Train safety: are rail companies thinking laterally?

ELECTRONICS WORLD

NOVEMBER 2001 £2.80

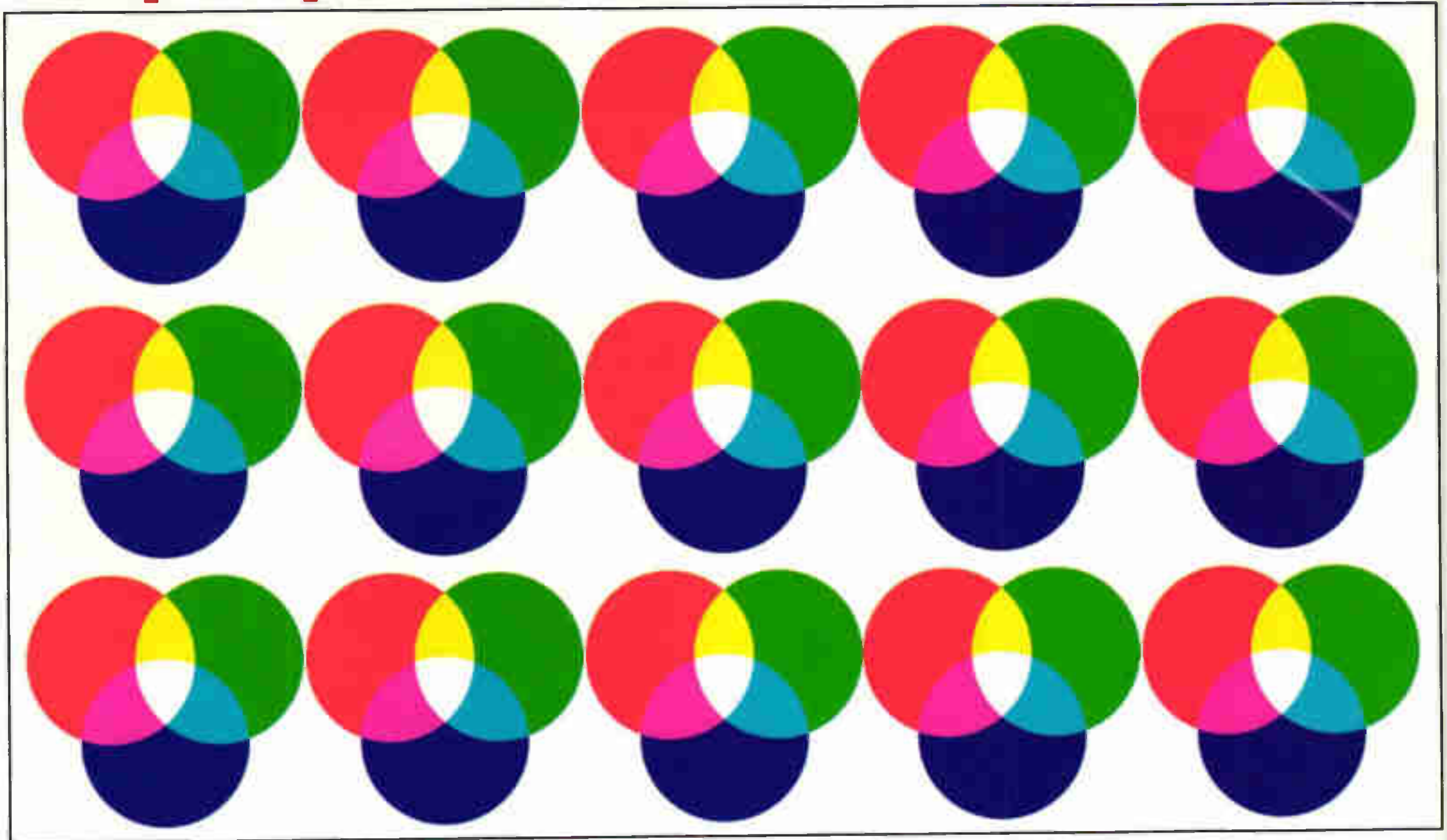
Circuit ideas:

- Class-A MOSFET audio
- V-to-F converter
- Smoke alarm timer
- Scope calibrator
- Auto NiCd charger
- Fan speed control
- Latching relay
- Magnet sniffer

100MHz active scope probe

MOSFET modelling

CRT phosphor issues



Receiver design IV: dynamic performance

Is a PRBS Gaussian?

Analogue programmable array

11>
9 770959 833073

Telnet

Quality second-user test & measurement equipment

Hewlett Packard	
8642A – high performance R/F synthesiser (0·1-1050MHz)	**£4750**
3335A – synthesiser (200Hz-81MHz)	**£2200**
Hewlett Packard	
436A power meter and sensor (various)	**from £750**
Hewlett Packard	
Marconi 6310 – programmable sweep generator (2 to 20GHz) – new	**£2750**
Marconi 6311 Prog'ble sig. gen. (10MHz to 20GHz)	**£3500**
Marconi 6313 Prog'ble sig. gen. (10MHz to 26.5GHz)	**£5750**
Hewlett Packard	
5370B – universal time interval counter	**£1500**
Hewlett Packard 8662A synth. sig. gen. (10kHz to 1280MHz)	**£8250**
Hewlett Packard 3324A synth. function/sweep gen. (21MHz)	**£2500**
Hewlett Packard 3314A Function Generator 20MHz	**£1250**
Hewlett Packard	
8904A Multifunction Synthesiser (opt 2+4)	**£1950**
R&S SMG (0.1-1GHz) Sig. Generator (opts B1+2)	**£2950**
Hewlett Packard 4278A 1kHz/1MHz Capacitance Meter	**£4000**
Hewlett Packard 53310A Modulation Domain Analyser (opts 1&3)	**£7000**
Hewlett Packard 4191A R/F Impedance Analyser (1-1000MHz)	**£5500**
Hewlett Packard ESG-D3000A (E4432A) 250 kHz-3 GHz) Signal Gen.	**£8250**

OSCILLOSCOPES

Gould 400 20MHz - DSO - 2 channel	£800
Gould 1421 20MHz - DSO - 2 channel	£600
Gould 4068 150MHz 4 channel DSO	£1500
Gould 4074 100MHz - 400 Ms/s - 4 channel	£1350
Hewlett Packard 54201A - 300MHz Digitizing	£995
Hewlett Packard 54600A - 100MHz – 2 channel	£750
Hewlett Packard 54502A - 400MHz-400 MS/s 2 channel	£1800
Hewlett Packard 54810A 'Infinium' 500MHz 2ch	£4000
Hewlett Packard 54520A 500MHz 2ch	£3000
Hameg 205-2 20MHz DSO	£550
Hitachi VI52/V212/V222/V302B/V302F/V353F/V550B/V650F	from £125
Hitachi VI 100A - 100MHZ - 4 channel	£900
Intron 2020 - 20MHz. Dual channel D.S.O. (new)	£450
Iwatstu SS 5710/SS 5702 -	from £125
Kikusui COS 5100 - 100MHz - Dual channel	£350
Lecroy 9314L 300MHz - 4 channels	£3000
Meguro MSO 1270A - 20MHz - D.S.O. (new)	£450
Philips PM3094 - 200MHz - 4 channel	£1750
Philips 3295A - 400MHz - Dual channel	£1600
Philips PM3392 - 200MHz - 200Ms/s - 4 channel	£1995
Philips PM3070 - 100MHz - 2 channel - cursor readout	£750
Tektronix 465 - 100MHZ - Dual channel	£350
Tektronix 464/466 - 100MHZ - (with AN. storage)	£350
Tektronix 475/475A - 200MHz/250MHz -	from £450
Tektronix 468 - 100MHZ - D.S.O.	£650
Tektronix 2213/2215 - 60MHz - Dual channel	£350
Tektronix 2220 - 60MHZ - Dual channel D.S.O	£995
Tektronix 2235 - 100MHZ - Dual channel	£600
Tektronix 2221 - 60MHz - Dual channel D.S.O	£995
Tektronix 2245A - 100MHZ - 4 channel	£900
Tektronix 2440 - 300MHz/500 MS/s D.S.O.	£2450
Tektronix 2445A/2445B - 150MHz - 4 channel	£1000
Tektronix 2445 - 150MHZ - 4 channel + DMM	£1200
Tektronix TAS 475 - 100MHZ - 4 channel	£995
Tektronix 7000 Series (100MHZ to 500MHZ)	from £200
Tektronix 7104 – 1GHz Real Time – with 7A29 x2, 7B10 and 7B15	from £2500
Tektronix 2465/2465A/2465B - 300MHz/350MHz 4 channel	from £1250
Tektronix 2430/2430A – Digital storage - 150MHz	from £1250
Tektronix TDS 310 50MHz DSO - 2 channel	£750
Tektronix TDS 320 100MHz 2 channel	£850
Tektronix TDS 340A 100MHz DSO - 2 channel	£1250

SPECTRUM ANALYSERS

Advantest R3361A (9kHz – 2.6GHz)	£4950
Advantest 4131 (10kHz–3.5GHz)	£3950
Ando AC 8211 - 1.7GHz	£1500
Avcom PSA-65A - 2 to 1000MHz	£850
Anritsu MS 610B 10KHz - 2GHz – as new	£3500
Anritsu MS3606B (10KHz-1GHz) network Analyser	£3500
Anritsu MS 710F (100 kHz-23Ghz)	£4750
Advantest/TAKEDA RIKEN - 4132 - 100KHz - 1000MHz	£1500
Hewlett Packard 8756A/8757A Scaler Network Analyser	from £1000
Hewlett Packard 853A Mainframe + 8559A Spec. An. (0.01 to 21GHz)	£2750
Hewlett Packard 182T Mainframe + 8559A Spec. An. (0.01 to 21GHz)	£2250
Hewlett Packard 8568A (100Hz - 1500MHz) Spectrum Analyser	£3500
Hewlett Packard 8567A - 100Hz - 1500MHz	£3995
Hewlett Packard 8752A - Network Analyser (1.3GHz)	£5995
Hewlett Packard 8754A – Network Analyser 4MHz-1300MHz	£1500
Hewlett Packard 3561A Dynamic signal analyser	£3995
Hewlett Packard 35660A Dynamic signal analyser	£3250
Hewlett Packard 8753A (3000KHz-3GHz) Network An.	£3500
Hewlett Packard 3582A (0.02Hz-25.5kHz) dual channel	£1750

Radio Communications Test Sets

Marconi 2955	£1500
Marconi 2955B/60B	£3995
Marconi 2955A	£2000
Marconi 2955R	£2200
Antritsu MS555A2	£1200
Hewlett Packard 8922B (GSM)	£4000
Hewlett Packard 8920A (opts 1,2,3,4,5,11)	£5250
Hewlett Packard 8920B (opts 1,4,7,11,12)	£7250
Hewlett Packard 8922M	£6000
Schlumberger Stabilock 4031	£3500
Schlumberger Stabilock 4040	£1500
Racal 6111 (GSM)	£1750
Racal 6115 (GSM)	£3995
Racal 6103 (GSM) Digital Radio Test Se	£7000
Rhode & Schwarz CMTA 94 (GSM)	£4995
Rhode & Schwarz CMT 55 (2GHz)	£8000
Rhode & Schwarz CMT 90 (2GHz) DECT	£4995
Rhode & Schwarz CMD 57 GSM test set (opts B1/34/6/7/19/42/43/61	£9995
Wavetek 4103 (GSM 900) Mobile phone tester	£1500

Wavetek 4106 (GSM 900, 1800, 1900) Mob. Phone tester

Hewlett Packard 3585A (20Hz–40MHz)	£3750
Hewlett Packard 8590A (opt 01, 021, 040) 1MHz–1.5MHz	£2750
Hewlett Packard 8560A (50Hz – 2.9GHz) High performance	£8250
with Tracking Generator option (02)	£9750
IFR A7550 - 10KHz-1GHz - Portable	£1950
Meguro - MSA 4901 - 30MHz - Spec.Analyser	£700
Meguro - MSA 4912 - I MHz - IGHZ Spec Analyser	£995
Tektronix 2712 Spec. Analyser (9kHz - 1.8GHz)	£3750
Wandel & Goltermann TSA-1 system analyser (100Hz-180MHz)	£2750
Wiltron 6409 - 10-2000MHz R/F Analyser	£1750

MISCELLANEOUS

Anritsu S330 Sitemaster (3300MHz) in carry case and Transit case	£4300
Eaton 2075-2A – Noise Gain Analyser	at £2750
EIP 548A 26.5GHz Frequency Counter	£1995
ENI 440LA (150KHz-300MHz) 35 Watt Power Amp	£2500
ENI 1040 (10KHz-500KHz) 400 Watt Power Amp	£2750
Fluke 5100A/5100B/5200A – Calibration Units (various available)	from £1000
Hewlett Packard 339A Distortion measuring set	£1200
Hewlett Packard 3457A multi meter 6 1/2 digit	£950
Hewlett Packard 3784A - Digital Transmission Analyser	£4500
Hewlett Packard 3785A - Jitter Generator & Receiver	£1250
Hewlett Packard 5385A - 1 GHZ Frequency counter	£650
Hewlett Packard 6033A - Autoranging System PSU (20v-30a)	£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)	£800
Hewlett Packard 8350B – Sweep Generator Mainframe	£1500
Hewlett Packard 8656A Synthesised signal generator	£850
Hewlett Packard 8656B Synthesised signal generator	£1250
Hewlett Packard 8657A Synth. sig. gen. (0.1-1040MHz)	£1750
Hewlett Packard 8901B - Modulation Analyser	£2750
Hewlett Packard 8903A, B and E - Distortion Analyser	from £1250
Hewlett Packard 16500A + B – Logic Analyser Mainframes	from £1000
Hewlett Packard 37900D - Signalling test set	£3750
Hewlett Packard 83220A DCS/PCS test sets	£3000
Hewlett Packard 8657B - 100KHz-2060 MHz Sig Gen	£3995
Hewlett Packard 8657D - XX DQPSK Sig Gen	£4500
Hewlett Packard 8130A – 300 MHz High speed pulse generator	£5250
Hewlett Packard 4275A LCR Meter (10KHz-10MHz)	£3250
Hewlett Packard 4276A LCZ Meter (100Hz-20KHz)-	£1500
Hewlett Packard 5350B 20GHz Microwave Freq. Counter	£2250
Hewlett Packard 8508A +85081B (1GHz) Vector Voltmeter	£2750
Hewlett Packard 3708A Noise and Interference Test Set	£12500
Marconi 2305 – modulation meter	£999
Marconi 2610 True RMS Voltmeter	£550
Marconi 6950/6960/6960B Power Meters & Sensors	from £400
Marconi 2840A 2Mbit/s Transmission Analyser	P.O.A.
Philips 5515 - TN - Colour TV pattern generator	£1400
Philips PM 5193 – 50MHz Function generator	£1500
Leader 3216 Signal generator 100KHz - 140MHz - AM/FM/CW with built in FM stereo modulator (as new) a snip at	£795
Racal 1992 – 1.3GHz Frequency Counter	£500
Rohde & Schwarz NRV dual channel power meter & NAV Z2 Sensor	£1250
Advantest R3361A (9kHz – 2.6GHz)	£4950
Rohde & Schwarz FAM (opts 2, 6 and 8) Modulation Analyser	£4250
Tektronix ASG100 - Audio Signal Generator	£750
Wavetek 178 Function generator (50 MHz)	£950
Wayne Kerr 3245 – Precision Inductance Analyser	£1995
Wayne Kerr 6245 – Precision Component Analyser	£2500

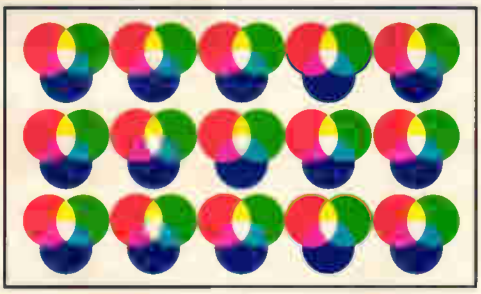
All equipment is used - with 30 days guarantee and 90 days in some cases
Add carriage and VAT to all goods.

