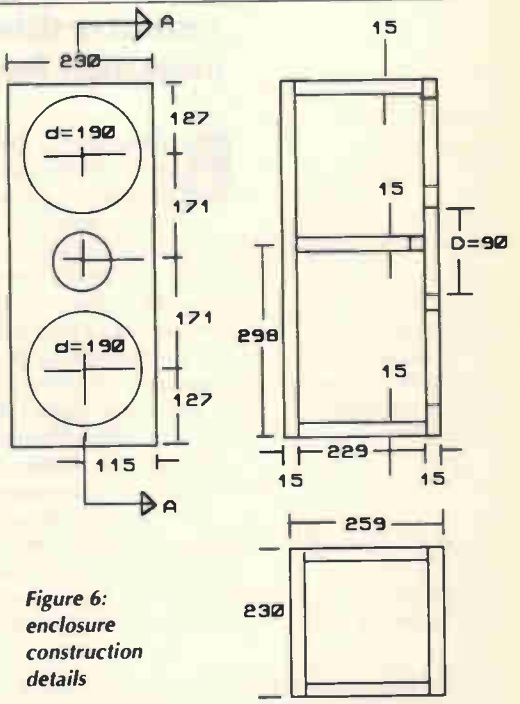


Figure 6: enclosure construction details

emitters whilst slowly adjusting PR1 clockwise. Set this voltage between 10-20mV using a multimeter. Apply a signal to the input and advance VR1. Undistorted sound should emanate from your speaker. All that remains is to fit the rear panel .

In order to do this proceed as follows. Temporarily tape the rear panel into place with masking tape. Drill 3mm holes around the periphery of the panel into the assembled cabinet. Countersink the holes. Remove the tape and insert some foam strip between the surfaces to ensure an airtight seal. Screw the back panel into place with some 25mm, No 8 ST screws. You now have a functioning system.

As a final note I would recommend this system to any hi-fi enthusiast who likes constructing their own gear. The combination of motional feedback and the lack of crossover give an excellent transient response. Bass is solid and extended and the stereo imaging is three dimensional with good recordings. ■

(Part 2)

Transparent V-I protection in Audio Power Amplifiers

"The aversion cultivated by some designers to *V-I* limiting in audio power amplifiers is wholly illusory," argues Michael Kiwanuka in his second article on the topic of implementing no-compromise output protection for audio power amplifiers.

*Figs 1-25 were presented in last month's article, as were equations 1-9, Ed.

Michael Kiwanuka, B.Sc. (Hons), Electronic Engineering.

Building on last month's discussion of single-slope, single-breakpoint non-linear foldback limiting, this next section covers a dual-slope alternative.

Introducing a resistor, R_d, in series with the diode in **Fig. 27** causes the voltage drop across the series combination to increase linearly above the diode's conduction threshold. In turn, this induces a net linear increase in potential across the voltage divider R_{2A}, and R_{2B}. This gives rise to segment B-D in the protection locus, **Fig. 26**, whose gradient can be varied linearly with R_d about point B. This allows greater flexibility with regard to optimal placement of the breakpoint. For brevity the essential diodes D_F and D_P described in part 1 of this paper are omitted in all subsequent figures.

As is the case with single-slope, linear foldback limiting, segment B-D must intersect the safe operating area's V_{ce} axis at a value greater than the sum of the moduli of the supply rails, if spurious limiter activation is to be prevented. Available current per output pair at V_{ce}≈4V, is further increased to 12A8 compared to 7A1 for the locus in Fig. 13*.

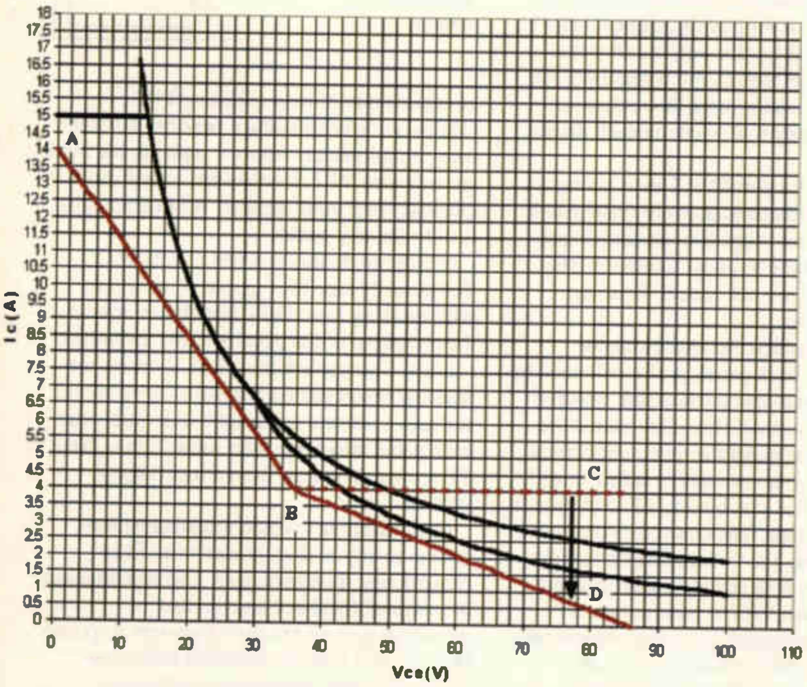


Figure 26: Dual slope, single breakpoint, non-linear foldback protection locus

Initially, resistor values without R_d are calculated for segment A-B-C, **Figs 28, 29,** and the value of R_d established *in situ*, **Fig. 30,** using any convenient set of points along B-D.

With reference to Fig. 28, and selecting R_1=8K2; I_d=1mA:

$$I_1 = I_d + I_2 + I_3 \qquad (10)$$

And,

$$R_{2B} = \left(\frac{0.6}{0.88}\right) R_{2A} \qquad (11)$$

From equation 10:

$$\frac{(40-4.6)}{8k2} = 1mA + \frac{0.88}{R_{2A}} + \frac{0.6}{R_3} \qquad (12)$$

From Fig. 29, and invoking equation 11:

$$0.6 = \frac{3.08R_{2A}(0.6/0.88)}{R_{2A}(0.6/0.88) + R_{2A} + 8K2R_3/(8K2+R_3)} \qquad (13)$$

Solving (12), and (13), simultaneously:

$$R_3 \approx 704R7,$$

$$R_{2A} \approx 356R9.$$

And,

$$R_{2B} = (0.6/0.88)R_{2A} \approx 243R3.$$

With reference to Fig. 30:

$$I_2 = (0.6/R_{2B}) = (0.6/243R3) \approx 2.47mA$$

$$V_X = (I_2R_{2A} - 39V4) \approx -38V52$$

$$V_{R3} = (V_X + 39V89) \approx 1V37$$

$$I_3 = (V_{R3}/R_3) \approx 1.94mA$$

But,

$$I_d = I_1 - (I_2 + I_3) \qquad (14)$$

Where,

$$I_1 = (40 - V_X)/8K2 \approx 9.58mA$$

$$I_d = 9.58mA - (2.47mA + 1.94mA) \approx 5.17mA$$

$$R_d = (V_{Rd}/I_d) = (V_{R3} - 0.6)/I_d \approx 149R1.$$

It is worth considering that the forward voltage drop, V_f is around 0V6 when I_d is about a milliamp for most small signal diodes at 27°C. For a suitable device though, such as the 1N4148, V_f is around 0V65 when I_d is 5mA. This requires that R_d calculated above be revised downwards for enhanced precision. Thus,

$$R_d = (V_{Rd}/I_d) = (V_{R3} - 0.65)/I_d \approx 139R3$$

As previously recommended, the calculated resistor values should be made up from series, and/or parallel combinations of 1% components where necessary.

The dual-slope, single-breakpoint scheme in Fig. 31, sometimes erroneously[1] described as 'treble slope', (sic), is an amalgam of the circuits in Figs 5 and 18.

As in Fig. 18, the breakpoint occurs at $V_{out} \approx 0$V, i.e. $V_{ce} \approx V_{cc}$, giving locus A-D-E-F, **Fig. 32**. However, segment D-E-F, being part of C-D-E-F, is established by R_1 and R_3. As a result, its efficacy is therefore dependant on the value of R_e as the network in Fig. 5.

Resistor R_2 merely pulls the base of the protection transistor low as required for $0V \leq V_{ce} < 40V$. This gives segment A-D, whose position in the safe operating area is