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

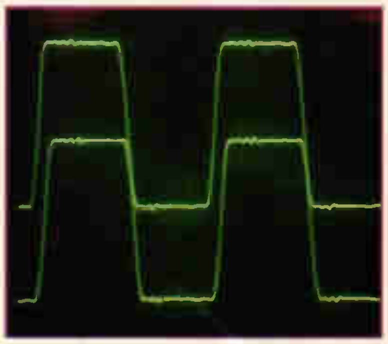
Tel: 02476 650 702
Fax: 02476 650 773

CIRCLE NO. 101 ON REPLY CARD

CONTENTS



Sorry, this picture's too complicated to explain in a caption. You'll have to turn to our news stories, starting on page 812.



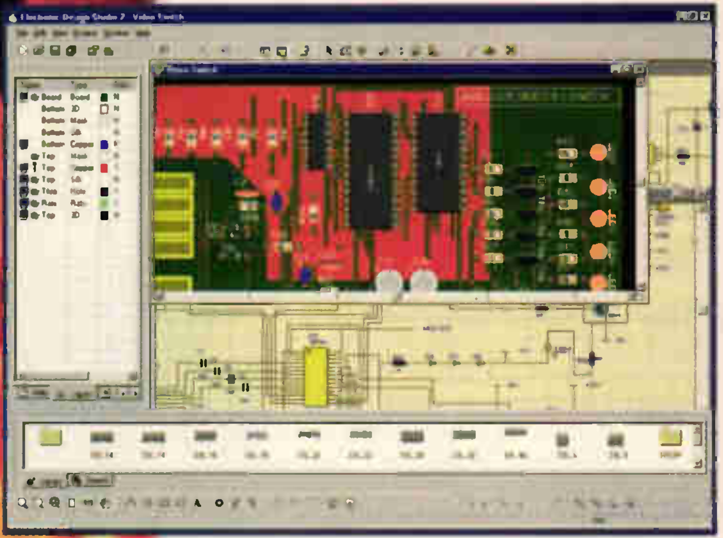
Spot the difference. This is a 5MHz square wave before and after passing through Cyril Bateman's active oscilloscope probe, described in full detail on page 842.

Even when the proposed automatic stopping system has been installed in every train, it still won't prevent the sort of accident that occurred recently when a Land Rover fell onto the line. Wilf James' solutions would though. Find out how on page 832.

Picture courtesy Railway Gazette.

December issue on sale 1 November

Next Generation Electronics CAD



Introducing Electronic Design Studio 2, the new modular electronics design system that includes simulation, schematic, PCB, autorouting and CADCAM modules as standard.

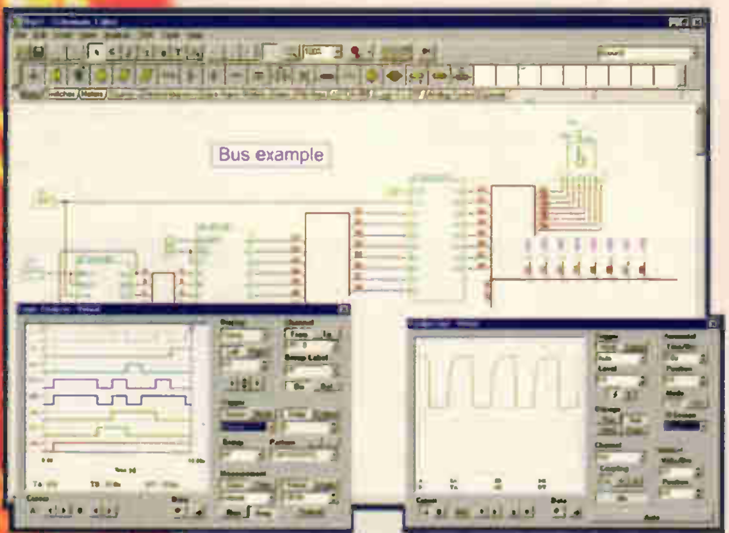
Our state of the art integrated design environment brings powerful management to your projects and now features expanded libraries with 3D style PCB footprints, and the new Viper autorouter. EDS 2 Advance also includes rip up and retry routing, net styles, shape based realtime design rule checking (DRC), full copper pour support with unlimited automatic zones, split power planes with router support, cross probing, netlist navigation, DTP quality feature rich schematics and a wide range of import/export options.

EDS2 is fully compatible with TINA Pro 5.5 with support for FAST TINA net import using the Project Wizard.

electronic design STUDIO 2

	Standard	Advance
Schematic, Simulation, PCB & CADCAM Modules	Yes	Yes
Viper Autorouter	Single Pass	Ripup/Retry
Multiple copper pour, thermal relief, power planes		Yes
Cross probing & Net Styles		Yes
Shape based Design Rule Check		Yes
Price*	£199	£349

Award Winning Professional Simulation



The international award winning TINA Pro circuit simulator combines ease of use with an incredible range of features. Fully mixed mode, TINA Pro Industrial includes over 20,000 models, 21 types of analysis, 9 virtual instruments, hierarchical schematic design with teamwork and bus support, professional graph presentation (Bode, Nyquist, poles & zeros, transient, temperature sweep, Smith and polar, etc), electrical rules check (ERC), bill of materials (BOM), easy importing of SPICE models and sub-circuits, and PCB netlist export support.

TINA Pro is also fully compatible with EDS 2 and now features EDS footprint selection within the schematic editor.

TINA PRO

	Classic	Industrial
Models Included	10,000	20,000
Full range of analysis and output options	Yes	Yes
Advanced hierarchical Schematics & Teamwork		Yes
SPICE Library manager & Parameter Extractor		Yes
Component Generator		Yes
Price*	£169	£299

Information & Demonstration Software

www.dotqr.com

CIRCLE NO. 104 ON REPLY CARD

QUICKROUTE SYSTEMS

Quickroute Systems Ltd
Regent House, Heaton Lane,
Stockport SK4 1BS UK
Tel/Fax 0161 476 0202/0505
Email sales@dotqr.com
*Price excludes P&P and VAT.
(C) 2001 Quickroute Systems. E & O.E.

EDITOR
Martin Eccles

CONSULTANT
Ian Hickman

EDITORIAL ADMINISTRATION
Jackie Lowe
020 8722 6054

EDITORIAL E-MAILS
J.lowe@cumulusmedia.co.uk

GROUP SALES EXECUTIVE
Pat Bunce
020 8722 6028

ADVERTISEMENT E-MAILS
p.bunce@cumulusmedia.co.uk

EDITORIAL FAX
020 8722 6098

CLASSIFIED FAX
020 8770 2016

NEWSTRADE ENQUIRIES
020 7907 7777

ISSN 0959-8332

Such a simple task...

It's ironic that an industry that has persuaded people in 78 per cent of British homes to buy a mobile phone cannot convince them they are safe. In statistical terms, it must be predominantly the same people who are happy to use the things – and expect seamless radio coverage – that also rebel whenever the erection of a new transmitter is proposed.

Although people have no problem using the things, they go into blind panic if a mobile mast should sprout in local school grounds or by some village green. The objections range from fear of death rays to impaired visual amenity, with no consistency in their objections.

That of course is nothing new; when the passenger train travel was launched in the 1830s eminent pundits predicted people would die of suffocation if they travelled faster than 30mile/h, and cattle in nearby fields would become barren and cease giving milk. It was drivel then and it's drivel now.

But 'Mast Action UK' – a high-profile pressure group opposed to mobile radio towers – reportedly includes Jerry Hall, Glenda Jackson and Caron Keating among their campaigners. Another organisation, the 'Mobile Phone Mast Action Group', has a more graphic (but less literate) campaigning website. For all the rant these sites contain, it cannot be denied their viewpoint is catching the media's attention.

The importance of this debate to electronics professionals is clear; if the idea that transmitters and radio devices are dangerous takes hold, this could put a serious damper on the development of 3G mobiles, wireless LANS, broadband radio data distribution and even Bluetooth. The irrationality of the arguments proposed is irrelevant.

Educating people about RF issues should not be difficult. There's no need for the industry to make heavy weather convincing the public transmissions are safe. People have lived with high-powered UHF transmitters for decades without ill effects. Take the Crystal Palace television transmitter in south London for instance; bang in the middle of an urban area but no-one complains.

It needs also to be explained that the amount of radiation directly underneath a transmitter is minimal (the 'lighthouse effect') because the radiation pattern is optimised to cover a wider area. And since handsets are much closer to people's brains than the base station, this signal, although weaker than the base station's, is likely to have considerably more effect (radiation decreasing as the square of the distance).

Since handsets turn down their own radiated power when receiving a strong signal, there's a powerful argument for building more, not fewer, base stations. This point was argued convincingly at the British Association science festival at Glasgow University in September by electrical engineer Alasdair Philips.

Unfortunately there's a lot of ignorance around that needs to be corrected. During September a businessman in Ireland blamed burns on his hands, chest and ears on exposure to his cellphone, while a mobile phone mast in West Lothian was blamed for the disappearance of over 50 racing pigeons. Now, along with hundreds of fellow fanciers, he is considering taking legal action against the mobile companies responsible for ruining the homing instincts of their feathered friends.

Meanwhile, in London's Harley Street, a storm is brewing after a private hospital agreed to the installation of base station antennas. This is despite the fact that the heart hospital claims that it conducted a survey to prove there were "no health effects" from the antennas and that they would not interfere with hospital equipment.

Nearby residents knew better of course, despite the reassurance of the government's Stewart Report last year that affirmed, "the balance of evidence indicates there is no general risk to health". Dr Adam Burgess, author of a forthcoming book, 'Mobile Phones, Public Fears and a Culture of Caution,' also states the health issues are marginal but has allowed them to become, "a powerful Trojan Horse for other objections".

Planning delays are already showing a serious cause for concern to the build-out of 3G mobile services and could hinder the system's chances of success. These will not be helped by Kent County Council's unilateral decision, in contravention of government guidelines, to refuse mobile network companies permission to install any phone masts on its property. Equally unhelpful is the news that mobile operators are finding it increasly difficult to obtain liability insurance cover, with some insurers declining to quote for this risk.

There's no doubt that jobs are at risk from what Cellnet calls, "emotion versus logic". The electronics industry cannot allow these uninformed views to persist any longer; it must act now and with a united voice. It should also pressure the government to lend a hand in the same way as the farmers did earlier this year.

If the government can be persuaded to issue categorical statements on the triviality of foot and mouth disease, then giving an authoritative reassurance on radiation should be a no-brainer. As agendas go, it really is a simple task. ■

Andrew Emmerson

SUBSCRIPTION HOTLINE
Tel (0) 1444 475662
Fax (0) 1444 445447

SUBSCRIPTION QUERIES
rbp.subscriptions@rbi.co.uk
Tel (0) 1444 445566
Fax (0) 1444 445447

Electronics World is published monthly. By post, current issue £2.80, back issues (if available). Orders, payments and general correspondence to **Jackie Lowe, Cumulus Business Media, 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: Quadrant Subscription Services, Oakfield House Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 01444 445566. Please notify change of address.
Subscription rates 1 year UK £36.00 2 years £58.00 3 years £72.00. Europe/Eu 1 year £36.00 2 years £82.00 3 years £103.00
ROW 1 year £61.00 2 years £98.00 3 years £123
Overseas advertising agents: France and Belgium: Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008. United States of America: Ray Barnes, Reed Business Publishing Ltd, 475 Park Avenue South, 2nd Fl New York, NY 10016 Tel; (212) 679 8888 Fax; (212) 679 9455
USA mailing agents: Mercury Airfreight International Ltd Inc, 10(b) Englehard Ave, Avenel NJ 07001. Periodicals Postage Paid at Rahway NJ Postmaster. Send address changes to above.
Printed by Polestar (Colchester) Ltd, **Filmsetting by** JJ Typographics Ltd, Unit 4 Baron Court, Chandlers Way, Southend-on-Sea, Essex SS2 5SE.
Cumulus Business Media is a division of **Highbury Communications PLC**

Cumulus BUSINESS MEDIA

Breakthrough could herald low-cost GaAs devices

Cardiff-based wafer maker IQE and Motorola claim to have perfected the manufacture of gallium arsenide (GaAs) chips on 300mm silicon wafers.

The move, if taken successfully to production, could dramatically cut the cost of GaAs devices. Raw silicon wafers are several times cheaper than their smaller 150mm GaAs counterparts, and significantly more robust.

Attempts to grow III-V materials such as GaAs and indium phosphide on top of silicon normally result in cracks as the lattice constants of the two crystals differ by around four per cent.

Scientists at Motorola used an intermediate material – strontium titanate – that can match with both silicon and GaAs. The technology could allow standard silicon circuits to be made on the same substrate as laser diodes and LEDs for optical comms applications.

Meanwhile, IQE and recently privatised research centre Qinetiq (formerly DERA) are collaborating on the development of advanced semiconductor materials.

They will form an as yet unnamed company based in Malvern to carry out R&D projects and materials assessments using epitaxial growth technology.

"For the first time we will have a true R&D capacity, enabling us to develop new technologies that will be incorporated back into our main business in the future," said Steve Byars, managing director of IQE Europe.

Both firms will transfer staff into Qinetiq's Malvern site, while new facilities should be built within three years.

New Bluetooth chip duo cheaper than single chip

Alcatel Microelectronics is developing a two-chip version of its Bluetooth design – a move that could reduce cost even though component count is increased.

Alcatel was perhaps the first firm to offer a single chip for Bluetooth, but shrinking process technology makes a two-chip version a better economic proposal.

The split has been forced by the shift to more advanced processes such as 0.13μm for the digital baseband part of the design. This process is not yet available for the analogue RF section, which uses a 0.25μm process.

A shift to a smaller process for the digital functions also allows much more memory to be added to the chip set. Alcatel has an agreement with TSMC for integrating flash memory. The 0.25μm version integrates 2Mbit of flash.

Moreover, a two-chip system will enable designers to select an RF chip from Alcatel or another supplier.

Fast low-k chip technology gets a boost

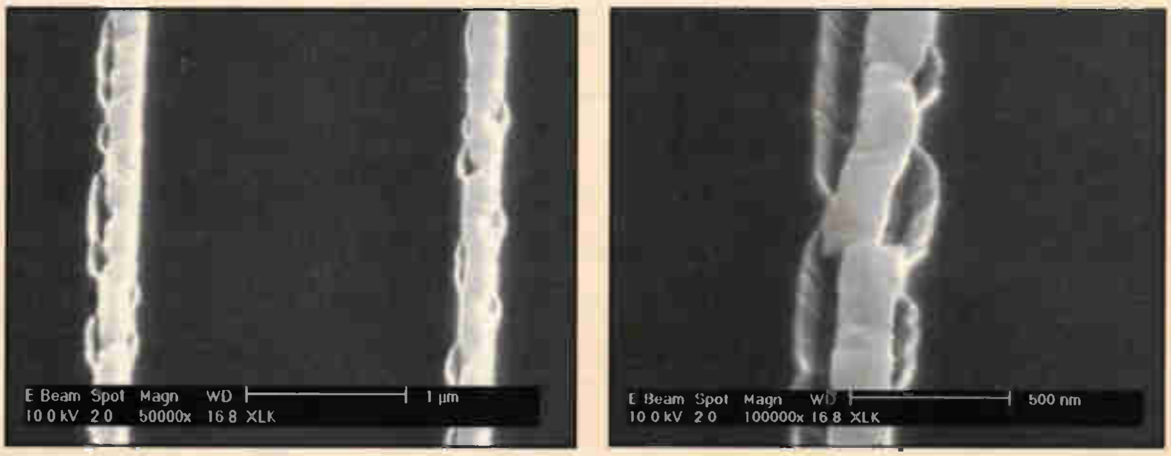
A new wafer polishing technique from a Californian company could cut copper-on-low-k-dielectric chip-processing problems.

Low-k (k is dielectric constant) materials can improve chip speeds by reducing capacitance, but they are not as robust as conventional SiO_2 and SiN insulators and can compress or tear when smoothed by chemical-mechanical polishing, or CMP – particularly near flimsy fine geometry copper tracks.

The company, ACM, claims its 'stress-free copper polishing' (SFP) works with dielectrics with a k of less than 2.2 on chips and feature sizes of 0.13μm and below.

"The latest results demonstrated by using ACM Ultra SFP confirm what we expected," said Michel Rehayem, director of sales at ACM. "No mechanical damage to copper interconnect lines or to the ultra-low-k dielectrics. The material between the copper lines could be micro bubbles of air, without the concerns of stress or delamination."

SPF removes copper by electro-polishing, the reverse of electro-plating. In the past, experiments with electro-polishing were abandoned because of unsuccessful results on the wafer, said Dr David Wang, founder of ACM, who has developed a proprietary technique to solve the problems using "localised control" of some form.



Microscope photos of low-k conductors subjected to 'stress-free polishing', left, and conventional polishing, right.

New battery for electric vehicles has 15 year operating life

US company ElectraStor is predicting a 15-year operating life and 3000 discharge cycle life for a new electric vehicle battery based on nickel-hydrogen (NiH) chemistry.

The company claims its battery will be competitive with experimental lithium ion and lithium polymer batteries.

NiH batteries are not new, they have been used by NASA in spacecraft since 1976.

Hydrogen is, apparently, stored in a safe, solid, state in the ElectraStor battery and it can accept overcharge, reversal and 100 per cent discharge.

Sizes between 30 and 90kWh will be available and there will be a conventional automotive starting version as well.

Intel and Texas license ARM version 6

Two big US players. Intel and Texas Instruments, have taken out licences for version 6 of the ARM architecture.

Intel will use v6 for future XScale processors while TI will use the architecture in its OMAP mobile phone platform.

"The new licensing agreement provides Intel with a strong foundation upon which we can continue to build features for XScale products," said Peter Green, general manager of Intel's hand-held computing group.

Details of the ARM v6 architecture are being kept secret until October's Microprocessor Forum. Simon Segars, v-p engineering at ARM, told EW why v6 has been developed. "We looked at our current architecture, and how to improve its performance when integrated into systems, for example, flushing the cache on context switch," he said.

Towards this TI, which has been working with ARM for many years, has been involved in the v6 design.

"TI has influenced it [the ARM design] even more in the last two years. The new ARM will have a closer on-chip relationship with our DSP through improved data synchronisation and a shared memory manager," said Christian DuPont, European wireless director of TI. A v6 ARM will share chip space with TI's C55x in the latest version of OMAP.

Along with bias towards effective system-on-chip integration, the v6 will include features revealed last year. "It includes the media extensions we spoke about at last year's Microprocessor Forum, additional instructions for video and audio," said Segars.

However, v6 "is fundamentally a 32-bit architecture", according to Segars – therefore not the extended 64-bit ARM processor that has been mooted.

Cambridge design consultancy TTPCom has developed technology to put console type games onto mobile phones. The 'wireless game engine' uses just 40kbyte of memory, yet it can support multi-layer graphics, chromakey transparency and functions such as blit, zoom, rotate and scale.

Filter software routines for programmable analogue chip

UK field-programmable analogue array (FPAA) company Anadigm has added filter synthesis to its configuration software.

This means that high-order classical filters can now be programmed into the chip alongside other analogue conditioning circuitry without a deep understanding of the FPAA.

Dubbed 'FilterDesigner', the new tool comes free with the latest version of Anadigm's FPAA software package.

Users can choose from high-pass, low-pass, band-pass and band-stop filter types. Coefficients are produced for implementation using combinations of the bilinear and biquad filter elements provided in Anadigm's drag-and-drop library of ready-to-use 'IPmodules'.
www.anadigm.com/filtersynth.html

Fastest Java processor planned

Two UK companies, Amino Communications and Vulcan Machines, plan "The fastest and most flexible processor for Java based technology available on the market."

It will combine Amino's network appliance technology with Vulcan's native processor for Java. Code named IntActMoon the combination increases the flexibility of Vulcan's Moon processor by enabling other devices to be added without the need to port device drivers.

RF signal processing firm gets a boost

Isle of Wight signal processing specialist RF Engines has completed a second round of funding, bringing its total to over £1m.

RF Engines' technology is called a 'pipelined frequency transform'; from which it has developed a series of cores that can be integrated into Asic and system-on-chip designs.

"We have created and patented a whole new way of handling large amounts of digital signals – a need that is growing every day as we move more and more into the Digital Age," explained John Lillington, RF Engines' CEO.

Applications for the cores are those handling real-time processing of wideband RF signals, including mobile basestations, broadband fixed wireless access, satellite systems and defence.

The company says it is currently negotiating with firms for the first licences of the technology.

India develops a computer that anyone can use

Designers in Bangalore are developing a computer to meet the needs of the Indian population – even poor illiterate people who have never used a computer before.

Called the Simputer, it arose out of discussions at the 1998 BangaloreIT.com IT show and has subsequently been supported by the Simputer Trust – an academic-industry partnership with members predominantly from the Indian Institute of Science and Encore Software, both Bangalore-based.

To meet its design-brief the Simputer is PDA-style touchscreen-and-stylus based and avoids on-screen words by using a Linux-based custom pictorial interface language called IML (see box). Synthesised and pre-recorded speech are used for complex data output.

The design cost is R9000 (£130 – 100000 units) putting the unit out of reach of much of the population. With this in mind, a smartcard interface is included.

A smartcard will personalise the Simputer, reducing the cost of use to the price of a smartcard and a computer rental charge.

To push Simputers into the wider community the trust is looking for uses that will mean companies and organisations distribute the machines as part of their businesses. "We hope government and large multilateral organisations will use the Simputer as a platform for various IT initiatives, indirectly making it affordable for poor communities to get access to Simputers," said the trust.

Whatever uses are found or developed, they will have to operate without local bulk storage as Simputer has none beyond the smartcard.

Mass-storage in servers can be reached through the in-built modem.

Technical specification:
200MHz SA-1100
StrongArm CPU
32Mbyte DRAM
24Mbyte flash
320 by 240
monochrome LCD
+ touch-panel overlay

Connectors:
Loudspeaker
Microphone
Smartcard Connector
Telephone (RJ-11)
USB

Size 8x13x2cm
3 AAA-sized NiMh batteries

www.simputer.org

Software
GNU-based Linux
V.34/V.17 data/fax soft modems
Perl/Tk scripting environment
Web browser for Internet and email
'Tapatap' (Graffiti-like) stylus data input
'Dhvani' text-to-speech
MP3 Player

Information mark-up language

Information Mark-up Language, or IML, has been developed especially for the Simputer, which must be usable by people who cannot read. "It could well be an Illiterate Mark-up Language," said a Simputer Trust spokesperson.

HTML and Wireless mark-up language (WML) were considered but, "HTML is not currently as versatile as IML and we don't control the standards and hence cannot make the necessary changes to our requirements," said the trust. "WML caters to one extreme of device capabilities, while HTML caters to the other. There is a clear space between these two extremes that correspond to the space of hand-held PCs like the Simputer."

IML is an XML application whose features are a superset of WML although there is no provision for a script language.

Text entry is through a soft-keyboard through a Graffiti-like language called 'tapAtap' which does not require the user to be familiar with windows, slidebars or pull-down menus.

A browser-like programme, implemented with perl/Tk, keeps the interface simple and consistent says the trust.

Potential manufacturers

The Simputer Trust will not be making computers but will license the reference design to manufacturers. March 2002 is mooted as the earliest production date.

One licensee is PicoPeta Simputers, a new venture started by the four faculty members of the Indian Institute of Science who are part of the Simputer team.

PicoPeta claims to be a "Simputer solutions company" whose primary business is "to use the Simputer as a building block to provide large scale IT solutions to International clients."

PicoPeta has been operational since May of 2001
www.picopeta.com

Runaway tyre prompts wind-driven ball for Mars

A 6-metre diameter ball on Mars could move at about 10m/s (22mile/h) pushed along by Martian afternoon winds of 20m/s.

After a lucky accident, NASA may develop a Mars rover that is more Spacehopper than Sojourner.

The potential Martian is a huge inflatable ball that would be blown across the landscape by breezes in Mars' thin atmosphere.

The idea came after a thin-walled balloon tyre fell off another prototype rover and blew away. "It went a quarter of a mile in nothing flat," said technician Tim Connors, who had to hitch a lift on a passing all-terrain vehicle to catch it.

Tests with a 1.5m-tall version of the 'tumbleweed rover' in the Mojave Desert suggest a 6m-diameter bouncer should be able to climb over or around one-metre rocks and travel up 25° slopes on Mars.

The proposal involves slinging instruments inside with bungee cords and partially deflating the ball to stop it or hold it steady. Some steering is possible, said NASA, by actively displacing weights inside as it rolls.

"With a 20 kilogram ball and 20 kilogram payload, the 6-meter diameter tumbleweed ball is light enough that it could be added on to another lander and deployed from the ground, or it could be in its own delivery vehicle," said researcher Jack Jones. The large, lightweight ball could possibly also serve as its own parachute and landing air bag.

Internet DES security standard has a new rival

Design firms Amphion from Northern Ireland, D'Crypt from Singapore, and Cambridge-based Helion Technology have all announced cores supporting the Rijndael encryption algorithm.

The Rijndael algorithm is at the heart of AES, the advanced encryption standard designed as a replacement for the current Internet security algorithms DES and 3-DES.

It was developed by Joan Daemen and Vincent Rijmen, and is a block cipher using 128, 192 or 256-bit keys. Belfast intellectual property developer Amphion is developing over 20 cores supporting AES.

"It's quite conceivable that every mobile communicator, server, and Internet-enabled appliance in the communications infrastructure world-wide will embed strong encryption technology in some form or other," said James Doherty, CEO of Amphion.

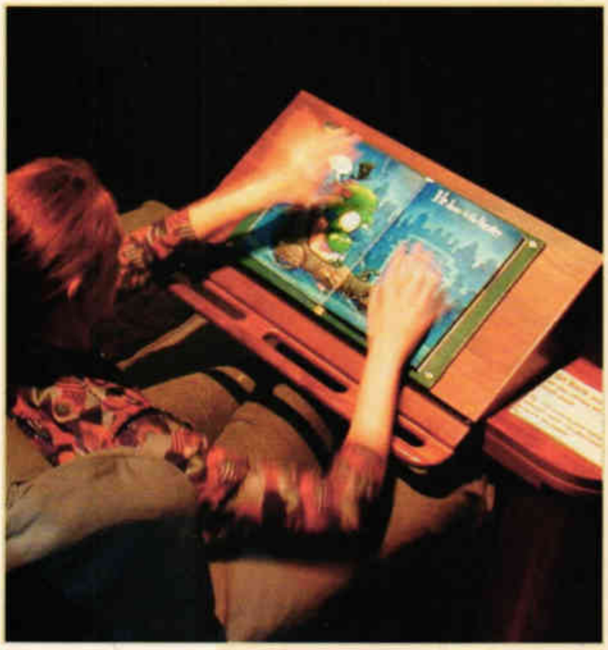
Although the algorithm can be implemented in either hardware or software, Amphion's cores will be hardware based. This, the firm says, gives anything from one to five orders of magnitude faster encryption and decryption times.

Meanwhile, Helion has cores for both Asic and Xilinx FPGA users. "We have worked very hard to optimise the performance of these cores," said Graeme Durant, CEO at Helion. "As data rates get higher, there is more and more pressure on a system's encryption capabilities."

Durant claims the fast Asic version is capable of encrypting data at well over 2Gbit/s, while a pipelined variant will run at over 25Gbit/s.

The Xilinx version can encrypt data at rates well in excess of 10Gbit/s, he said. D'Crypt, on the other hand, is aiming its cores at users of Altera Apex 20KE programmable logic, and can encrypt or decrypt data at up to 2.5Gbit/s. "These cores are possibly the fastest of their kind in the world today," said Dr Antony Ng, D'Crypt's CEO.

The encryption core uses 6167 logic elements, the decryption core 6784 logic elements. This is about a sixth of a million gate FPGA.



'Museum' shows interactive story book

Xerox's famous PARC research labs has designed, built and is running a 'museum' exhibit on the future of reading – especially the interaction of digital technology with reading.

Central to the exhibit is the Listen Reader, an interactive children's story book which plays suitable ambient sounds as the child turns the pages to read.

Three of the Listen Readers graced the first outing of the exhibition. "It was common to see several children squished together into the easy chair, reading the books together – to the surprise of the museum staff, who did not think that reading was a very compelling topic," said lead designer Maribeth Back.

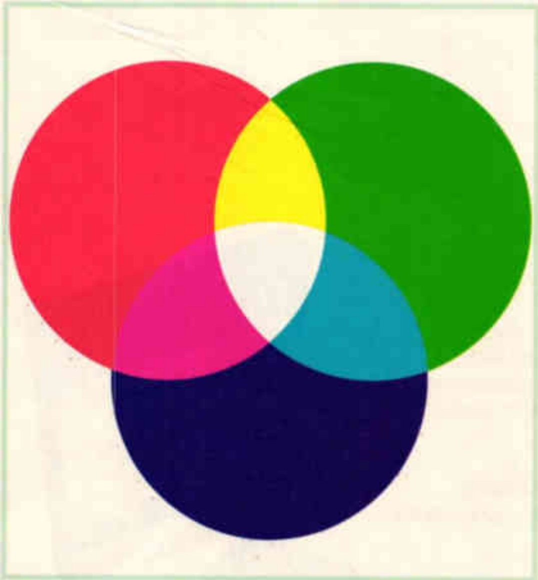
The sounds for each page are multi-track with the volume and mix controlled by the child waving a hand over the page.

This seemingly magic capability comes courtesy of four book-mounted Qprox capacitive field sensors, from Southampton-based Quantum Research.

RF identification tags in the pages tell the book which part of the story the child has reached so it can play sounds appropriate to that part of the story.

What has been learned from the exhibition may affect the future of electronic books and learning.

www.parc.xerox.com/red/projects/xfr
www.qprox.com



Douglas Clarkson looks at the composition of the colour dots that make up the picture on your TV screen.

CRT phosphor technology

The final process in the creation of a colour CRT image is the release of light from the red, green and blue phosphors on the glass screen's surface. There are three component colours primarily because colour in the human visual system is perceived to originate from sensing of three components of colours associated with three distinct sets of retinal cones.