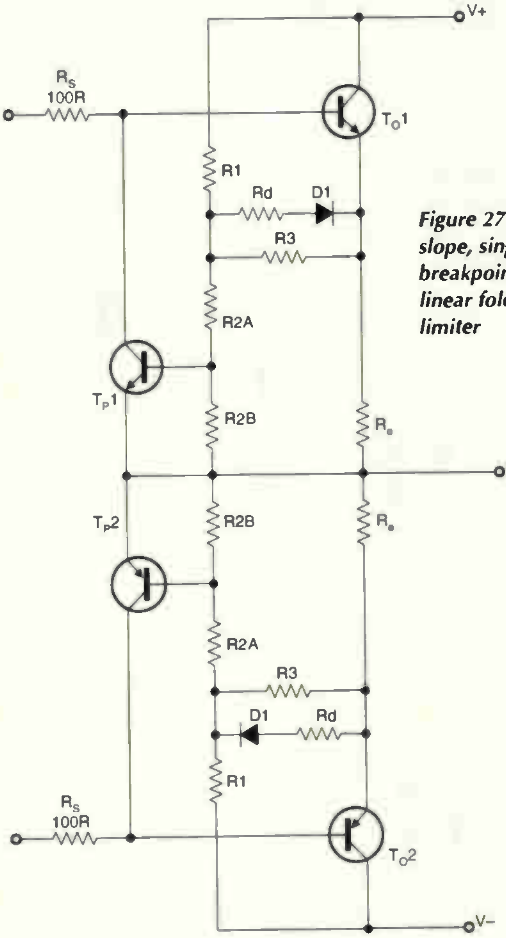


Figure 27: Dual slope, single breakpoint, non-linear foldback limiter

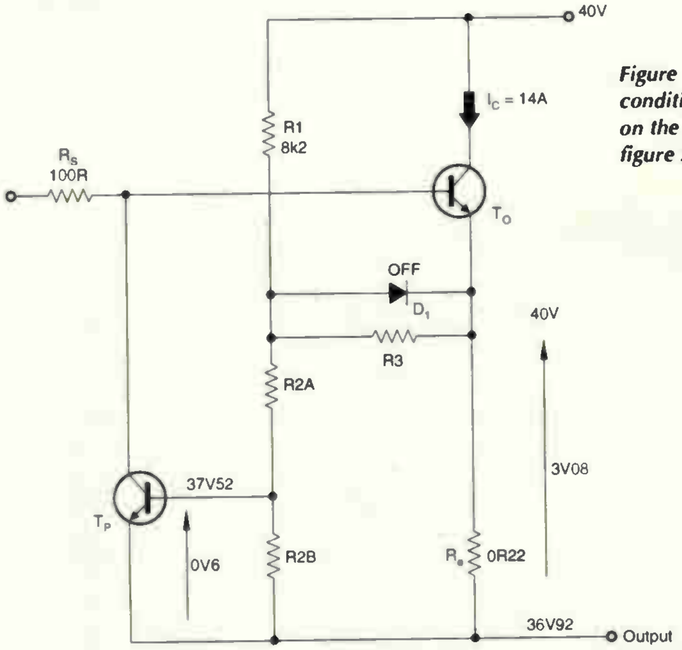


Figure 29: Output conditions at point A on the locus in figure 26

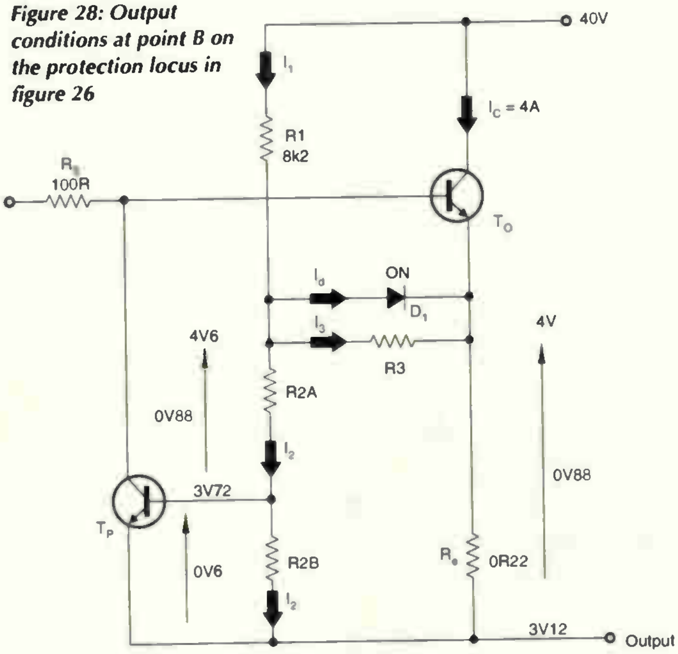


Figure 28: Output conditions at point B on the protection locus in figure 26

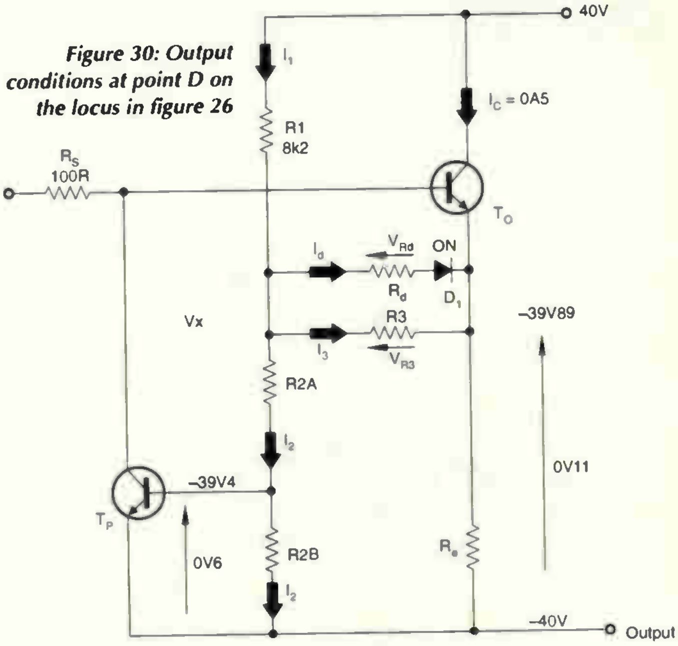


Figure 30: Output conditions at point D on the locus in figure 26

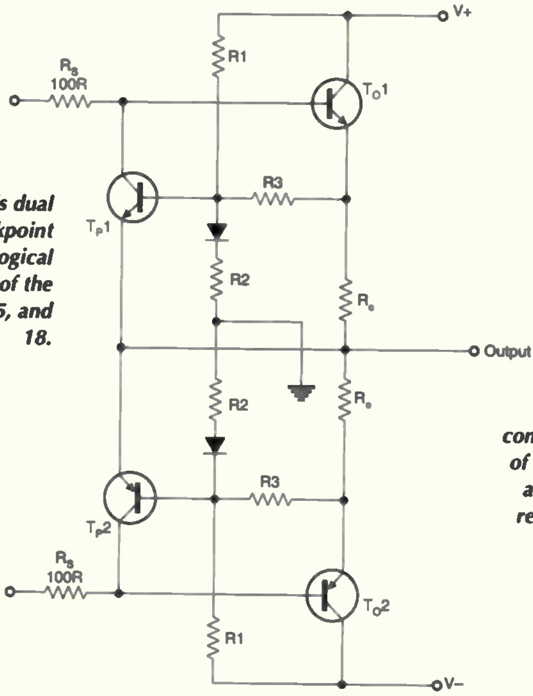


Figure 31: This dual slope single breakpoint scheme is a logical development of the circuits in figures 5, and 18.

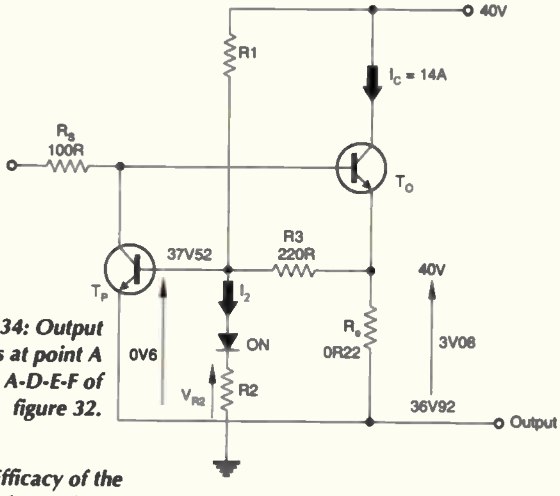
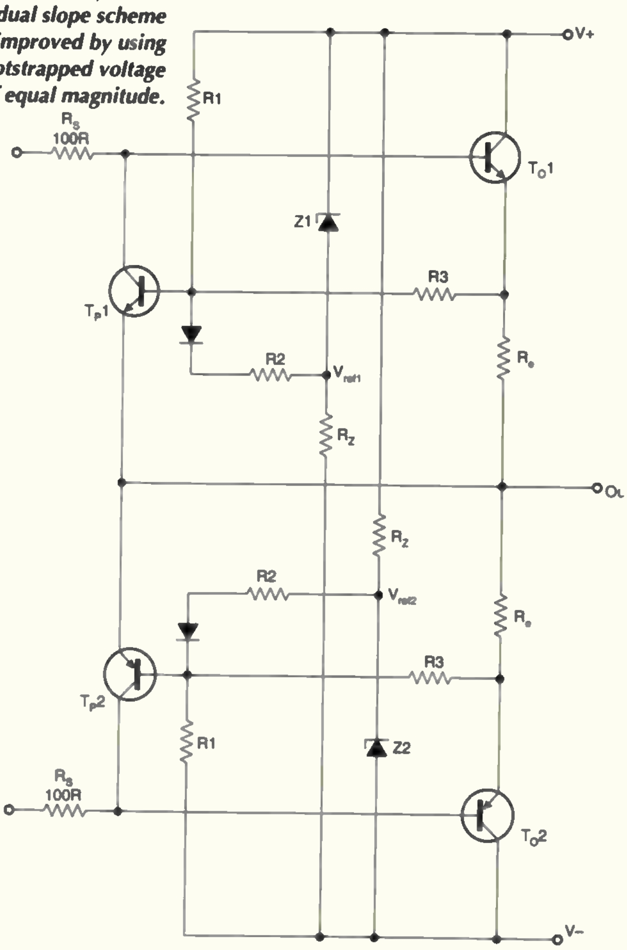


Figure 34: Output conditions at point A on locus A-D-E-F of figure 32.

Figure 35: Efficacy of the compromised dual slope scheme of fiure 31 is improved by using arbitary, bootstrapped voltage references of equal magnitude.



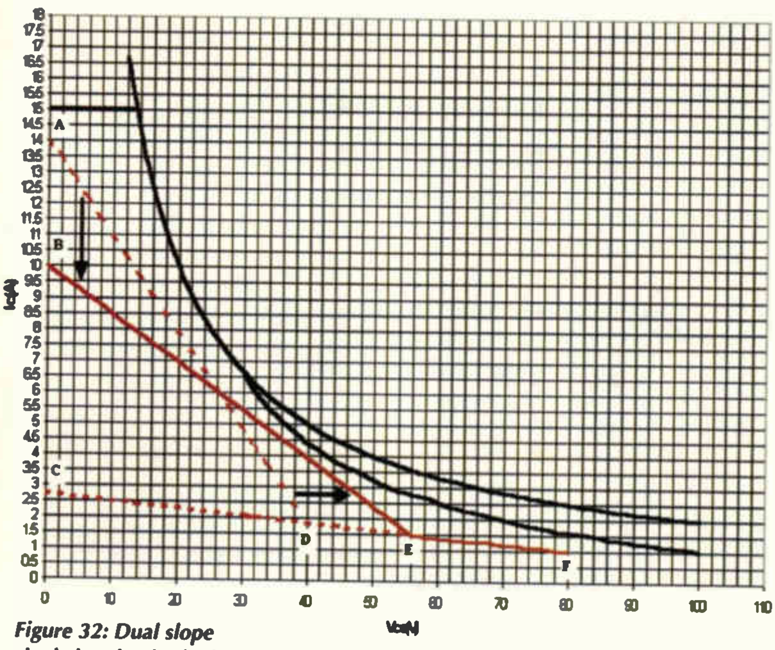


Figure 32: Dual slope single breakpoint loci described by the circuits in figure 31 and 35.