The first attempt to make objective measurement of the eye's response to colour was in 1931. Then, the CIE, or Commission Internationale de l'Eclairage, defined a nominal colour response system for the eye. The basic components of colour are in fact spectral combinations of 'blue', 'green' and 'red' as indicated in **Fig. 1**.

In theory, any colour could be described as a combination of primary components red, green and blue. Specific red, green and blue phosphors commonly used for CRT display technology do not map exactly to the separate colour responses of the eye, so in fact it is not possible to use CRT technology to display every possible colour.

The human eye, however, would be hard pressed to determine any such deficit. Using this initial CIE colour space, a specific colour can be described as a value of X, representing red, and Y, green, as indicated in **Fig. 2**. The value corresponding to blue, i.e. Z, is not typically shown since it is assumed that $X+Y+Z=1$.

In theory, there is an absolute chain of reference from the colour of an object imaged by a TV camera to the colour displayed on a TV display. While this is very much the challenge of the broadcast TV engineer, much less consideration is given to this by the viewing public, who have really very little appreciation of the basics of colour theory.

To walk through a retail outlet where various models of TV are all tuned to the same station will usually reveal that there are significant differences in colour rendition. While there are a number of factors involved in determining colour 'quality', it will be useful to consider basic aspects of phosphor technology.

Phosphor attributes

Over time, considerable effort has gone into developing phosphors used with CRT displays. Factors that affect the

Table 1

General attributes of CRT phosphors.
Specific name (TEPAC-WW)
CIE emission 'colour' (X and Y values)
Peak wavelength (nm)
Decay time to 10% (micro seconds)
Efficiency (%)
Chemical composition
Typical particle size

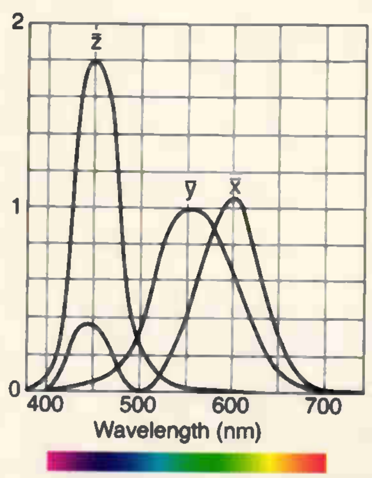


Fig. 1. Nominal colour response of the eye according to CIE.

quality of pixel colour include:

- Relative brightness of phosphor colour.
- Spectral light distribution of phosphor colour
- The phosphor's persistence
- Chemical stability

The use of inefficient phosphors requiring large excitation currents will tend to require more expensive electronic circuitry. Phosphors should also provide closeness to the primary responses of the eye so that as wide a range of colours as possible can be faithfully represented. Phosphors should also have acceptable stability over the lifetime of the CRT display device.

Phosphor technology is used across a wide range of industries, with the main application that of display technology. In conventional CRTs, electrons are accelerated to voltages up to 30kV, imparting their energy to specific phosphors which in turn release part of this energy as visible light. The key parameters to describe specific phosphors is indicated in **Table 1**.

Monochrome phosphors such as P4 decay down to 10% in 60μs, while colour phosphors have a shorter persistence of around 10 to 20μs.

While the emphasis has been with high-voltage CRT displays, there is considerable interest in development of low-voltage phosphor technology. Already, the rich green luminescence of zinc oxide, or ZnO, has been extensively used in green-only displays. A key research focus has been to develop blue and red low-voltage phosphors of comparable luminous efficiency.

Increased demand for more precise printing of CRT phosphor arrays requires the production of phosphors with well-defined particle size distributions. Phosphors of one to two micrometres in diameter have excellent packing characteristics – giving rise to dense, thin deposition layers. The use of thin layers requires less material to achieve high brightness characteristics and improve resolution. Best results are also obtained when phosphors are generally spherical.

An intrinsic feature of TV displays is the proportion with which individual red, green and blue phosphors contributions are mixed to produce specific colour – and in particular white. In order to assess relative brightness, consideration has to be made of the eye's visual or 'photopic' response which peaks at 555nm and decreases for shorter or longer wavelengths.

In terms of relative values of luminous flux (lumens – unit lm: analogous to watts of radiant energy) as perceived by a human observer, the ratios for white generation on CRT displays is commonly described as 0.3 lm red, 0.59 lm of green and 0.11 lm of blue.

A set of 'standard' colour primaries has been identified for

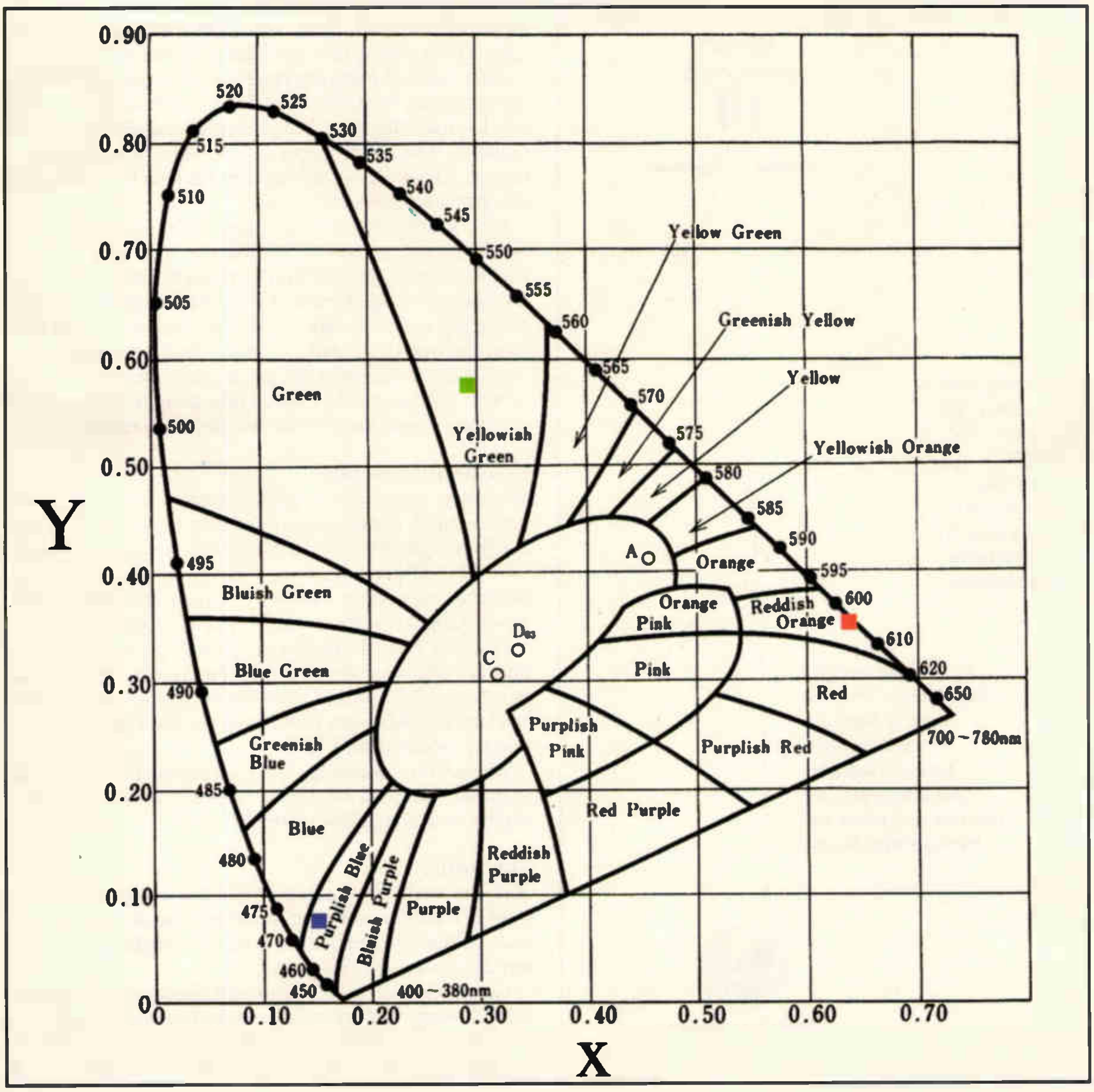


Fig. 2. CIE colour space as a means of mapping specific colours into values of X and Y. The colour spots are approximately where the R, G and B phosphors lie.

colour television display tubes in the UK, **Table 2**.

Table 3 indicates some commercially available CRT phosphors which match closely to the set CIE components identified in Table 2.

The position of the specific primaries are identified in Fig. 2, which shows the structure of the CIE diagram as R, G and B. The various phosphors occupy points of a triangle within the 'horseshoe' of the locus of the visible spectrum.

The absolute definition of 'white' on the TV screen, however, is rather more complicated and relates to identification with a specific spectral description of 'white' light. The standard adopted for colour TV in the UK is D6500. This is a spectral distribution identified as approaching the spectral distribution of a black body radiating at 6500K. This standard seeks to replicate white as being close to 'standard' daylight.

Table 2

Specific primary phosphors defined for UK and EBU.

Colour	CIE X	CIE Y
Red	0.64	0.33
Green	0.29	0.60
Blue	0.15	0.06

Table 3

Active phosphors which closely match primaries defined in UK and EBU.

Colour code	CIE X	CIE Y	Composition key
Red P22-X(R)	0.647	0.343	Y2O2:Eu R
Green P20-KA	0.297	0.571	(Zn:Cu)S:Ag G
Blue P11-BE	0.147	0.076	ZnS:Ag B

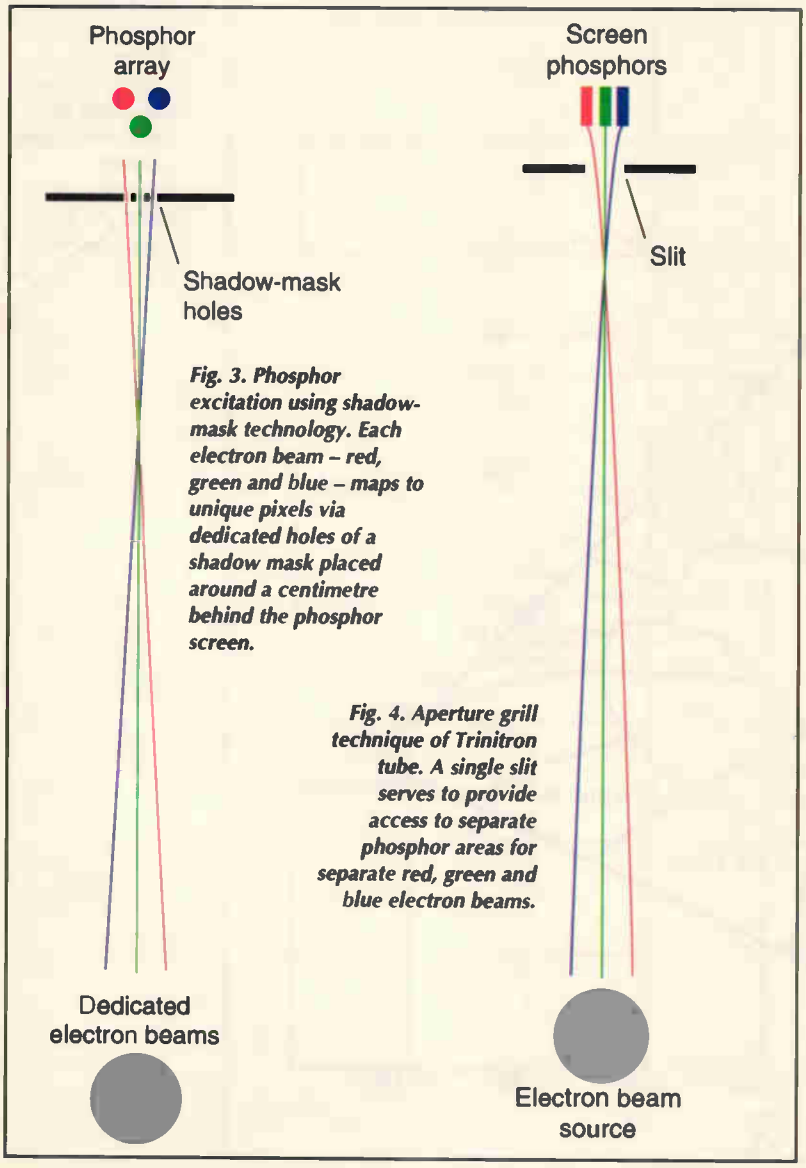


Fig. 3. Phosphor excitation using shadow-mask technology. Each electron beam – red, green and blue – maps to unique pixels via dedicated holes of a shadow mask placed around a centimetre behind the phosphor screen.

Fig. 4. Aperture grill technique of Trinitron tube. A single slit serves to provide access to separate phosphor areas for separate red, green and blue electron beams.

Phosphor dot geometry

Most CRT systems use so-called shadow-mask technology. Separate electron beams for red, green and blue are intercepted by a shadow mask about 1cm behind the phosphor surface as indicated in **Fig. 3**.

The shadow mask ensures that only phosphor dots corresponding to the colour of the incident electron beam are illuminated. The mask is about 0.15mm thick and typically fabricated from thin sheet steel. This sheet is photoetched from both sides, producing a tapered hole that reduces electron scattering.

In one method of such shadow mask production, one specific phosphor layer is deposited on the inside of the glass screen and the shadow mask secured in place. The mask/screen is then irradiated with an intense beam of ultraviolet light at the position of the specific electron gun. This etches in the 'pixels' to correspond to the specific phosphor. This is then repeated for the other phosphor types.

After the final phosphor layer has been applied, the inner screen surface is coated with a thin layer of aluminium. This acts to protect the deposited phosphors and also reflect light outwards from the phosphor targets, which would otherwise be lost. About 80% of the incident electron beam energy is dissipated on the shadow mask.

Sony's Trinitron tube generates three separate electron beams for red, green and blue but can fire them through a single slot in an 'aperture grill' to reach the phosphor surface as indicated in **Fig. 4** and still maintain phosphor separation. Using this technique, around 30% more in the way of electrons can reach the phosphor screen – leading to brighter picture quality. So called in-line gun display tubes share features of both delta-gun and Trinitron tube designs. The so-called slot mask passes more of the electron beam energy.

Phosphor evolution

With early colour TV systems incorporating three separate tube displays, some degree of filtering of early 'yellow-red' borate phosphors was necessary. The development of single-tube CRT displays however focused the development of phosphor technology. This in particular lead to introduction of so-called rare earth elements such as europium.

Typically high electron-beam currents are needed to produce red relative to those required for green or blue. The relatively small proportion of blue necessary to create 'white' can lead to a noticeably less intense rendition of screen areas that are predominantly blue.

Where CRT systems are being used primarily for text and graphics, increased brightness can be provided by using a sightly desaturated blue phosphor.

The future

With the world more and more inclined to spend its time in front of a display system of some kind, the market for phosphor products to provide the necessary brightness for such devices has never been greater.

The widespread use of systems for displaying and printing colour images has given rise to an increasing interest in 'describing' colour in a more objective way – in order to ensure more faithful representation of such images. ■

Is a PRBS Gaussian?

In the July issue, Ian Hickman described how shift registers can generate pseudo random bit sequences and noise. In an earlier article, on probability density distributions, he repeated the generally held view that a low-pass filtered pseudo random bit sequence provides Gaussian white noise. This article looks again at the subject, questioning that generally received wisdom.