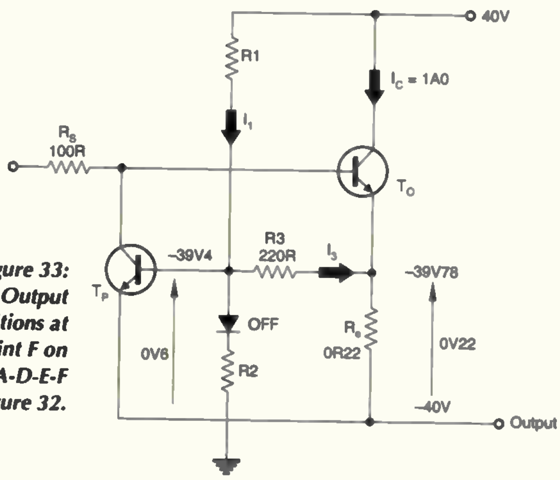


Figure 33: Output conditions at point F on locus A-D-E-F of figure 32.

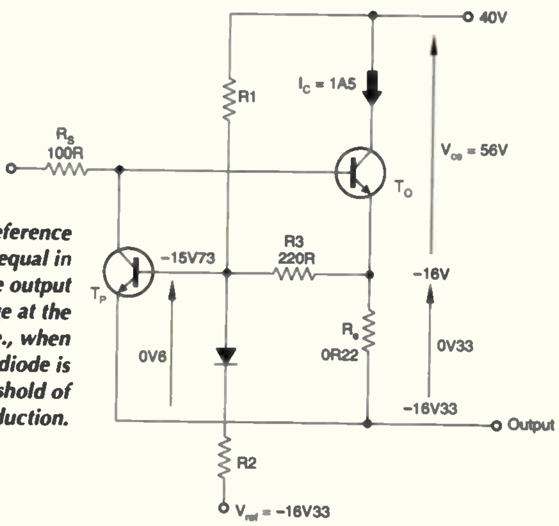


Figure 36: The reference voltage is made equal in magnitude to the output voltage at the breakpoint, (i.e., when Vce=56V); the diode is then at the threshold of conduction.

ill-defined for non-ideal supply rails, due to the use of an invariant voltage reference.

Since the breakpoint for this arrangement is fixed at $V_{ce} \approx V_{cc}$, only points A and F on locus A-D-E-F are required to obtain a solution.

With reference to **Fig. 33,** let R_3=220R. and $V_{cc} \approx$40V:

$$I_1 \approx I_3$$

Where,

$$I_3 = (-39.4 + 39.78)/220R \approx 1.73\text{mA}$$

and,

$$R_1 = (40 + 39.4)/1.73\text{mA} \approx 46K$$

With reference to **Fig. 34:**

$$I_2 \approx (40 - 37.52)/(R_1 // R_3) = 2.48/219R \approx 11.33\text{mA}$$

With $V_f \approx$0V7 at 11mA.

$$R_2 = V_{R2}/I_2 = (37.52 - 0.7)/11.33\text{mA} \approx 3K3$$

This scheme is clearly inferior to the standard linear foldback arrangement of Fig. 1. It delivers only 1A5 at $V_{ce} \approx$45V97, requiring a minimum of six output pairs for 4Ω∠±60° load drive from ±40V supply rails.

As in Fig. 22, the network in Fig. 31 can be usefully improved, **Fig. 35,** by changing the diode reference from zero to an arbitrary voltage, V_{ref}, such that, $0\text{V}<|V_{ref}|<|V_{cc}|$. This enhances the flexibility of the circuit, as the breakpoint can now be moved freely along segment C-F. This gives rise to a more efficient locus, B-E-F, Fig. 32, whose position in the safe operating area is unaffected by supply rail variation.

The reference voltage is established by determining the output conditions at the breakpoint, **Fig. 36**. Therefore for locus B-E-F in Fig. 32, V_{Ref1}=−16V33 and V_{Ref2}=+16V33. This calls for a nominal 56V33 zener diode. As previously recommended, multiple low-voltage devices should be used to minimise series impedance.

With reference to **Fig. 37:**

$$I_1 \approx I_3$$

Where,

$$I_3 = (-39.4 + 39.78)/220R \approx 1.73\text{mA}$$

$$R_1 = (40 + 39.4)/1.73\text{mA} \approx 46K$$

Referring to **Fig. 38:**

$$I_2 = (40 - 38.4)/(R_1 // R_3) = 1.6/219R0 \approx 7.3\text{mA}$$

With $V_f \approx$0V65 at 7mA.

$$R_2 = V_{R2}/I_2 = (38.4 - 0.65 + 16.33)/7.3\text{mA} \approx 7K4$$

Note that there is no change in the value of R_1 and R_3 in the circuits of Figs 5, 31, and 35, with different values of R_2 required to merely pull the base of the protection transistor low as appropriate when the series diode is forward biased.

Although the efficacy of the protection locus is in part ameliorated by the means described above, the gradient of segment E-F, being part of C-D-E-F, is determined by resistors $R_{1,3}$, and limited by practical values of R_e – an affliction absent in the circuit of Fig. 27.

Complete independence from R_e of both segments of the dual slope protection locus described by the circuit in Fig. 35 can be accomplished by the introduction of a base-emitter resistor, R_2, **Fig. 39,** for each protection transistor. The result is in fact merely a union of the linear single slope scheme of Fig. 1, and the non-linear single slope circuit of Fig. 22.

The linear, single slope locus in Fig. 2 is reproduced in

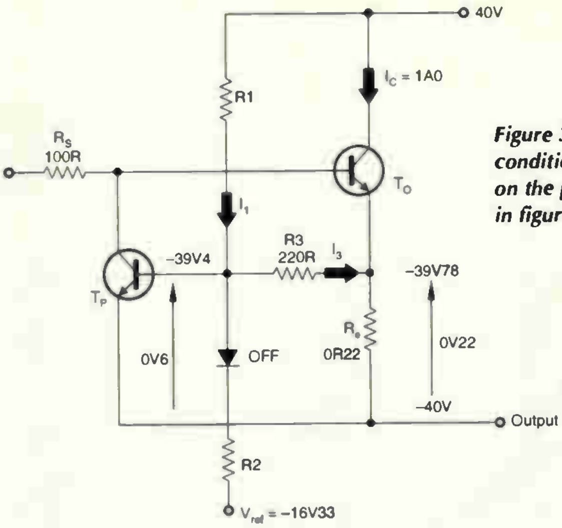


Figure 37: Output conditions at point F on the protection locus in figure 32.

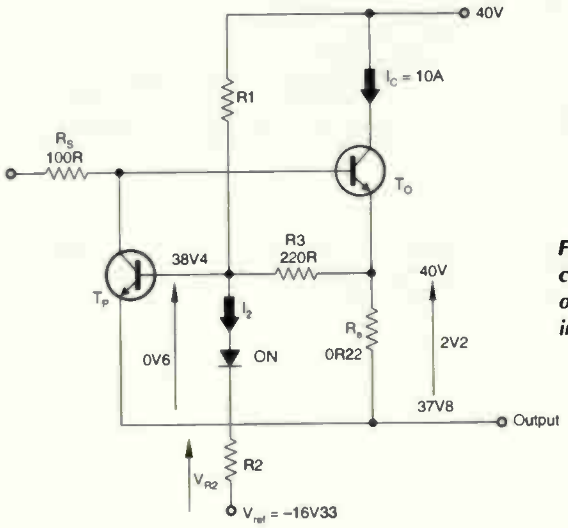


Figure 38: Output conditions at point B on the protection locus in figure 32.

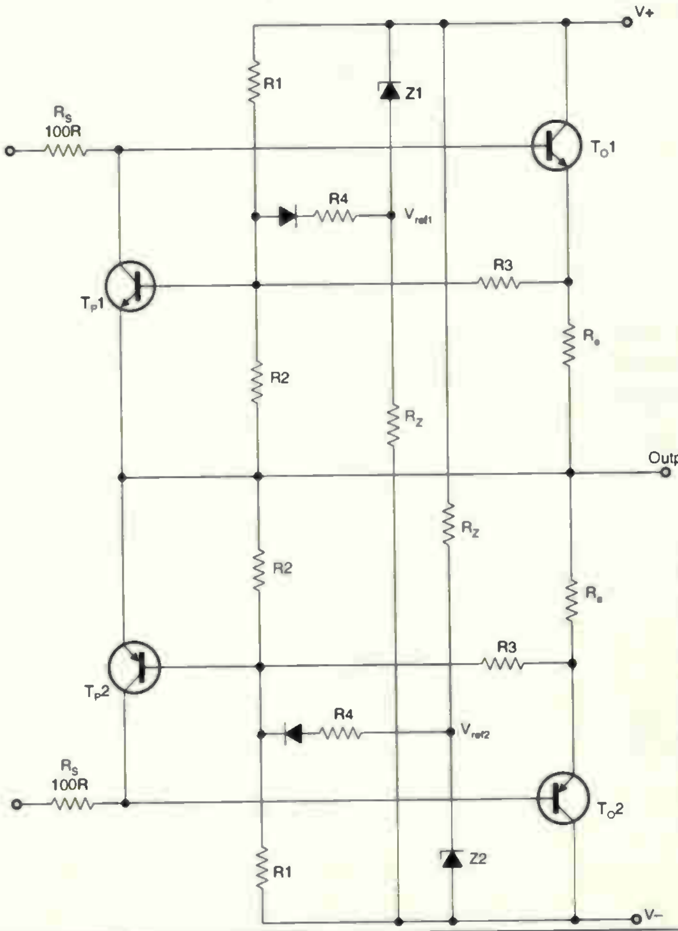


Figure 39: Introducing resistor R_2 into the circuit of figure 35 permits placement of an arbitary locus in the S.O.A., without undue dependence on the value of R_e.