In a recent article,[1] I illustrated the Gaussian voltage density distribution of random noise. The range of voltage level was repetitively swept at a fairly slow rate across a waveform under test. A very simple low-pass filter was used to derive the cumulative voltage at each point. Consequently, the noise had to be high-pass filtered before applying it to the test circuit.

This filtering was of no importance in itself. As the article explained, the voltage distribution depends only on the wave shape, and hence independent of frequency.

Table 1

Run length	consecutive 1s	consecutive 0s
n	1	0
n–1	0	1
n–2	1	1
n–3	2	2
n–4	4	4
"	:	:
"	:	:
2	2^{n-4}	2^{n-4}
1	2^{n-3}	2^{n-3}

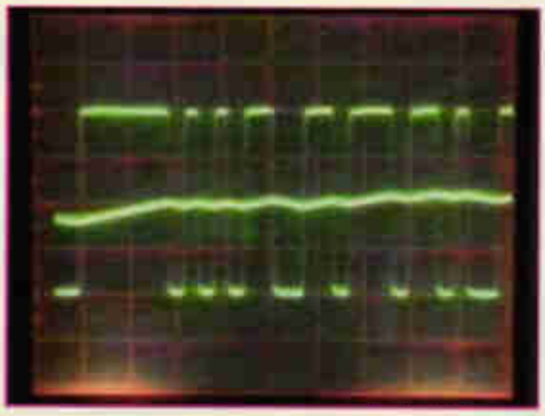


Fig. 1. Showing a short segment of a pseudo-random binary sequence from a linear feedback shift register, and the same waveform after low-pass filtering. Both are at 5V/div. vertical, 20μs/div. horizontal

The noise used for this experiment was provided by an audio-frequency noise generator that I made some years ago.[2] It obtains the noise from the low-pass filtered output of a linear feedback shift register. This LFSR is connected so as to provide a pseudo random bit sequence, or PRBS, of maximal length.

With a 28-stage shift register, its sequence is $2^{28}-1$ bits long. Being clocked at about 6MHz – a period of 166ns – the sequence repeats every $(2^{28}-1)\times 166$ns, which is just under 45 seconds.

The way that different length runs of noughts or ones result in a pseudo noise waveform is illustrated in Fig. 1. This shows a segment of a PRBS, together with a low-pass filtered version of the same.

Thus the noise consists not of a truly continuous spectrum like 'real' noise, but of spectral lines, all of equal amplitude, at a fundamental frequency of ($^1/_{45}$)Hz and all harmonics thereof.

The spectrum extends up to the cut-off frequency of a simple first-order low-pass filter, which was set at 80kHz. It thus covers the whole audio spectrum, with a couple of octaves in hand, for good measure. The result is a flat spectrum up to 20kHz.

A fault rectified

When the noise generator was switched on, there was a period of a few, or many, seconds before the noise output appeared. During this interval, there would be silence, or a high pitched whistle or other strange noises.

At the time that I built the instrument, I thought that it was entering the sequence from a 'side-arm', as in figure 3 of ref. 3. This was of course nonsense, since any possible state of the 28 stages must be a member of the maximal length sequence, as several readers wrote in to point out at the time.

As my range of instrumentation is now much better than when the original article, 'Wide-range noise generator', was published back in 1982, some investigation was called for. Following the signal through the various stages, immediately following switch-on, revealed that the thirteenth stage of the shift register did not operate straight away, but only after a 'warm-up' period.

This was a little surprising, as components usually work, or fail, completely. It is ironic that only recently I was telling students at the RF Club at Portsmouth University that when their circuits don't work, in nine hundred and ninety nine cases out of a thousand, the fault is with their construction, not with a component. So this was the odd thousandth case. Replacing the 7495 duly cleared the fault. But nonetheless, a curious riddle remained.

Not symmetrical

Although the instrument now burst into life instantly on switch on, the positive-going noise peaks of the audio noise seemed definitely larger than the negative-going, **Fig. 2**. Could this really be so, or was there a silly mistake somewhere?

To check, I fed the sequence through an inverter prior to the low-pass filter. This simply resulted in the negative-going peaks being the larger, **Fig. 3**. The conclusion was inescapable; the effect was real, and the noise waveform was not truly Gaussian in distribution.

This was puzzling, as the noise from this same generator, used as a test signal in the voltage density distribution experiment described in ref. 1, did not show this asymmetry: see Fig. 5 of that article. But then I remembered that the noise had been high-pass filtered, which would have nullified the effect of long runs of noughts and ones.

The exclusive-ored feedback input to the shift register was taken from stage three, and the last stage. This corresponds to what is, I believe, the only trinomial of 28th degree. Taking the feedback from stages 24 and 28 would give the same maximal length sequence of noughts and ones, but in the time-reversed order. However, this would not affect the voltage distribution, by the same token that the voltage distribution of a sawtooth waveform is the same, whether the slopes are positive-going, or negative-going, or equal as in a triangular wave.

To see whether the unequal distribution of peaks was simply a fluke, peculiar to the choice of a 28-stage LFSR, I took the exclusive-or feedback from stages 3 and 25, giving a rather shorter maximal length sequence of $2^{25}-1$.

The result was as in **Fig. 4**, and the asymmetry in the amplitude of positive-and negative-going peaks is even more marked – time to don the thinking cap.

How random is random?

Table 1 gives the number of runs of noughts and ones, of various lengths, for a maximal length sequence of any degree (number) of shift-register stages, n. Apart from lengths n and $n-1$, there are as many runs of length m of noughts, as of ones (m less than $n-1$). But this gives no information whatever about how they are distributed – where they occur in the sequence.

With 28 shift-register stages – or even 25 – it is difficult to see what is going on. So I shortened the shift register to a mere six stages. This gives a maximal length sequence of 63, corresponding to the trinomial x^6+x+1, using feedback from the first and sixth stages.

The resulting low-pass filtered noise shows a gross asymmetry in the size of positive and negative peaks, and closer study indicates why, **Fig. 5**. A run of four ones is followed by a single nought and a run of five ones, taking the voltage net eight units positive. This is followed immediately by a run of six noughts, resulting in a large positive peak, as shown.

By contrast, longish runs of noughts are interspersed with runs of ones, so there is no large negative-going

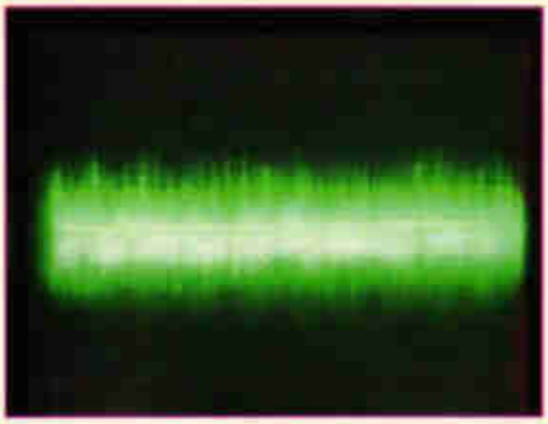


Fig. 2. Low-pass filtered waveform at a much slower time base speed of 2ms/div. horizontal – the positive-going spikes seem larger than the negative-going ones.

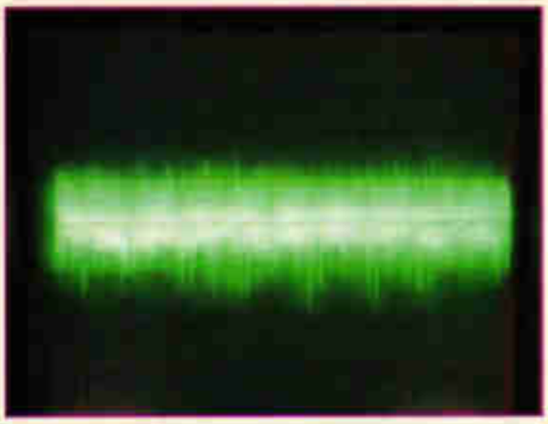


Fig. 3. As Fig. 2, but the PRBS inverted before low-pass filtering. Result – the negative-going pulses are as large as the positive ones were before the inversion.

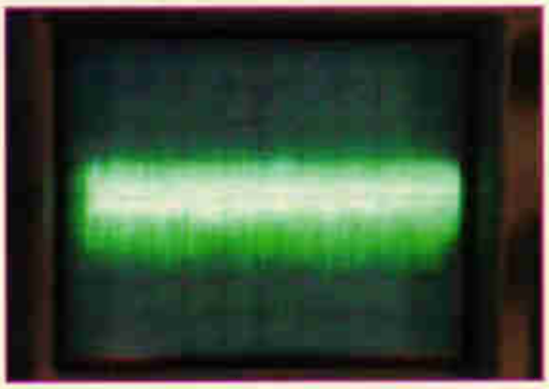


Fig. 4. Low-pass filtered noise produced by a 25-stage LFSR shows even more asymmetrical peaks than a 28-stage LFSR.

Fig. 5. An even shorter LFSR with just six stages produces this 'noise' waveform.

peak. Evidently the same occurs, to a greater or lesser extent with much longer LFSRs.

There are numerous other feedback connections for a 28-stage shift register, giving other sequences, also of maximal length. They all require more than one exclusive-or gate, as they are not trinomials.

Maybe some erudite reader knows whether these arrangements with more non-zero coefficients would provide low-pass filtered noise, giving a more symmetrical distribution of peaks.

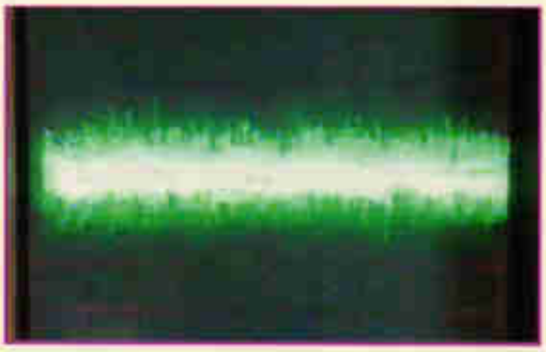


Fig. 6. The low-pass filtered noise from a Gold code using 20 and 11 stage shift registers shows no asymmetry of the positive and negative peaks.

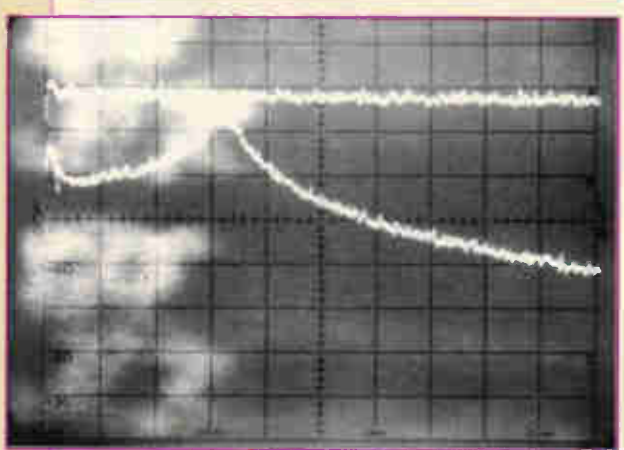


Fig. 7. Full bandwidth noise output of the modified generator (upper trace). Span 0 to 20kHz, vertical 10dB/div., reference level (top of screen) 0dBV, resolution bandwidth 300Hz, post detector smoothing minimum, sweep rate 50seconds/div. In the lower trace is noise output with band-pass filtering (peaked low-pass), settings as before, except reference level +20dBV.

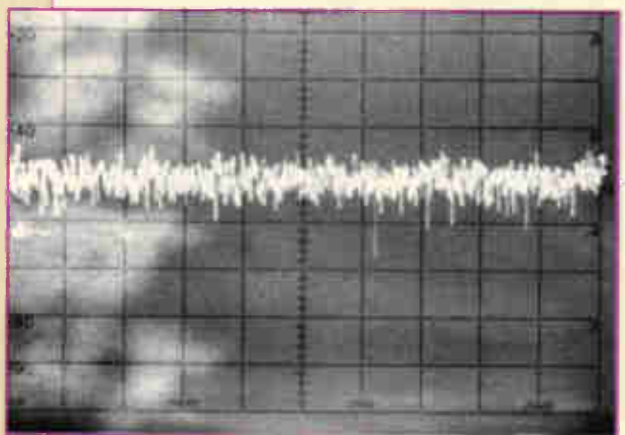


Fig. B. Full-bandwidth noise output of the modified generator shows no 100Hz component. Span 75Hz to 125Hz, vertical 10dB/div., reference level (top of screen) 0dBV, resolution bandwidth 1Hz, post detector smoothing medium, sweep rate 100seconds/div.

Gold codes to the rescue

Having discovered that an asymmetrical distribution of peaks was unavoidable, using a 28th degree trinomial, the question was what could be done about it?

An obvious answer was to invert the sequence periodically. Clearly the inversion should be less frequent than every 28th clock pulse, to avoid breaking up the longest runs of noughts and ones. Even then, however infrequent, the inversion could occur in the middle of a long run.

In true Gaussian noise, occasional large spikes of either polarity occur; even the odd spike of infinite amplitude. It's just that such spikes occur infinitely infrequently – fortunately. Although the spike amplitude it provides is strictly limited, nevertheless an LFSR with as many as 28 stages can in principal give a good approximation to the theoretical bell-shaped Gaussian distribution.

Such periodic inversion though is only an artificial fix. There is no method for choosing how often to invert the sequence.

A much better idea seemed to be to invert the sequence randomly, with another, different, maximal length sequence. In other words, the two sequences are simply ex-ored together: this is known as a Gold sequence. The length of the Gold code produced by ex-oring two shift registers, of n and m stages, is,

$$(2^n-1)\times(2^m-1)$$

The circuit modified

A pair of convenient trinomials of degrees n and m, where $n+m=28$ does not exist, and I did not wish to shorten the overall length of the sequence. So another 7495 four stage shift register was added, and values of 20 and 11 stages used for the two shift registers. Both correspond to trinomials. Maximal length sequences were obtained with feedback from the third and twentieth stages, and the second and eleventh, respectively.

The length of the sequence is now,

$$(2^n-1)\times(2^m-1)\times166\text{ns}$$

which is around 6 minutes.

Incidentally, for many values of n, (2^n-1) is not prime. For even values of n, up to 34, (2^n-1) factorises, with $(2^{20}-1)=7\times7\times127\times337$, while $(2^{11}-1)$ also factorises, equalling 23×89. There are no common factors between the two, although I do not believe it would affect the Gold code even if there were.

Figure 6 is a segment of the noise output from the modified circuit, and shows a good balance of negative and positive peaks. While the longest run of 20 ones from one shift register is likely to be broken up by the exclusive-or input from the other, there will be instances of a segment of one sequence happening to match a segment of the other, or its inverse. Presumably this would result in a run of up to 30 or 31 noughts or ones.

Certainly, occasional quite large spikes, of either polarity, are evident in Fig. 6.

Not forgetting the spectral response...

It was important to know that the spectrum of the noise is flat, and this is proved by the upper trace, covering 0 to 20kHz, in Fig. 7. The trace appears to be – and indeed is – 20dB below the reference level. With the spectrum analyser's input attenuator set to the next more sensitive 10dB step, the overload indicator lit, due to the high ratio of peak-to-rms value of the signal.

For this test, the variable filter in the generator was set to low pass, with a 100kHz cut-off frequency, i.e. above the cut-off of the fixed 80kHz filter mentioned earlier. The variable filter can be set to low pass or high pass, with the cut-off frequency adjustable in a 1-2-5 sequence. There is in addition a variable control filling in the range between these settings, and a flat position is also available.