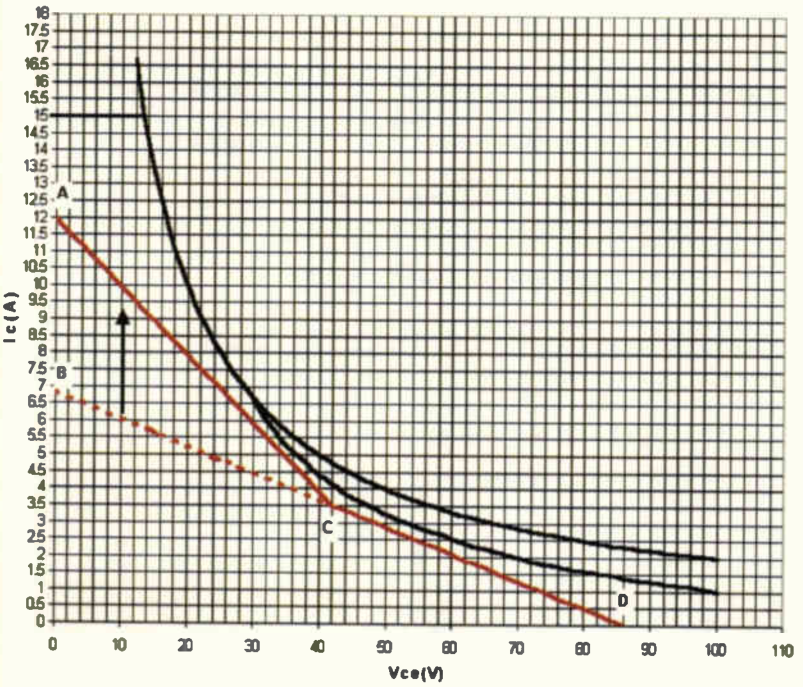


Figure 40: Dual slope, single breakpoint locus described by the circuit of figure 39. Resistor R4 modifies the linear single slope segment B-C-D, of figure 2 by effecting a vertical translation of segment B-C about point C.

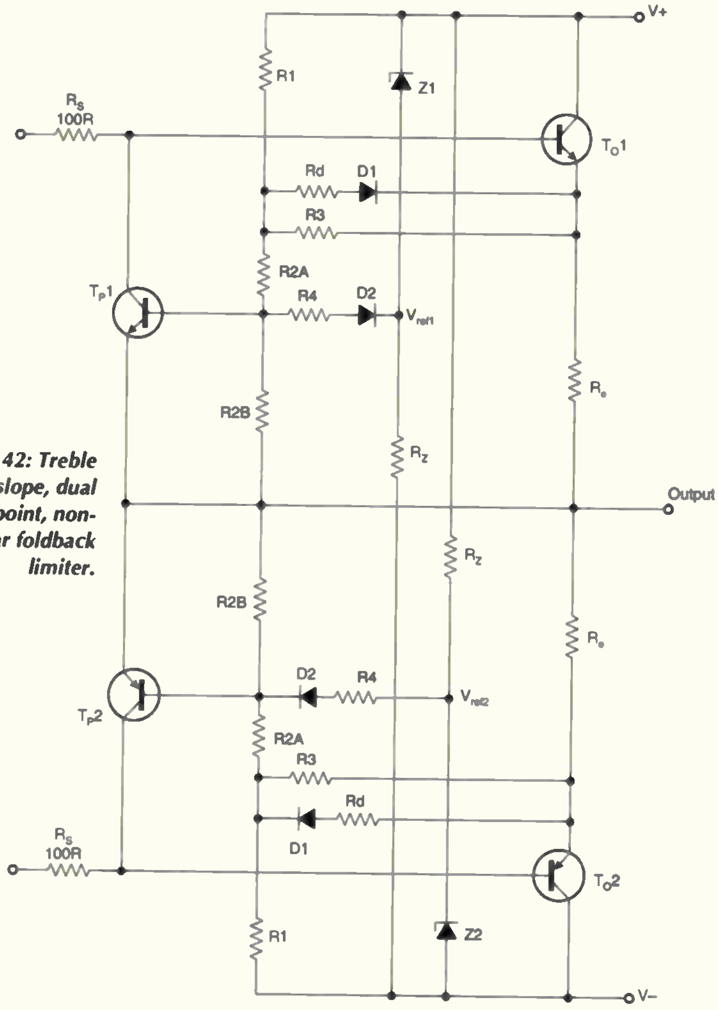


Figure 42: Treble slope, dual breakpoint, non-linear foldback limiter.

Figure 41: Output conditions at point A on protection locus A-C-D in figure 40.

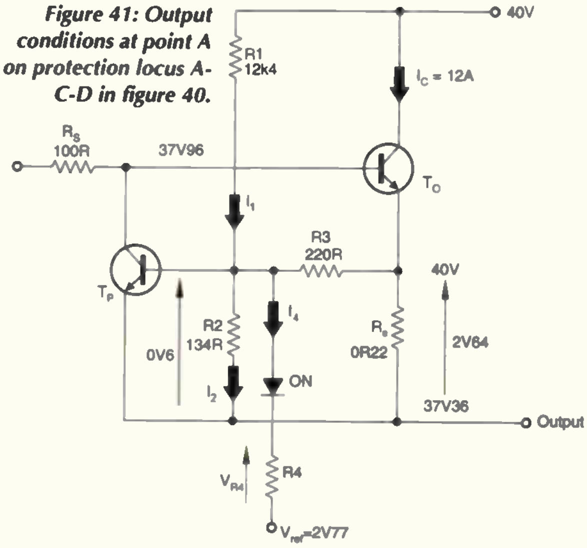


Fig. 40 as segment B-C-D, for which equations (1) and (3) are valid. So, referring to **Fig. 41,** with R_3=220R, then R_1=12K4kΩ, and R_2=143R. Resistor R_4 pulls the base of the protection transistor low as required for 0V$\leq V_{ce}\leq$42V, giving segment A-C.

The reference voltage is equal to the output voltage when V_{ce}=42V, thus,

$$V_{Ref1} = 40V - \{42V + (3A5 \times 0R22)\} = -2V77,$$

and V_{Ref2}=+2V77.

Referring to Fig. 41:

$$(I_2 + I_4) = (I_1 + I_3)$$

$$I_4 = (I_1 + I_3 - I_2)$$

$$I_4 =$$

$$(40 - 37.96)/12K4 + (40 - 37.96)/220R - 0.6/143R$$

$$I_4 = 5.24\text{mA}$$

With $V_f\approx$0V6,

$$R_4 = V_{R4}/I_4 = (37.96 - 0.6 + 2.77)/5.24\text{mA}$$

$$R_4 = 7K7$$

The flexibility of the scheme in Fig. 39 is significantly improved relative to Fig. 35. However such flexibility is easily surpassed by the network in Fig. 27, whose accuracy is not compromised by dependence on discreet value zener references.

Treble-slope, (dual-breakpoint) non-linear foldback limiting

With modern power transistors and practical loudspeaker systems, an optimally located dual-slope protection locus realised by the limiter in Fig. 27 can hardly be improved upon with respect to efficiency in the critical $|V_{cc}|\leq V_{ce}<2|V_{cc}|$ region.

However, for purely resistive laboratory loads with which a power amplifier's published specifications are obtained, the 0V$\leq V_{ce}\leq|V_{cc}|$ region of the safe operating area is of primary interest, Fig. 10.

In a competitive market place therefore, even when the truth of the matter is known, an amplifier designed to maintain its rated voltage swing across resistive loads of decreasing magnitude – down to 1Ω – without limiter intrusion, may be commercially rewarding. A suitably robust power supply and conservative thermal management are assumed.

To this end the treble-slope design in **Fig. 42** is presented. The circuit is a straightforward amalgam of the dual-slope scheme of Fig. 27, and the single slope, single breakpoint network of Fig. 22.

The circuit in Fig. 27 produces the dual slope characteristic B-D-F. **Fig. 43**, while resistor R_4 pulls the base of the protection transistor low as appropriate for $0V \le V_{ce} \le 42V$, giving segment A-C. Fifty-volt supply rails are assumed; a treble-slope locus with ±40V rails is vastly unnecessary.

The reference voltage is equal in magnitude to the output voltage V_{out} at breakpoint C, Fig. 43. Thus,

$$\left|V_{Ref1}\right| = \left|V_{Ref2}\right| = \left|V_{out}\right|_{V_{ce}=42V} = 7V23$$

with V_{Ref1} at $7V23$ and V_{Ref2} at $-7V23$.

As previously established for Fig. 27, component values without R_d are calculated for segment B-D-E. (**Figs 44** and **45**), and the value of R_d established *in situ*, **Fig. 46**, using any convenient set of points along D-F. Resistor R_4 is then calculated for a nominal V_{ce}=0V, at point A **Fig. 47**.

With reference to Fig. 44, let $R_1 = 8K2$, and $V_f \approx 0V6$ when $I_d = 1\,mA$.

$$I_1 = I_d + I_2 + I_3 \tag{15}$$

And,

$$R_{2B} = \left(\frac{0.6}{0.44}\right) R_{2A} \tag{16}$$

From equation 15:

$$\frac{(50 + 11.4)}{8K2} = 1mA + \frac{0.44}{R_{2A}} + \frac{0.6}{R_3} \tag{17}$$

From Fig. 45, and invoking equation 16:

$$0.6 = \frac{1.474 R_{2A}(0.6/0.44)}{R_{2A}(0.6/0.44) + R_{2A} + 8K2 R_3/(8K2 + R_3)} \tag{18}$$

Solving (17) and (18) simultaneously:

$$R_3 \approx 160R7$$

$$R_{2A} \approx 159R8$$

$$R_{2B} = (0.6/0.44)R_{2A} \approx 217R9$$

With reference to Fig. 46:

$$I_2 = (0.6/R_{2B}) = (0.6/217R9) \approx 2.75mA$$

$$V_X = (I_2 R_{2A} - 49V4) \approx -48V96$$

$$V_{R3} = (V_X + 49V89) \approx 0V93$$

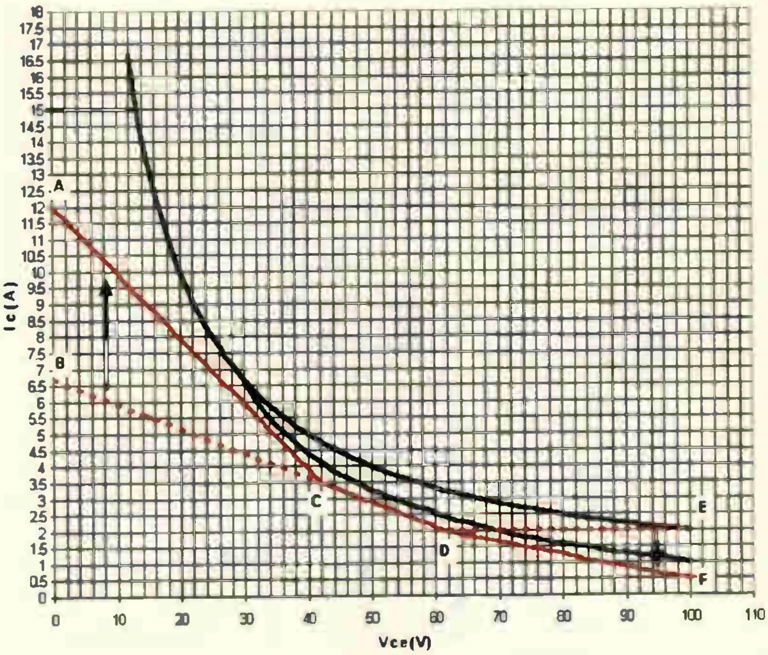


Figure 43: Treble slope, dual breakpoint protection locus described by the circuit of figure 42, Resistor R4 modifies the dual slope characteristic B-D-F by effecting a vertical translation of segment B-C about point C.

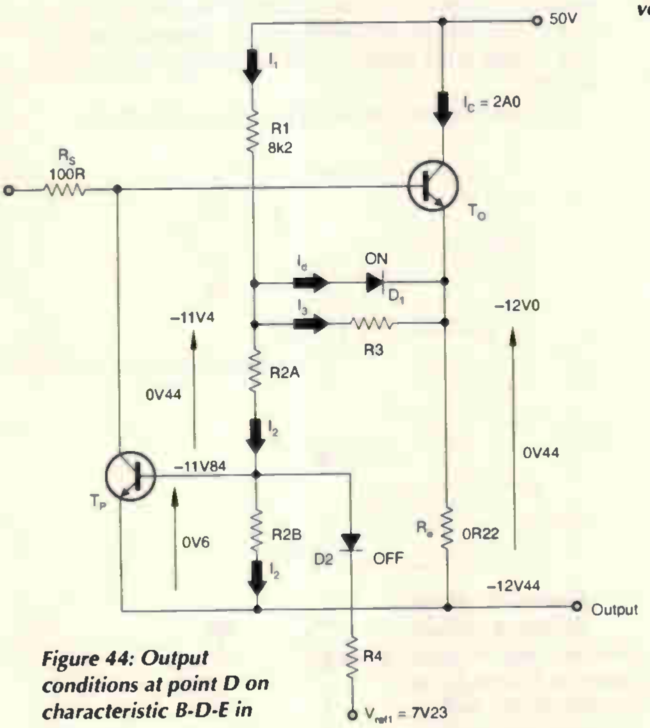


Figure 44: Output conditions at point D on characteristic B-D-E in figure 43.

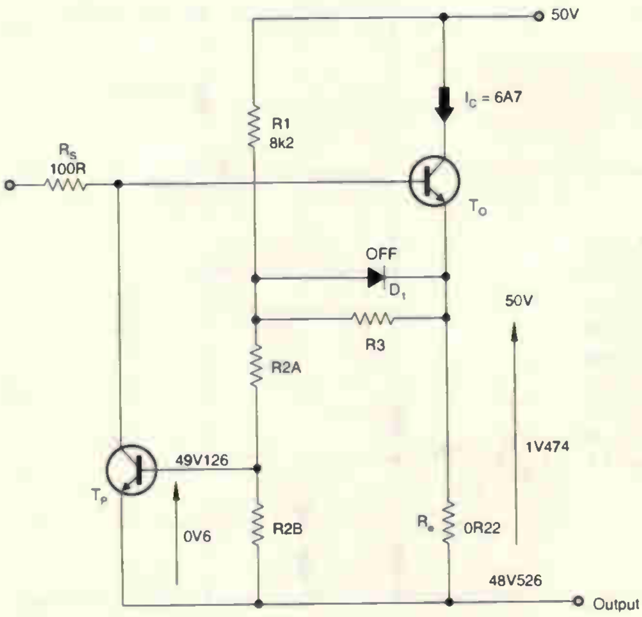


Figure 45: Output conditions at point B on characteristic B-D-E in figure 43.

But,

$$I_d = I_1 - (I_2 + I_3) \qquad (19)$$

Where,

$$I_1 = (40 - V_X)/8K2 \approx 10.85mA.$$

$$I_d = 10.85mA - (2.75mA + 5.79mA) \approx 2.31mA$$

$$R_d = (V_{Rd}/I_d) = (V_{R3} - 0.6)/I_d \approx 143R0$$

From Fig. 47:

$$R_4 = (V_{R4}/I_4) \qquad (20)$$

Where:

$$I_4 = I_{2A} - I_{2B} \qquad (21)$$

$$I_4 = \frac{(50 - 47.96)}{\{(R_1 // R_3) + R_{2A}\}} - \frac{0.6}{R_{2B}} \approx 3.67mA$$

$$R_4 = (47.96 - 7.23 - 0.6)/3.67mA \approx 10K9$$

A $4\Omega\angle\pm60°$ load driven to ±50V rails requires $i_c \approx 9A5$ when $v_{ce} \approx 59V$, resulting in peak transistor dissipation, $P_{d(max)} \approx 561W$. The treble slope protection locus of Fig. 43 allows 2A at $v_{ce} \approx 59V$ for a single complementary transistor pair. Therefore, five complementary pairs are required to drive a notional $4\Omega\angle\pm60°$ loudspeaker system from ±50V supply rails without intrusive limiter activation.

The required reference voltage calls for a nominal 42V77 voltage drop across Z_1 and Z_2. As previously recommended, the required voltage drop should be realised with multiple low-voltage devices, of 6V to 12V, as a series combination of these should collectively possess a significantly lower series impedance than a single high voltage device.

In practice, Z_1 and Z_2 may each consist of five ZPD6.8RL, in series with a single ZPD8.2RL, biased at a nominal quiescent current of 10mA by R_z.

A more elegant – if rather tedious – approach[2] compensates for variation in zener voltage drop with temperature. This calls for the introduction of typically two to four forward biased diodes in series with the zener diode.

The decreasing voltage of the forward biased p-n junctions with increasing temperature, (negative temperature coefficient), tends to counteract the increase in zener voltage with increasing temperature, (positive temperature coefficient), and conversely. Therefore Z_1 and Z_2 may each consist of a series combination of three IN961B 10V zeners, a single ZPD8.2RL 8.2V device, and seven 1N4148 forward biased diodes.

For brevity perhaps, in place of Z_1 and Z_2, the shunt-feedback circuit of **Fig. 48** may be used with a single, temperature compensated zener reference diode, such as the 6.2V 1N829A. This circuit permits the synthesis of a high voltage source without recourse to loose-tolerance, high voltage zener diodes, or indeed multiple small-value devices.

However, the variation in zener voltage drop due to

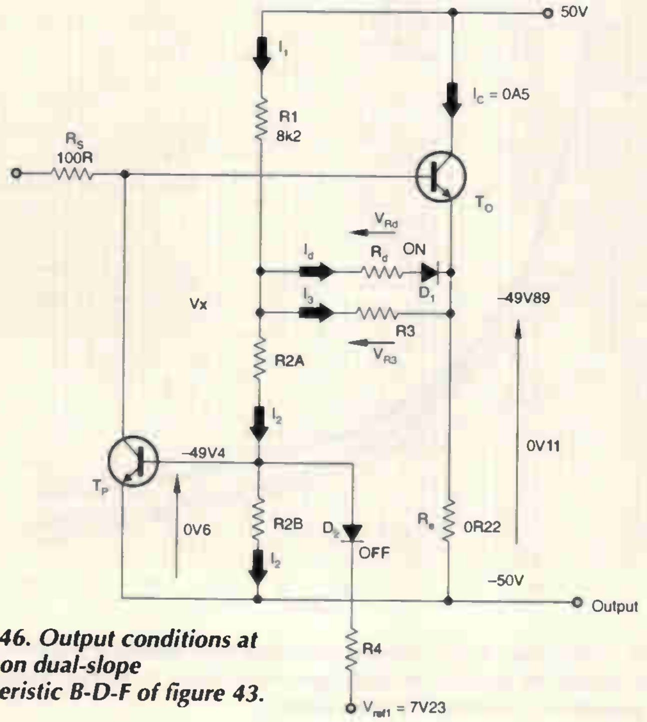


Figure: 46. Output conditions at point F on dual-slope characteristic B-D-F of figure 43.

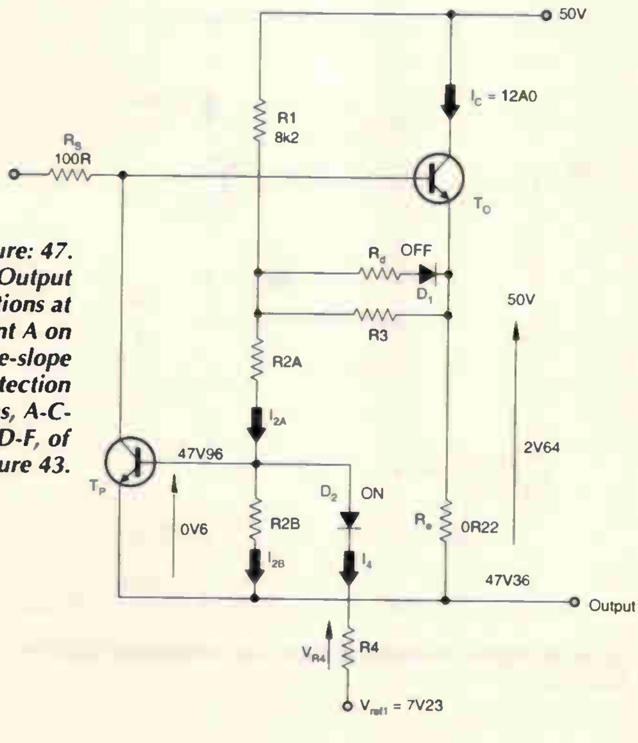


Figure: 47. Output conditions at point A on treble-slope protection locus, A-C-D-F, of figure 43.