The high-pass setting was used for the test in the Beginners' Corner article on waveform distributions[1]. In the low-pass position, the variable filter can also be set to provide a peaked response of varying magnitude, giving, in effect, a band-pass response. This is shown, at one of its less extreme settings, in the lower trace in **Fig. 7**. To avoid overload, the spectrum analyser's input attenuation has been increased by 20dB.

Figure 8 looks very boring, but in the context is a

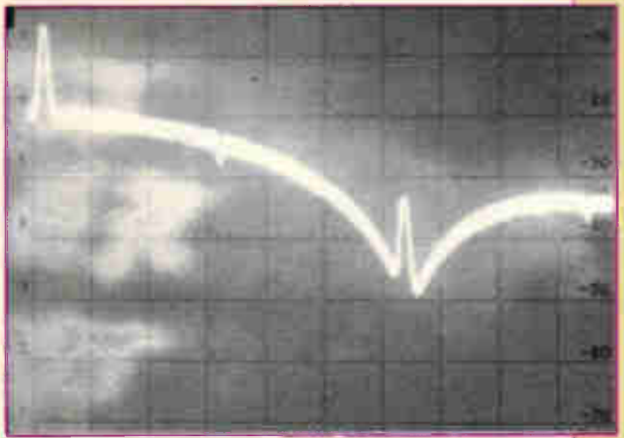


Fig. 9. Broadband noise output, showing the sinx/x response with the null at the clock rate marked by some clock breakthrough. Span 0Hz (marker at left) to around 10MHz, ref. level 0dBm, 10dB/div. Vertical, 100kHz resolution bandwidth, video filter setting at maximum.

More on random bits

In response to Ian's first article on pseudo-random binary sequences in the July issue, Rafael Deliano has provided this supplementary information on why a PRBS doesn't always have gaussian distribution. Rafael also outlines a method for checking short registers.

Some explanation as to why the signal after the low-pass filter doesn't always have gaussian distribution can be found in Gaugg, Weinrichter "Verarbeitung von Pseudozufallssignalen durch digitale Filter" NTG-Fachtagung 1973.

The authors have first a look at the probabilities of transitions of bits. The ideal is shown in **Fig. A**, with: 0,0=He; 1,1=He; 0,1=Ha; 1,0=Hz. The 'sparse' trinomial, **Fig. B**, of an eight-bit LFSR is worse than a configuration with 50% of the taps used, **Fig. C**. This 50% version gets closer to ideal as the length of the register increases, **Fig. D**. Sets with too many taps deteriorate again.

The authors then show that 50% gives best results for the gaussian distribution of filtered data too. Since published tables rarely list anything other than trinomials, they are not much help. For short registers, it is quite easy to test whether numbers generate *m*-sequences. A simple example would be an eight-bit LFSR.

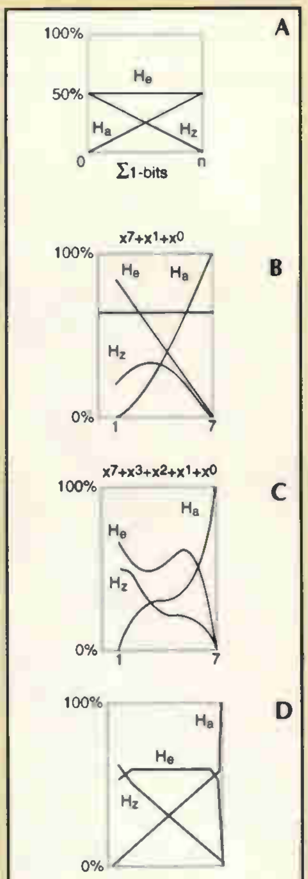
You can programs the LFSR in assembler on a computer. The LFSR is best implemented in Galois configuration as shown in the upper circuit of **Fig. E**. The Fibonacci-configuration in the lower circuit will work with the same polynomials.

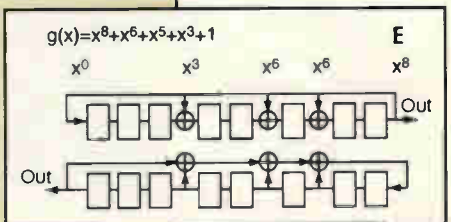
For testing, load the LFSR with a pattern, like AA_{16}, then clear an eight-bit counter and start counting. While the LFSR and the counter are running, look for the pattern.

On an *m* sequence the pattern repeats as the counter overflows to 00_{16}. If the counter overflows to any other value, the LFSR is stuck in a short cycle. If the pattern repeats early, the same has happened.

This simple test of a polynomial is good enough to do an exhaustive search for short lengths like eight bits, for all 256 polynomials. Using my 6502-based computer and Forth, the calculations take only seconds.

For longer LFSRs, 16 bits, say, a full search of all patterns is no longer possible. Tests to exclude impossible polynomials – an odd number of taps for example – are necessary. It is still possible to search groups like 'all patterns with 50% taps used'. It takes hours on a 6502, but a PC will do the job a lot quicker. ■





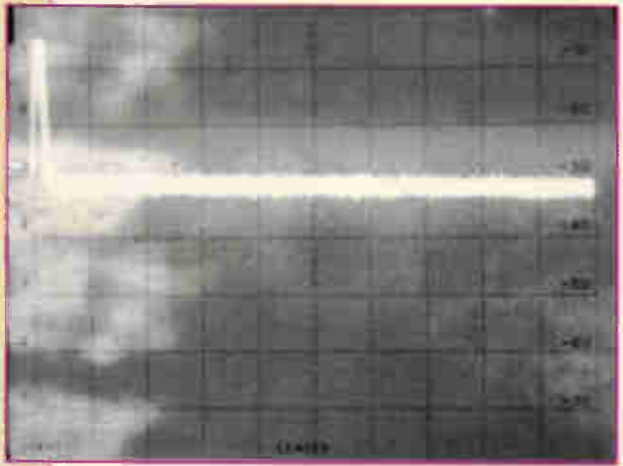


Fig. 10. As Fig. 9, except 0Hz to 1MHz and 10kHz resolution bandwidth.

very important piece of evidence. It shows a span covering 75 to 125Hz, with a 1Hz resolution bandwidth. Given the 360 seconds period of the Gold sequence, the spectral lines constituting the noise are 0.0027Hz intervals. So there are 360 of them within the analyser bandwidth, forming virtually a continuous spectrum.

The important piece of evidence is the absence of any trace of a hump at 100Hz, indicating the absence of any hum from the full wave rectified supply rails.

In principle, if you could sufficiently narrow the analyser's bandwidth further, a suspicion of hum might be apparent. In this case, you would ultimately be comparing its level with just one of the 360 spectral lines in a 1Hz bandwidth of the noise waveform.

Even at the 1Hz setting, a very slight bump was visible at 100Hz, before the smoothing capacitor on the positive rail supplying the +5V stabiliser, was increased from 1500μF to 4700μF. ■

References

1. Hickman, I., 'Waveform Distributions', (Beginners' Corner), *Electronics World*, January 2001, pp. 54-57.
2. Hickman, I., Wide-Range Noise Generator, *Electronics World*, July 1982, pp. 38-40.
3. Hickman, I., 'Pseudo-random bits', *Electronics World*, July 2001, pp. 500-503.

Programmable

Yehuda Sonneblick and colleagues* have been investigating Zetex's Trac programmable evaluation board for the analogue designer. An AM receiver illustrates its versatility.

Designers of digital equipment are now well used to having general-purpose devices that can be configured to almost any pattern desired. Such devices, which include gate arrays and PLDs, have been around for a long time.

Analogue computers consisting of various circuits that can be patched together have also existed for many years. These enable various differential equations to be solved. Although such devices preceded digital computers, they are still around and mostly used in aerodynamic and mathematics departments.

Analogue computers usually consist of a number of discrete circuits on a large board. These circuits can be patched together to make the desired circuit configuration. They are almost invariably used for solving differential equations. They can also be used to solve integral equations, but with less accuracy.

A programmable analogue device

A new device has appeared on the market in recent years. It is a totally reconfigurable and programmable analogue circuit device: the TRAC020LH. A development board is available for the device. This board accommodates four such devices giving 80 possible cells.

The development board is not fully programmable though. For some of the functions, it is necessary to add external components such as resistors or capacitors.

The manufacturer refers to the chip as a 'field-programmable analogue array or FPAA. This ingenious device is in a 36-pin small-outline package. It has 20 general-purpose cells. Each can be configured – and indeed reconfigured – into an almost unlimited combination of circuits.

Configuration is carried out by programming from a computer using a three-digit binary code. The data is sent serially from the computer to the chip. In general, the various functions operate between –1.5V and 1.5V input voltage with a maximum 1.5V or –1.5 V output voltage. The values given by the manufacturer are shown in Table 1. Full details of this device can be obtained from http://www.fas.co.uk.

Figs 1 & 2 show two examples. The first is a simple amplifier, the second a more complex low-pass filter.

The functions available for each of the Trac's elements are: add, negate, non-inverting pass, log, antilog and off. While a cell is 'off', no signal can pass through it, so that it is effectively removed from the circuit. In addition there are rectifier and amplification functions. Thus, provided your circuit has fewer than 80 cells, you can configure the chip to carry out almost any analogue task that your imagination allows.

* The authors – Yehuda Sonneblick, Michael Slifkin and Shaoul Israeli – are with the Department of Electronics, Jerusalem College of Technology

Table 1

Maximum positive and negative voltage swings depend on what function a particular Trac cell is programmed to perform.

Cell function	$V_{in-(max)}$	$V_{in+(max)}$	$V_{out-(max)}$	$V_{out+(ma)}$
NIP	–1.5	1.4	–1.5	1.4
NEG	–1.4	1.2	–1.5	1.4
ADD	–1.5	1.4	–1.5	1.4
LOG	–1.4	1.4	–0.8	0.8
ANT	–0.8	0.8	–1.5	1.4
REC	–0.8	1.4	0	1.4
AUX	–1.4	1.4	–1.5	1.4

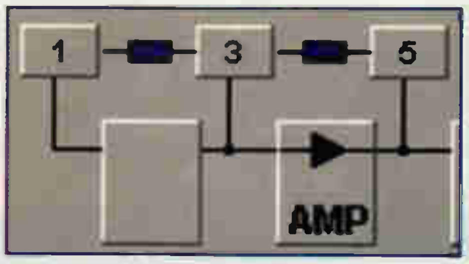
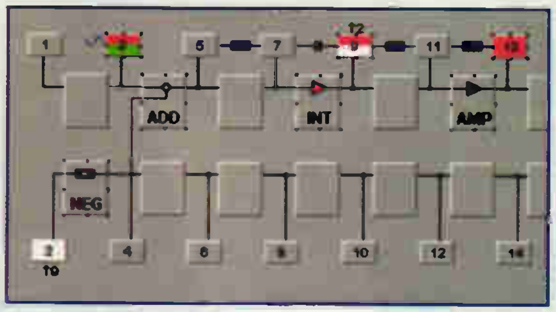


Fig. 1. One of the Trac IC's twenty blocks configured as an amplifier using the Trac programming software.



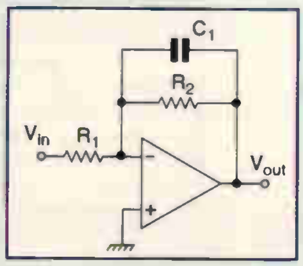


Fig. 2. Part of a Trac IC configured as a low-pass filter, left, and its op-amp equivalent, right.

analogue board

In a way, this device is an analogue equivalent to a DSP development board in that you can use programming to effect a wide variety of functions. However, unlike a DSP there is a certain minimal amount of external patching to be done. We were struck by the obvious utility of this device and bought the development board to find out if it really came up to the manufacturer's specifications.

Figure 3 shows the manufacturer's schematic diagram of the device. It does require a clock, which

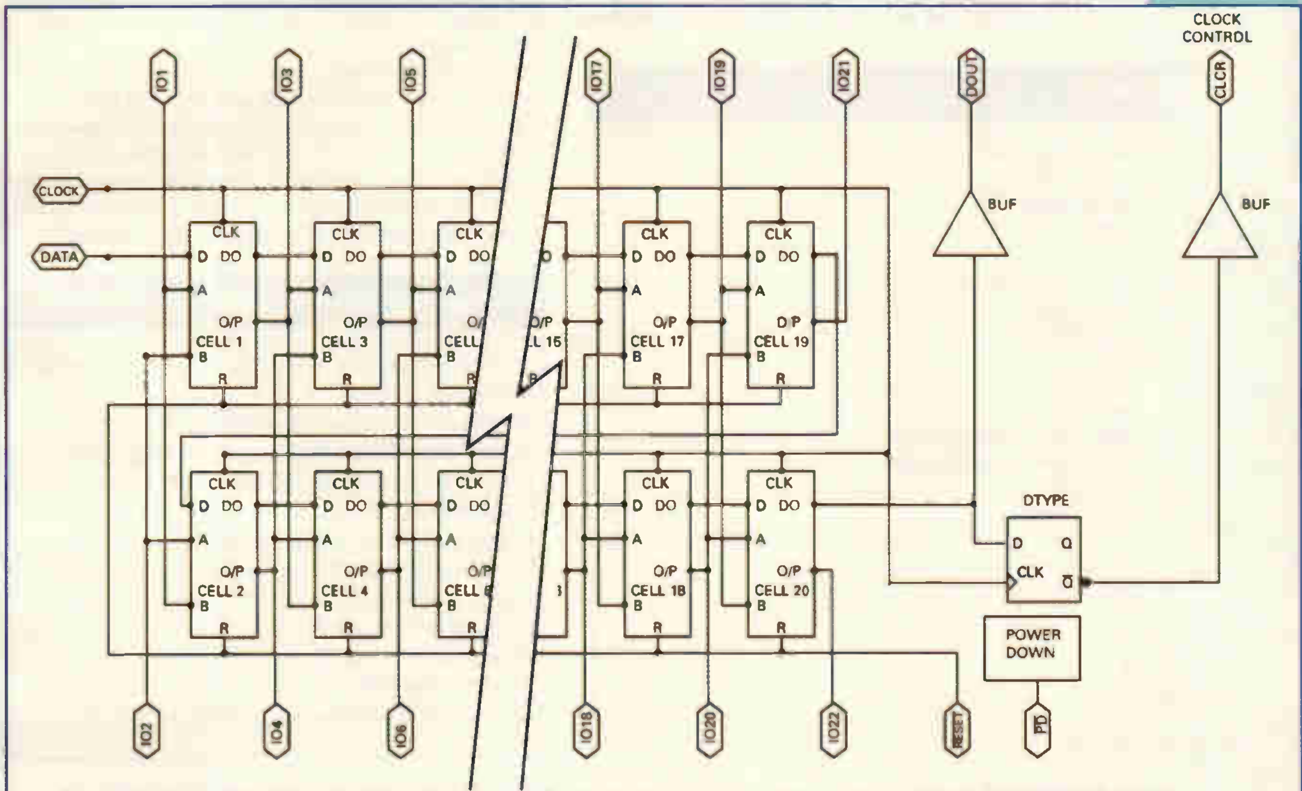
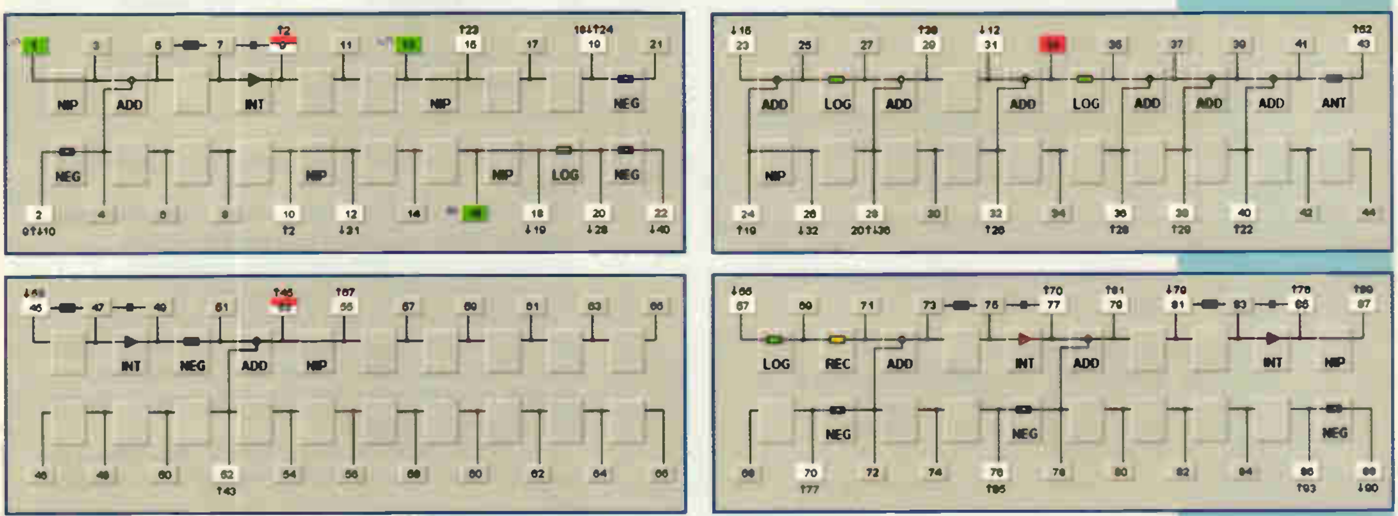


Fig. 3. Circuit outline of the Trac020, showing how the device is programmed by a string of binary data that's clocked in from the left. Note that not all of the 20 cells are shown as they all interconnect identically.