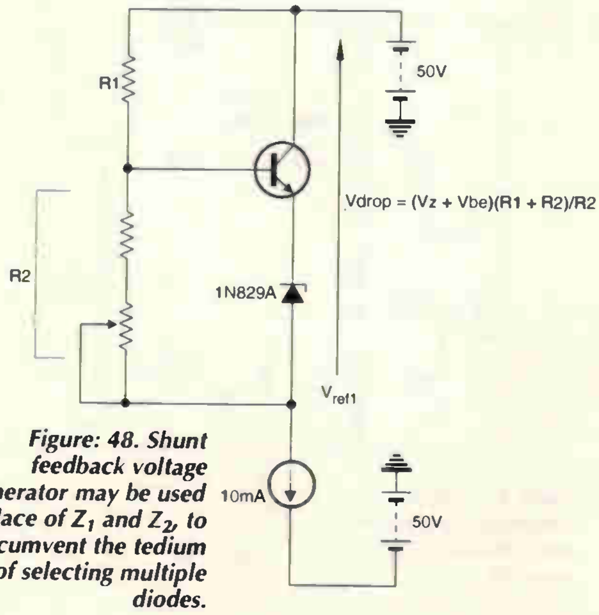


Figure: 48. Shunt feedback voltage generator may be used in place of Z_1 and Z_2, to circumvent the tedium of selecting multiple diodes.

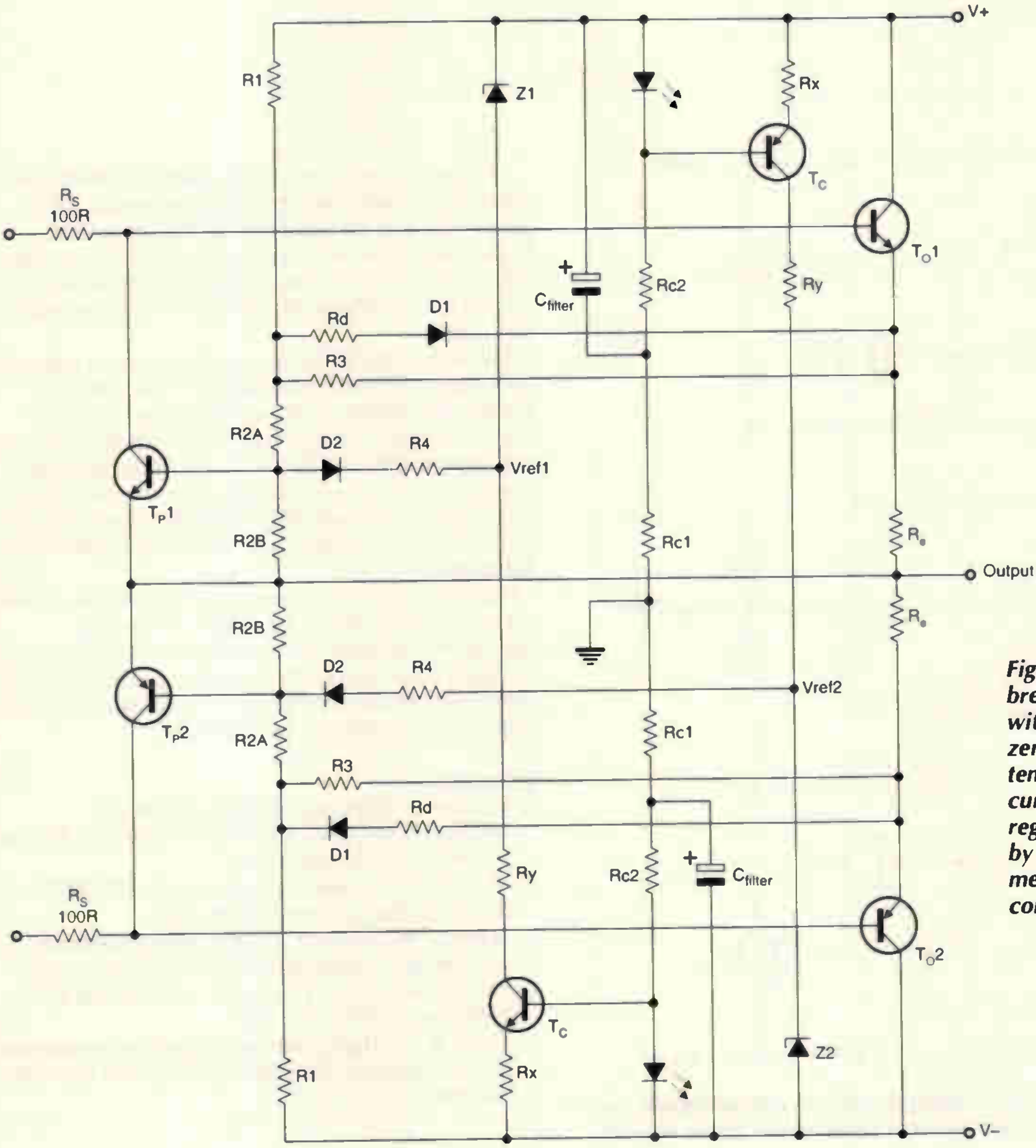


Figure: 49. Treble-slope, dual breakpoint limiter of figure 42, with improved regulation of zener voltage, V_z by means of a temperature compensated current source/sink. Such regulation is further enhanced by the introduction of a measure of temperature compensation to Z_1 and Z_2.

current fluctuation is invariably more significant than that due to change in temperature. Where cost is no object, R_z may be replaced with a temperature compensated[3,p.226] current source/sink, **Fig. 49.** This can be in the guise of a LED-biased transistor, T_c.

LED current limiting resistor R_c is split symmetrically into two components, R_{c1} and R_{c2}, whose intersection[4] is decoupled by capacitor C_{filter} to the supply rail. The single-pole filter comprising C_{filter} and R_{c1} across the LED's internal resistance, in series with R_{c2}, improves the regulation of the voltage drop across the LED by diminishing power supply ripple in the current established by R_{c1} and R_{c2}.

A time constant, $\tau_{filter}=C_{filter}R_{c1}$, of the order of two seconds is sufficient. Connecting C_{filter} directly across the LED is sub-optimal, as a commensurately larger component would then be required for the same time constant.

Resistor R_y minimises power dissipation in T_c; a collector-emitter voltage drop of the order of 20V for a collector current of 10mA should suffice with suitable small signal transistors, such as Motorola's 2N5551/2N5401.

Protecting paralleled complementary output transistors

Emitter resistor, R_e, performs current-voltage conversion for the *V-I* limiter. It also promotes thermal stability by maintaining equable current distribution in a paralleled pair output stage. For this reason some designers suggest[5,p.257] that it is only necessary to monitor transistor current in a single complementary pair in a multiple-pair output stage.

Alternatively, the calculated value of the current sensing resistor, R_3, for a single complementary transistor pair is multiplied by the number of paralleled output pairs, *N*, with each resistor of value NR_3, used to monitor the current in each transistor, as shown in **Fig. 50.**

Note that using the non-linear limiter of Fig. 27 in this fashion requires that each resistor of value NR_3 be shunted by the diode in series with resistor, R_d, whose value remains unchanged.

An obvious disadvantage inherent in both schemes is that the failure of a rogue transistor in one half of the output stage could result in the disastrous alteration of the protection locus for the remaining devices in that section. With modern power transistors though, this

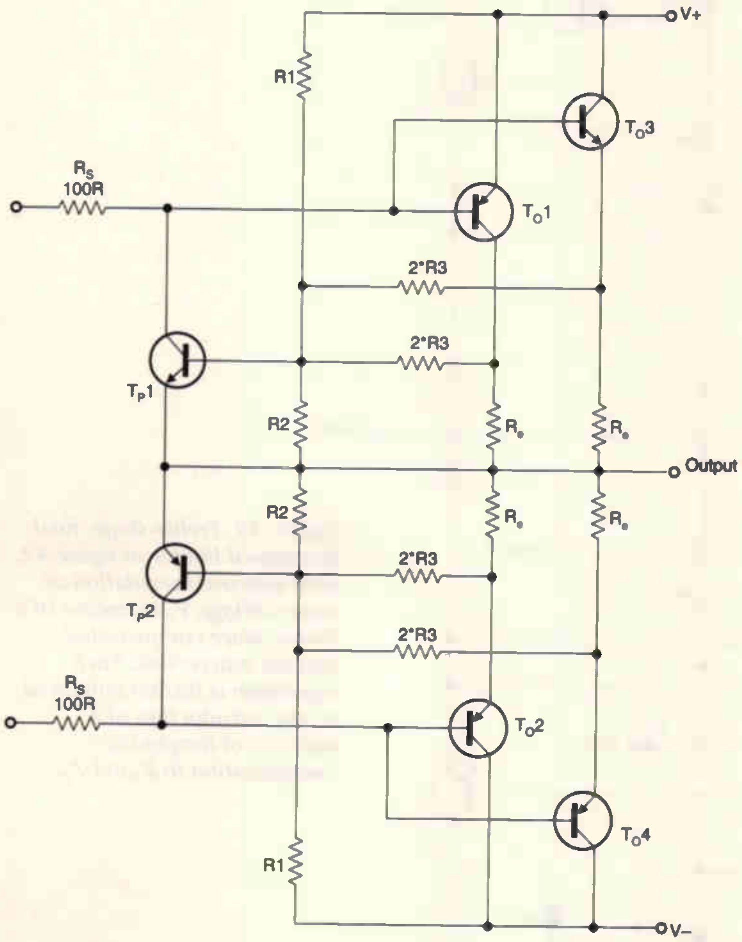


Figure: 50. In this single-slope, linear foldback scheme, voltage signals from multiple current sensing resistors are summed algebraically at the base of the protection transistor.

scenario is unlikely.

Using an independent *V-I* limiter for each complementary pair would eliminate this flaw, but such a solution would be financially indefensible for most commercial designs.

In summary

On grounds of safety and reliability, it is firmly recommend that all linear, complementary semi-conductor audio power amplifiers incorporate suitable *V-I* protection. The aversion cultivated by some designers to such is here shown to be wholly illusory.

A competently designed *V-I* limiter will remain demonstrably inert, and therefore completely unobtrusive with virtually all commercial loudspeaker systems, provided the output stage consists of sufficient complementary transistors to safely drive a 4Ω±60° load to the supply rails.

The dual-slope circuit of Fig. 27 represents a significant improvement in efficient safe operating area use relative to the single-slope topology of the previously published Fig. 1. Also, there's no significant penalty with regard to algebraic complexity.

As demonstrated in Fig. 26, the circuit's characteristic locus can be readily optimised to accommodate ±50V supply rails with MJL3281A/MJL1302A transistors. Higher supply rails are not recommended for worst-case reactive loads, as available collector current for these devices falls rapidly below 500mA with a V_{CE} of more than 100V.

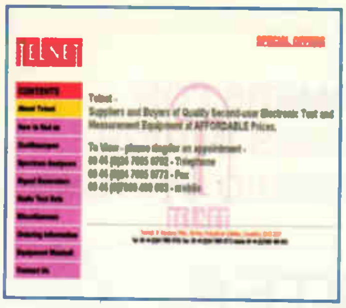
Although e-MOSFETs are at least an order of magnitude less linear than bipolar transistors[4,p.273], they provide significantly greater scope for reliable design[4] at high device voltages, ($2|V_{supply}| >> 100V$), with the promise of even greater efficiency in S.O.A. utilization, due to the absence of secondary breakdown. However, there is no need to endure the indignity of e-MOSFET non-linearity and on resistance voltage inefficiency in sub-200W into 8Ω designs.

More elaborate protection schemes are possible, with the use of as many diodes as the number of required breakpoints. However the increase in available current in the high voltage region, $|V_{cc}| \leq V_{ce} < 2|V_{cc}|$, where it counts with respect to reactive load drive, is negligible in relation to the circuit complexity thus engendered. ■

References

1. Duncan, B. 'High performance audio power amplifiers'. Newnes, ISBN 0-7506-2629-1, p. 202, and p. 204, Fig. 5.23, respectively.
2. Motorola TVS/Zener device data book, DL150/D, REV1, Section 11. www.onsemi.com
3. Self, D., 'Audio power amplifier design handbook', 2nd edition, Newnes, ISBN 0-7506-4527-X, p. 335.
4. Crecraft, D.I., *et al*, 'Electronics', Chapman & Hall, ISBN 0-412-41320-5, p. 566.
5. Slone, R. S., 'High-power audio amplifier construction manual', McGraw-Hill, ISBN 0-07-134119-6, p. 244, and 260.

In Michael's previous article, "D_F" should have been written as "D_P" in three places – 6, 8 and 18 lines from the bottom of the right-hand column of page 46. Also, the words, "Diodes DP and DF are omitted in subsequent figures in the interest of clarity." should have appeared at the end of the last paragraph on page 46. In Fig. 4, the voltage at the base of T_p should have read 3V72, not 33V72, in Fig. 7, the voltage at the base of T_p should have read –39V4, in Fig. 15, the voltages at the base of T_p should have read –23V73 → –23V4, and finally, in Figs 24 & 25, V_{ref} at the end of R_2 should have read –20V6. Apologies for these errors.



WEB DIRECTIONS

Put your web address in front of 18,000 electronic fanatics.

Electronics World acknowledge your company's needs to promote your web site, which is why we are dedicating over 3 pages in every issue to WEB ADDRESSES.

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

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

To take up this offer or for more information telephone

Reuben Gurunlian
Tel 0208 722 6028

E-mail
r.gurunlian@highburybiz.com

ANASOFT LTD

http://www.anasoft.co.uk

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

BEDFORD OPTO TECHNOLOGY LTD

http://www.bot.co.uk

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

CRICKLEWOOD ELECTRONICS

http://www.cricklewoodelectronics.co.uk

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

COMPONENT KITS

http://www.componentkits.com

"Component Kits LLC manufactures and distributes Electronic Component Kits used for professional engineering design, prototype, University lab, and hobbyist uses.
Visit our website to review our current product line, request our Free CD-ROM, or join our newsletter."

COOKE INTERNATIONAL

http://www.cooke-int.com

info@cooke-int.com

Test & Measuring Equipment
Operating & Service Manuals.

CROWNHILL ASSOCIATES LTD

http://www.crownhill.co.uk

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

DB TECHNOLOGY

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

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

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

DESIGNER SYSTEMS CO.

http://www.designersystems.co.uk

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

EAGLE PCB DESIGN SOFTWARE

http://www.puresoft.co.uk

- Professional PCB design made easy!
- Fully functional freeware download.

- Schematics, Layout & Autorouting.
- Free tech support

EDAForce

http://www.edaforce.co.uk

EDAForce is a division of the independent specialist recruitment consultancy TelecomForce. We specialise in placing engineers and engineering managers, either contract or permanent, in the role that is right for them. Visit the web site, email us on ew@edaforce.co.uk or call +44(0)1628 850273 to find out how we could help you.

EQUINOX TECHNOLOGIES UK LTD

http://www.equinox-tech.com

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

FELLER UK

http://www.feller-at.com

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

FIELD ELECTRIC LTD

http://www.fieldelectric.co.uk

Field Electric Ltd has been successfully trading since 1958 in the re- sale of used test & measurement equipment & computer hardware. We buy and sell in small or bulk quantities and can source equipment to particular requirements. Visit our web site or call 44 01837 83736.

TEST EQUIPMENT SOLUTIONS

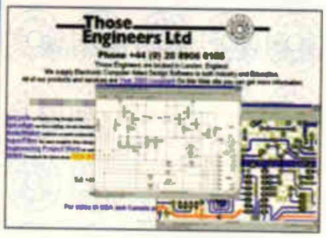
http://www.TestEquipmentHQ.com

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

THOSE ENGINEERS LTD

http://www.spiceage.com

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



TECHNICAL AND SCIENTIFIC SUPPLIES

http://www.technicalscientific.com

Suppliers of pre-1985 equipment and components.

- Test/Measurement equipment
- Valves and semiconductors
- Transducers and pressure gauges
- Scientific books and catalogues
- Manuals and data sheets

TOTAL ROBOTS

http://www.totalrobots.co.uk

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

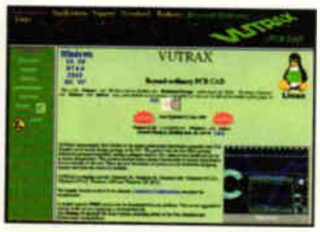
ULTRACOM

http://www.ultracom.fi

Ultracom specializes in the design and manufacture of data radio products including Radio Modules, Radio Modems, Filters and Antennas for real-time data communication. In addition to our standard RF-products we provide tailored solutions for customers wireless communications requirements.
Our wireless data radios are used in the most varied applications: transferring environmental data in tropical conditions, locating moving targets, remote-control of cranes, controlling pump stations in waterworks, monitoring real estates, transferring data in public transportation information systems. There are countless applications, what are yours?

VUTRAX PCB DESIGN SOFTWARE

http://www.vutrax.co.uk



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

WARWICK WIRELESS LTD

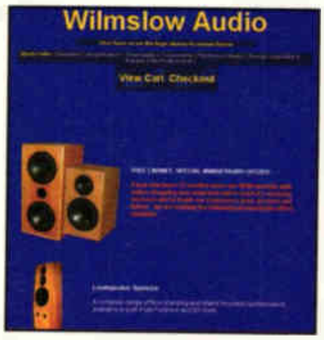
http://www.radiotelemetry.co.uk

Free data on Radio Modems, Radio Telemetry, Radio Modules and Wireless Video systems. The licence exempt radios can transmit data from 1 to 20Km

at baud rates of 19.2Kbaud to 128Kbaud. The UK based Company can offer customised derivatives of their products as well as turnkey RF Systems.

WILMSLOW AUDIO

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



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

WEB DIRECTIONS

Put your web address in front of 21,000 Electronics fanatics. Electronics World acknowledges your companys need to promote your web site, which is why we are now dedicating page's in every issue to WEB ADDRESSES.
This gives our readers the opportunity to look up your companys name, to find your web address and to browse the magazine page to find new sites.
We also understand that cost is an important factor, as web sites are an added drain on budgets. I am sure you will agree these rates make all the difference

FOR 12 ISSUES:
Lineage only will cost £150 for a full year just £12..50 per month. This includes your companys name, web address and a 25 word description.
Lineage with colour screen shot will cost £350 for a full year just £29.17 per month. This will include the above plus a 3cm screen shot of your site, which we can produce if required.
To take up this offer or for more information ring on 0208 722 6028.
E-mail: r.gurunlian@highburybiz.com