Fig. 4. Simulation of an AM transmitter using four Trac programmable analogue chips. There wasn't enough room on the evaluation board to try it out so we could only simulate it via the Trac simulator, which is available for download at the Trac web site.



can be provided from the computer. In addition, the manufacturer provides simulation software, which allows you to program the device on screen and to simulate its performance. The manufacturer's application notes also give a variety of different circuits that can be made.

We wanted to see how the evaluation board worked as a combined AM transmitter and receiver. However, there wasn't enough room to build the transmitter *and* receiver on the board so we could only simulate the transmitter, **Fig. 4**.

In/out descriptions shown in **Table 2** are more or less self-explanatory. Mixing of the carrier wave and the information signal is carried out by obtaining the logarithm of the carrier wave and the information signal and then adding them.

As logarithms can only be used with positive numbers though, a wholly positive wave results. To make the wave symmetrical about the base line, it is necessary to subtract and offset, referred to as 'E' in the table. Taking the antilogarithm then gives the correct CW plus signal that an AM transmitter emits.

The transmitter worked fine and the result of the simulation is as you would expect.

Table 2

I/O descriptions for the AM transmitter, Fig. 4.

Input signal descriptions

I/O	Description
2	bcosy

I/O signal descriptions

I/O	Description
1	Information wave
	Am*cosx
	x=Wm*t
3	lpf
9	Information wave after lpf
10	Information wave after lpf
12	Am*cosx
13	Carrier wave
	Ac*cosy
	y=Wc*t
15	Ac*cosy
	E
18	E
19	E
20	–logE
22	logE
23	Ac*cosy
24	E
25	–(Ac*cosy+E)
26	E
27	log(Ac*cosy+E)
28	–logE
29	–(log(Ac*cosy+E)–logE)=–log(Ac/E*cosy+1)
31	Am*cosx
32	E
33	–(Am*cosx+E)
35	log(Am*cosx+E)
36	–logE
37	–(log(Am*cosx+E)–logE)=–log(Am/E*cosx+1)
38	–(log(Ac*cosy+E)–logE)=–log(Ac/E*cosy+1)
39	log(Am*Ac*cosx*cosy/(E^2)+Am*cosx/E+Ac*cosy/E+1)
40	logE
41	–log(Am*Ac*cosx*cosy/E+Am*cosx+Ac*cosy+E)
43	Am*Ac*cosx*cosy/E+Am*cosx+Ac*cosy+E
52	Am*Ac*cosx*cosy/E+Am*cosx+Ac*cosy+E
	Lets do hpf on this design

Input signal parameters

I/O	Generation	Amplitude	Frequency
1	SINE WAVE	0.05	5000
13	SINE WAVE	0.1	300000
16	CONSTANT	0.2	0

An AM receiver

Next we decided to build an AM receiver to see how easy it was, and what the performance was like. Rather than build a conventional AM receiver, which would have been very easy, we opted for a less conventional approach using cascaded filters. This is probably not a very practical method. However, it does illustrate how quick and easy it is to set up circuits just to see how they behave, without the problem of hard wiring and troubleshooting.

It is useful to try out unconventional ideas. Of course you only really need to do the simulation to get a reasonable idea of how it works. In most instances, the hardware prototype will probably not differ significantly from the simulation results. However, read on to what we found with our circuit. The manufacturer does issue a warning every time you do a simulation that the simulated results may well differ from the real results.

Outlined in **Fig. 5**, the AM receiver, consists of three sections. These are a band-pass filter to prevent overloading at the front end of the receiver, an amplifier, and a somewhat unusual rectifier.

Figure 6. shows the AM receiver's configuration. The resistors are 80kΩ and the capacitors are 100pF. **Table 3** shows the In/Out description of the circuit. This printout is similar in format to that produced by the the manufacturer's software.

One of the features of the software is that each pin can be given a description. When the circuit is printed out,

Free design and simulation software

The following is an extract from the Trac area of www.zetex.com.

The free demonstration version of the TRAC software contains fully functional design and simulation packages. The developer's version, supplied with the TRAC Development Kit, also contains download and upload, plus development board management functions. Your design is sent via the PC parallel port – giving instant working silicon – and a diagrammatic view of the board allows error free placement of external connections and components. The current version of the software is Version 2.2.

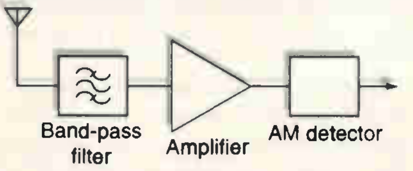


Fig. 5. Outline diagram of the AM receiver using cascaded filters for the detector.

the description is also printed, more or less as shown. You can also print out a whole range of different parameters, such as the links that we show here on the circuit diagram.

We used the simulation to show how the receiver converts the incoming CW plus information wave into the required signal. The various stages are shown in **Figs 7, 8,** and **9**. Finally we actually configured the circuit as per the diagram.

We tested the real AM receiver using a signal generator as the transmitter. It was connected to an antenna similar to the one at the input of the AM receiver. To prevent overload we placed a simple band-pass filter between the antenna and the board. This was just an inductor of 1mH in series with a capacitor of 1μF and a resistor of 250Ω The two instruments were placed about 2m away from each other.

The system worked well with signals from around 100 to 20kHz and carriers from 300 to 920kHz. In fact, the bandwidth of this board was slightly less than given in the manufacturer's specification.

There was a pronounced phase shift between the signal wave and the original detector for frequencies up to about 10kHz. This varies from 180° at low frequency to nothing at 20kHz. This was not predicted by the simulated results, which show only a very slight phase shift. While this shift is not important for an audio transmission, it could well be critical if on transmitting data, phase relationships need to be maintained.

Another difference is that the circuit turned out to be better than the simulation would suggest. The waveform we received from the actual circuit gave no sign of the carrier wave, which can still be seen as a ripple in the simulated wave shown in Fig. 9.

In summary

This board with its associated software is certainly of great value to anyone interested in analogue design. No longer do you have to hard-wire components on a breadboard. Everything is to hand on a single board with full simulation software.

The only drawback for the enthusiast is that it is rather expensive. However we would hope that if it becomes popular, the price will drop. But for someone with a yen to try out different ideas and to test them both by simulation and in practice this is a real boon. ■

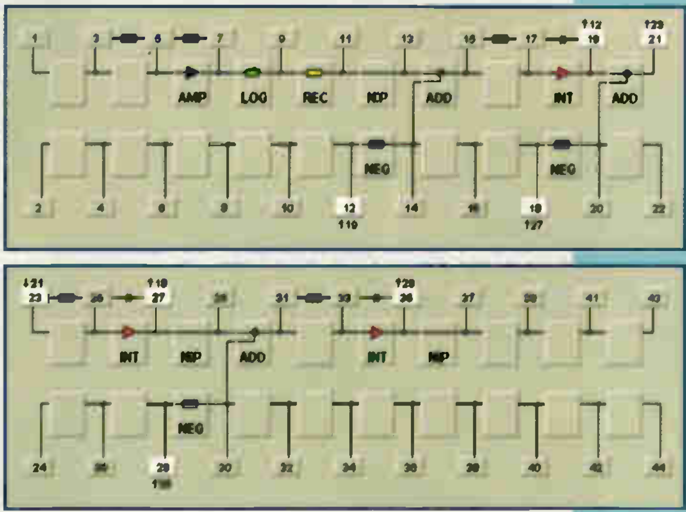


Fig. 6. AM receiver using cascades filters, implemented in a Trac020.

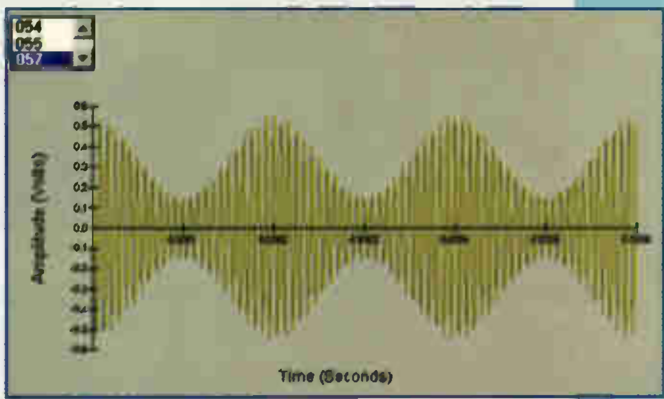


***Fig. 7.** Incident wave from the AM receiver after passing through the diode section. Carrier and its amplitude modulation are as you would expect.*

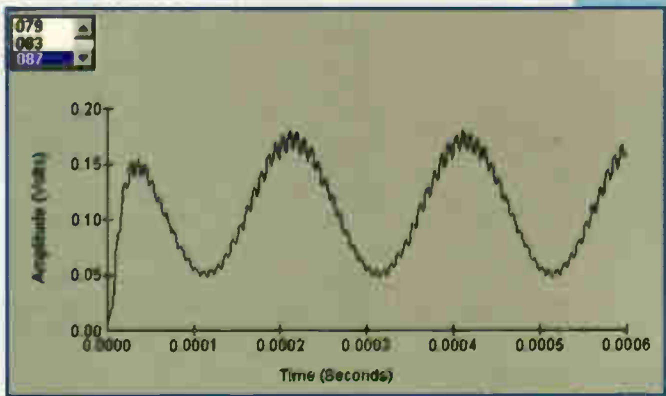


***Fig. 8.** Recovered modulation wave after further low-pass filter detector.*

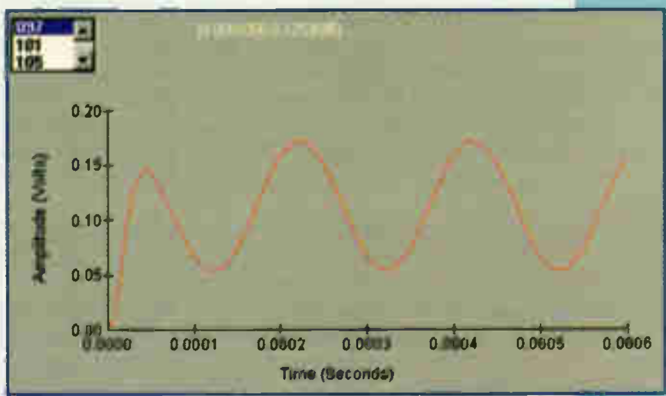


***Fig. 9.** After even yet more low-pass filtering.*

Table 3

I/O descriptions for the AM receiver, Fig. 6.

Input signal descriptions

I/O	Description
2	*bcosy*

I/O signal descriptions

I/O	Description
1	Antenna
2	*bcosy*
3	BPF
7	Amplifier
11	LOG+REC+DIODE
13	LPF
16	E
18	E
29	LPF

Train safety

Wilf James discusses the problems with train safety, and suggests how railways can be made much safer using electronics.

There is a proposal to make trains safer by using a method of stopping trains automatically if the signals are at red. It is estimated that it will take until 2008 to complete the installation of the system at a cost of three billion pounds.

Even when the automatic stopping system has been installed in every train though, it will not prevent the sort of accident that occurred when a Land Rover fell onto the line at Great Heck on 28 February this year.

The existing and planned train control systems assume that the only obstacle that may be encountered by a train is another train that is not derailed on the same track. There are two reasons for having any sort of automatic stopping system:

1. Trains are still using what is basically 19th century technology. In other words, the brakes are so poor that a driver cannot stop a train within the distance that he or she can see ahead.
2. A driver may suffer from sleepiness or otherwise lose concentration and fail to observe stop signals.

Trains stop slowly – very slowly

Using figures obtained from an American train accident enquiry, the deceleration rate for a passenger train was found to be between 0.8 and 1.1 feet per second per second. This was done with the aid of an anti-skid braking system.

Anti-skid braking systems on trains perform two functions. Firstly, they prevent flats from being created on the train wheels. Secondly, they attempt to optimise the braking effort. It would be hard to improve on these figures with manual braking control. Incidentally, train wheels have to be removed and reground to remove any flats that occur due to locked wheels.

At a stopping rate of 1ft/s – around 0.3m/s – the stopping distance for a 125mile/h, i.e. 201km/h, express train is 3.18 miles, or just over 5km. A theoretical motor coach travelling at 125mile/h could stop with a deceleration of around 0.8g in 218 yards, or just under 200m.

The thinking distance is not included in

A sideways look at trains

As a comparison, just imagine how silly it would be if buses were strung together in trains of six to twelve, or heavy lorries moved around in strings of thirty or forty.

I am sure that you would like trains that would run like individual motor coaches. A twelve coach train that runs hourly could be split up into individual coaches that run every five minutes. Just imagine what motorways would be like if vehicles were spaced five minutes apart.

If rail passenger coaches ran singly, there would be no need to make them extremely strong and heavy to withstand the extreme compressive forces that arise when a crash occurs. Single coaches could use track brakes that would not pull the track to pieces. These are a bit like one-sided bicycle calliper brakes.

The track brake would have rollers on the inside to prevent wear on the inside of the track so that the gauge can be maintained. Track brakes are unworkable with a twelve coach train weighing nearly 400 tons. Lighter, single coaches would cause less track wear.

Motor coach operators like National Express use one driver per coach and charge much less for fares than rail operators do. The accident rate for motor coaches is low yet the drivers do not have the overseeing benefit of signalmen or a track that dedicated to their sole use. A typical unladen motor coach weighs less than five tons. A typical railway coach weighs thirty tons or more.

these figures. The brakes on a long train work slowly. The vacuum or compressed air systems are usually activated with one vent for the whole train. Goods trains usually rely on the locomotive's brakes so the stopping distance is very much longer.