Company Name		Web address		

Service Link

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

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

ARTICLES WANTED

SERVICES

FOR SALE

SERVICES

WANTED

TEST EQUIPMENT SOLUTIONS

Quality Second User Test Equipment

With 12 Month Warranty

The Industry's Most Competitive Test Equipment Rental Rates

	Sale (GBP)	Rent (GBP)
AMPLIFIERS		
Amplifier Research 10W1000B 1GHz 10W RF Amplifier	3500	133
Amplifier Research 1W1000 1GHz 1W RF Amplifier	1350	65
HP 8349B 2-20GHz 15dB +20dBm Amplifier	2950	106
CALIBRATORS		
Fluke 5100B 4.5 Digit DMM Calibrator	2950	105
Keithley 220 Programmable Current Source	2750	145
COMPONENT ANALYSERS		
HP 4191A 1000MHz Impedance Analyser	6500	255
HP 4192A 13MHz Impedance Analyser	4950	224
HP 4263A 100KHz LCR Meter	2850	[illegible]
HP 4275A 10MHz Impedance Analyser	2800	135
Tek 370 Curve Tracer	18950	845
DATACOMMS		
HP J3446C LAN Fast Ethernet Internet Advisor	8500	328
Microtest PENTA SCANNER+ Cat 5 Cable Tester	975	51
ELECTRICAL NOISE		
HP 346A 18GHz Noise Source	1250	[illegible]
HP 8970B/020 2GHz Noise Meter	7950	299
ELECTRICAL POWER		
BMI 100G Power Visa Single Phase Mains Disturb Analyser	1950	89
Dranetz PP4300 Power Quality Analyzer	4950	195
Kikusui TOS8850 Insulation Tester	1450	75
Megger RM215/L/2 Breakdown Leakage Tester	1250	49
EMC		
Chase HFR2000 30MHz Measuring Receiver	1250	52
Chase LFR1000 9KHz To 150KHz Interference Measuring Rx	1150	[illegible]
Chase MN2050 30MHz LISN	650	37
Keytek MZ-15/EC ESD Simulator	2950	[illegible]
R&S EB100 20MHz-1GHz EMC Test Receiver	2950	126
Schaffner NSG200E EMC Mainframe	1150	49
Schaffner NSG1025 Fast Transient/Surge Generator	2950	119
Schaffner NSG426 Data Line Interference Coupler	450	25
Schaffner NSG432 ESD Simulator	2150	88
Schaffner NSG435 ESD Simulator	3650	138
ENVIRONMENTAL		
B&K 2231 Sound Level Meter (inc BZ7110 App Module)	1650	62
FREQUENCY COUNTERS		
EIP 578 26GHz Microwave Source Locking Counter	2750	155
HP 53131A/030 3GHz Universal Frequency Counter	1350	72
HP 53181A 225MHz 10 Digit RF Counter	895	59
Racal 1992/04C 1.3GHz Counter Timer	1150	48
FUNCTION GENERATORS		
HP 33120A 15MHz Function/Arbitary Waveform Generator	950	49
HP 3325B 21MHz Function Generator	3500	125
HP 8116A 50MHz Function Generator	2950	111
Tek AWG2021 250MS/s Arbitary Wavefom Generator	6950	275
LOGIC ANALYSERS		
HP 16500C Logic Analyser Mainframe	2850	135
HP 1660C 100MHz State 136 Ch Logic Analyser	4950	198
HP 1663C/015 100MHz State 34 Ch Logic Analyser	2150	99
MULTIMETERS		
HP 34401A 6.5 Digit Digital Multimeter	550	38
Keithley 2400 Digital Sourcemeter	2500	146
NETWORK ANALYSERS		
Anritsu S251B 2.5GHz Dual Port Scalar Network Analyser	7950	315
Anritsu S331A 3.3GHz Scalar Network Analyser	4750	189
Anritsu S331C 4GHz Scalar Network Analyser	5950	221
HP 11500F APC Cable 3.5mm	450	27

	Sale (GBP)	Rent (GBP)
HP 35677A 200MHz 50 Ohm S Parameter Test Set	1895	93
HP 3577A 5Hz-200MHz Network Analyser	4750	275
HP 41952A 500MHz Transmission/Reflection Test Set	1950	85
HP 4195A 500MHz Network/Spectrum Analyser	10500	[illegible]
HP 85032B Type N Calibration Kit	1150	49
HP 85044A 3GHz 50 Ohm Transmission/Reflection Test Set	2250	89
HP 85046A 3GHz 50 Ohm S Parameter Test Set	2950	131
HP 85131F 3.5mm Flexible Cable Set	1750	72
HP 8752A/003 3GHz T/R Vector Network Analyser	7500	295
HP 8753B/006 6GHz Vector Network Analyser	8500	358
HP 8753C 3GHz Vector Network Analyser	8500	358

Call today for your free copy of our new Summer 2002 Catalog!

	Sale (GBP)	Rent (GBP)
OSCILLOSCOPES		
HP 1152A 2.5GHz Active Scope Probe	950	68
HP 54501A 4 Channel 100MHz 20MS/s Digitising Scope	1250	66
HP 54502A 2 Channel 400MHz 400MS/s Digitising Scope	1500	78
HP 54602B 4 Channel 150MHz 20MS/s Digital Scope	1750	85
HP 54645D 2 Ch 100MHz 200MS/s + 16 Logic Analyser	2500	125
Tek 2465B 4 Channel 400MHz Analog Scope	2500	99
Tek A6302/AM503/TM501 Current Clamp System	1650	81
Tek P6243 1GHz Active Probe	350	28
Tek TAS455 2 Channel 60MHz Analog Scope	495	36
Tek TAS465 2 Channel 100MHz Analog Scope	595	42
Tek TAS485 4 Channel 200MHz Analogue Scope	1550	99
Tek TDS3054 4 Ch 500MHz 5GS/s Digital Phosphor Scope	6500	246
Tek TDS420A/1F/1M 4 Ch 200MHz 100MS/s Digitising Scope	3750	175
Tek TDS460A 4 Channel 400MHz 100MS/s Digitising Scope	3750	175
Tek TDS540 4 Channel 500MHz 1GS/s Digitising Scope	3950	185
Tek THS720 2 Channel 100MHz 500MS/s Digitising Scope	1650	69
POWER METERS		
HP 436A RF Power Meter	750	38
HP 437B RF Power Meter	1350	51
HP E4412A 10MHz-18GHz 100mW Power Sensor	695	31
HP E4418A Single Channel RF Power Meter	1650	70
Marconi 6960/GPIB RF Power Meter	695	39
POWER SUPPLIES		
Hunting SERIES 250 50KV 5mA Power Supply	850	55
Kikusui PLZ150W 150W Electronic Load	595	49
RF SWEEP GENERATORS		
HP 8340B 26.5GHz Synthesized Sweep Generator	19500	785
HP 83620A/001/008 10MHz-20GHz Synthesized Sweeper	15950	699
SIGNAL & SPECTRUM ANALYSERS		
Advantest R3361A 9KHz-2.6GHz Spectrum Analyser With TG	6950	269
Advantest R4131C 3.5GHz Spectrum Analyser	3950	198
Advantest R9211A 100KHz Dual Channel FFT Analyser	3750	170
Anritsu MS2601B 2.2GHz Spectrum Analyser	5500	225
Anritsu MS2602A/01/04 100Hz-8.5GHz Spectrum Analyser	9950	395
Anritsu MS2711A 3GHz Handheld Spectrum Analyser	5250	199
Anritsu MS610B 2GHz Spectrum Analyser	2650	125
Anritsu MS710C 23GHz Spectrum Analyser	8950	365
HP 3562A 100KHz Dual Channel Dynamic Signal Analyser	3950	178

	Sale (GBP)	Rent (GBP)
HP 35660A 102.5KHz Dual Ch Dynamic Signal Analyser	3250	125
HP 41800A 500MHz Active Probe	950	55
HP 70000 2.9GHz Spectrum Analyser System	[illegible]	450
HP 85024A 3GHz Active Probe	1450	65
HP 8560A/002/H03 2.9GHz Spectrum Analyser	8500	325
HP 8561E 6.5GHz Spectrum Analyser	14950	595
HP 8562A 22GHz Spectrum Analyser	14950	573
HP 8563A/103/104 22GHz Spectrum Analyser	15500	558
HP 8568B 100Hz-1.5GHz Spectrum Analyser	4950	285
HP 8590A/021 1.5GHz Spectrum Analyser	2250	99
HP 8591E/041 1.8GHz Spectrum Analyser	4950	295
HP 8592B 22GHz Spectrum Analyser	8950	365
HP 8593E 22GHz Spectrum Analyser	[illegible]	555
HP 8594E / 041/101/105 2.9GHz Spectrum Analyser	6500	255
HP 8595E/041/BD1 6.5GHz Spectrum Analyser	10750	425
HP 8901A 1.3GHz Modulation Analyser	950	120
HP 8903B/10/51 20Hz To 100KHz Audio Analyser	2450	135
HP 8903E 20Hz-100KHz Distortion Analyser	1250	99
HP E4407B/1AX 26.5GHz Spectrum Analyser	[illegible]	585
Marconi 2380/83/303G 4.2GHz Spectrum Analyzer (no TG)	5500	225
SIGNAL GENERATORS		
HP 83732B/1E1/1E5/1E8 0.01-20GHz Signal Generator	15950	595
HP 8642A/001 1GHz High Performance Signal Generator	2250	99
HP 8648C 9KHz-3.2GHz Synthesised Signal Generator	4250	185
HP 8657A/001 1GHz Synthesised Signal Generator	1750	[illegible]
HP 8657B/001 2GHz Synthesised Signal Generator	3950	185
HP 8657D/001/H01 1 GHz DQPSK Signal Generator	1950	99
HP 8672A 2-18GHz Synthesised Signal Generator	4950	299
HP E4422B/UNB ESG-4000B 4GHz Signal Generator	6500	269
R&S SMHU 4.32GHz Synthesized Signal Generator	10500	399
R&S SMY02 9KHz-2GHz Synthesised Signal Generator	4500	175
TELECOMS		
Fireberd 4000 Communications Analyser	3250	174
GN Nettest LITE 3000 2MBPS Error & Signalling Analyser	1350	99
HP 37717C/UKJ PDH Transmission Analyzer	2950	149
HP 3788A/001 2MBPS Error Performance Analyser	1350	98
Marconi 2840A 2MB Handheld Transmission Analyser	1500	85
Phoenix 5500A Telecomms Analyzer	2500	135
Trend AURORA PLUS Basic Rate ISDN Tester	350	[illegible]
TTC Fireberd 6000A Communication Analyser	4950	199
W&G PFA-35 Digital Transmission Analyzer	3950	162
TV & VIDEO		
Minolta CA-100 CRT Colour Analyzer	2650	127
Philips PM5418TDS +Y/C TV Pattern Generator Y/C + RGB	2450	95
R&S SFQ/B5/B6/B11/B15 TV Test Transmitter	25950	[illegible]
Tek 1751 PAL Vectorscope	3250	168
WIRELESS		
Anritsu ME4510B Digital Microwave System Analyser	13500	[illegible]
HP 83220E/010 GSM/PCS/DCS1800 (1710-1900) MS Test Set	2500	[illegible]
HP 8920A 1GHz Radio Comms Set (Various Options, from)	4950	[illegible]
HP 8922M/001/006/010/101 1GHz GSM MS Test Set	7500	[illegible]
Marconi 2955B 1GHz Radio Comms Test Set	3500	[illegible]
Marconi 2965/012 1GHz Radio Communications Test Set	6950	[illegible]
R&S CMS52/B1/B5/B9/B15/B28 1GHz Radio Comms Test Set	5750	[illegible]
R&S CMT54/B1/B4/B5/B6/B9 1GHz Radio Comms Test Set	3950	[illegible]
R&S CMTA54/B5/B6/B7 1GHz Radio Comms Test Set	5500	[illegible]
Schlumberger 4015 1GHz Radio Comms Test Set	4500	[illegible]
Wavetek 4201S Triband Digital Mobile Radio Test Set	3950	[illegible]

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

See our extensive online catalogue at www.TestEquipmentHQ.com

Flexible commercial solutions available on all products

FREE Palm m100 shipped with every order over £10K

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

01753 596000

Fax: 01753 59 6001

www.TestEquipmentHQ.com

email: info@TestEquipmentHQ.com