If trains could stop as quickly as a conventional long-distance motor coach (0.8g), or, dare I say it, as quickly as a Formula 1 racing car, (more than 2g) most of the need for an elaborate safety stopping system would be unnecessary.

However, it is unlikely that trains will be brought up to a 21st century standard for many years so an alternative way of making train travel safer is needed.

How can electronics make trains safer?

Alongside most railway tracks are a series of posts. These may be telephone poles or the supports for the overhead electrical power supply cables.

The posts are close enough to the track so that anyone who was on one of them would have a very clear view up and down the track – for half a kilometre or more in most cases. A television camera could view the same length of track quite easily – particularly if it had a zoom lens fitted.

Ordinary television cameras are very cheap nowadays and the humble web camera is even cheaper. Mobile-phone technology has reached an advanced stage so that it would be possible to use the GSM system to transmit slow scan television pictures from the cameras to the train drivers and the signalling staff quite easily.

Compression using, say, JPEG, could reduce the bandwidth needed to a low enough figure to suit existing GSM channels. A slow-scan system would enhance the camera's sensitivity in dim light.

I suggest that a video screen is fitted into every train driver's cab. The screen would normally display the next, say, nine sections of track in sections of the screen. The identification of each section would show the driver the sequence of views from the closest to the most distant.

The driver could select any section at will to enlarge it temporarily to the full screen size. The driver could also use the camera's zoom lens – using the GSM system to control it – to see a more distant view more clearly. The same information could be relayed to the signalmen covering the same track sections.

If the cameras have infra-red sensitivity as well as normal (human) vision, it would be possible to identify objects in view that were warmer or cooler than the track more easily. A false colour version of the view could easily be arranged.

A further addition would be a frame store that could be used to compare the standard view with the view currently showing. Any changes in the view would be a reason for an alert or warning that something unusual has occurred.

This system could work on its own in daylight in the absence of fog. It would enable drivers to see whether or not the track in front of them is clear for several miles. This alone would mean that nearly all accidents that might occur in daylight would be avoidable. This would at least halve the likelihood of serious accidents occurring.

In practice, the likelihood of accidents occurring is higher during daylight hours because more trains run during the daytime and there is a greater possibility that a road vehicle is stuck halfway across a level crossing.

Radar look ahead

A further improvement that would be fairly cheap to implement is radar.

Low-power radar is used extensively – and relatively cheaply – for road speed traps and for controlling traffic lights. Traffic-light radar could be used to monitor any changes that occur within its range on a section of railway line. It would also work well in dark tunnels.

Most of these changes would be caused by trains so the information thus gained could be relayed to signalmen to check the progress of scheduled train services. If a change is observed when a train is not expected, the signalling staff would know that something unusual and possibly dangerous has occurred. This could be anything from an animal or some other obstruction that has appeared on the line or that a land slip has occurred.

The speed-trap type of radar could be used to check that passing trains are travelling at the correct speed. For practical reasons it would be triggered by approaching trains – because trains are usually long vehicles. This would be the opposite of that used for road speed traps that check the speeds of departing vehicles.

As GSM is a two-way system, it could be used to relay snapshot views taken by a digital camera mounted on the front of the train. The camera could be triggered by the reception of a radar signal from a proximity (traffic light) radar transmitter mounted on a rail signal gantry. Such pictures could be used to check the visibility – or otherwise – of the rail signals as the train approaches them.

Avoiding sleepiness

There are several rules that can be used to reduce or eliminate the problem of driver sleepiness or inattention. I suggest that the first one must be included.

- If a train driver feels sleepy he/she should be able to report the fact by mobile phone without having to worry about his job or being paid for his shift. A replacement driver should be found at the next safe stopping place. No driver should ever be sacked for reporting sleepiness. If no accident occurs, a driver who passes a red signal without reporting sleepiness beforehand should be transferred to a lower risk job at a reduced salary.
- There must always be two – or more – rail staff on every passenger train. The other person could be a guard, a ticket collector or a dining car attendant. The person concerned should be instructed how to stop a train quickly and safely. There have been true stories about a passenger who has landed an aeroplane safely when the pilot became disabled. Stopping a train would be much easier.
- The drive power must be reactivated every, say, twenty seconds, otherwise the engine shuts down. If the train starts to slow down without an apparent reason, the other employee would be duty bound to find out why. An intercom connected to the the driver's cab would enable a quick check to be made. If the driver does not reply immediately, the other staff member could use a mobile phone to report the situation very quickly. A member of the train staff who travels on the same route regularly would be likely to realise that something was wrong if the train started to slow down where it had not done so previously. If two reactivations are missed, an automatic message can be sent to the signal control centre.
- The nine (or more) view video display could be equipped with a touch screen that would cancel the view of each section of track after it had been traversed. A failure to cancel the view would be treated as if an engine reactivation had been missed.
- A driver should report his or her status and position by phone whenever asked to do so by the signalling staff.
- The driver should be tested for his or her reaction time periodically to check that he or she is alert. This could be a visual or audio signal that has to be cancelled by pressing a button.
- A video camera in the cab may well discourage a driver from falling asleep. A driver is less likely to fall asleep with 'Big Brother' watching.

The British automatic train stopping system, when implemented, would have to be operated so that a train would be stopped within the appropriate safe distance for the train in question – assuming that it was travelling at the correct speed. The correct permutation of train types, normal running speeds, safe stopping distances and signal positions would have to be chosen by a computer in the signals control centre – when a red signal is passed. The cost and complexity of the planned system is mainly designed to deal with just one human failing – sleepiness.

And the cost?

I cannot say how much it would cost to implement the TV and/or radar systems, but I doubt that they would cost more than three billion pounds. Even if these systems cost more, they would be much more effective and could be implemented much sooner than 2008. They would overcome most of the limitations imposed by 19th century technology and driver sleepiness.

Readers of *Electronics World* have had to struggle continually to keep up with the advances in electronics technology from the time that its predecessor the Marconigraph was published. It is a pity that train operators have failed to improve their technology at a comparable rate. ■

Design competition

These entries from our recent design competition demonstrate not only the versatility of the ZXF36 oscillator/mixer, but also the imagination and competence of their designers. On the following pages you will find:

- Direct conversion AM radio receiver for 30kHz to 700kHz
- Frequency standard using the Droitwich long-wave transmitter
- Ultrasonic receiver
- BFO CW/SSB detector and filter
- Solution for direct-conversion side-band image problems
- Acoustic leak monitor

Frequency standard using the Droitwich long-wave transmitter

Before Droitwich's frequency was changed from 200kHz, it was relatively easy to produce a frequency standard locked to the highly stable carrier of the transmitter. The ground wave signal from this transmitter covers not only most of the UK but also some parts of Western Europe as well.

Figure 1 shows a block diagram of such a standard. The 10MHz from the crystal is divided down to 200kHz and then compared with the received signal to give a control signal which frequency or phase locks the crystal to the Droitwich transmitter.

Unfortunately, the Droitwich frequency had to be changed to fit in with the standard for Europe that all transmitter frequencies would be a multiple of 9Hz and so it is now at 198kHz.

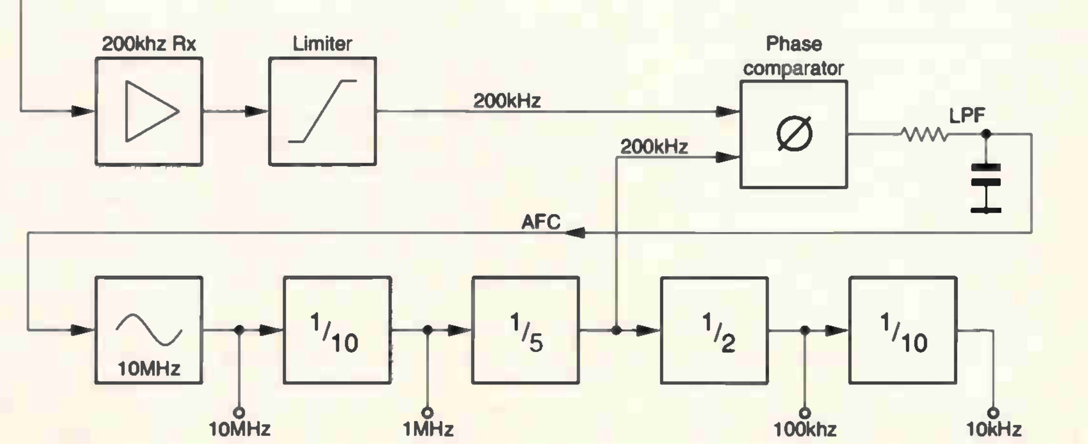
There is no easy way of dividing 10MHz to give 198kHz. Instead, you have to divide the 10MHz by 5000 and the received signal by 99 with the comparison being done at the highest common factor of 2kHz. The disadvantage of this is that the sensitivity to frequency or phase errors is reduced by a factor of 100.

Alternatively, a 200kHz output from the crystal divider chain can be mixed with the received signal. The difference frequency output of 2kHz is then compared with a 2kHz output from the crystal divider chain. This method only causes a 1% reduction in sensitivity to frequency or phase errors. **Figure 2** shows a block diagram for such a method.

Zetex's ZF36L01 ideally suited for this mixing function as it combines both the mixer and a filter that can be readily tuned to the required 2kHz difference frequency. **Figure 3** gives the circuit of a frequency standard using the ZXF26L01 in this manner. It is actually an old OMB '615 Off Air Frequency Standard' that was designed when Droitwich was on 200kHz and has been successfully modified with the ZXF26L01 to work with the new frequency.

Using appropriate division ratios, this method is suitable, for locking frequency standards to suitable transmitters on other frequencies. In general, only long wave transmitters should be used because of the greater area covered by their ground wave signals. At higher

Fig. 1. Outline of a scheme for obtaining a frequency reference from the Droitwich transmitter's signal.



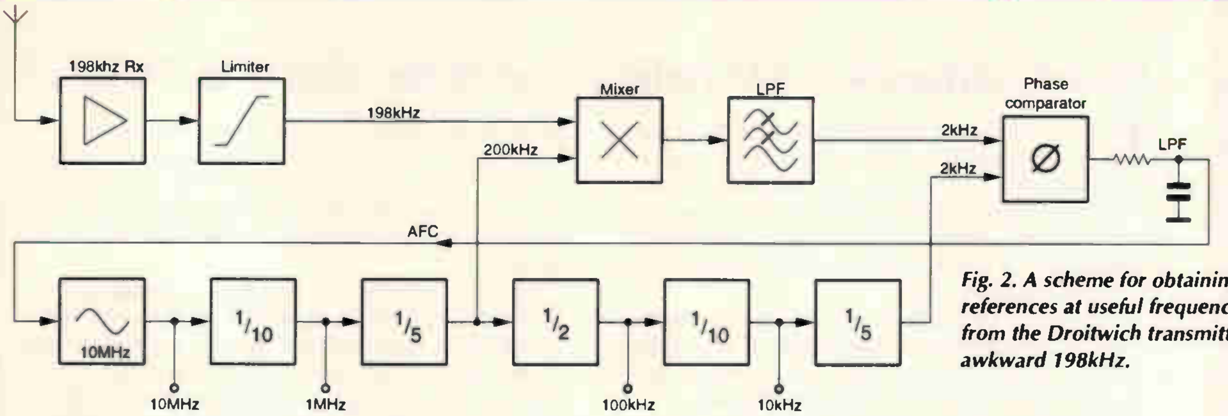


Fig. 2. A scheme for obtaining a references at useful frequencies from the Droitwich transmitter's awkward 198kHz.

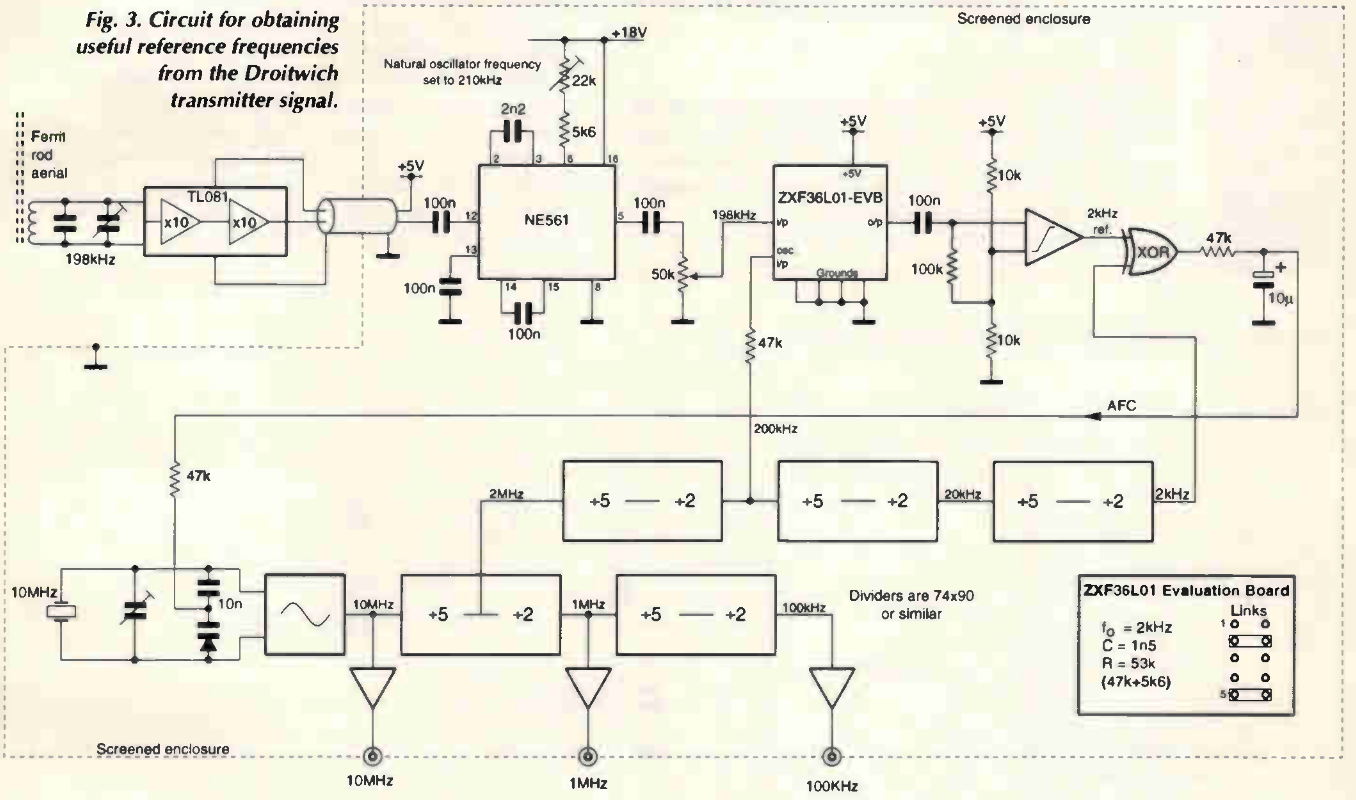


Fig. 3. Circuit for obtaining useful reference frequencies from the Droitwich transmitter signal.

frequencies the ground wave area is smaller and unless you are close to the transmitter, multipath reception of sky wave signals will cause problems especially after dark.

Circuit details

Originally, the RF amplifier for the ferrite-rod antenna involved nine transistors on the main circuit board. As the original ferrite rod was missing, I took the opportunity combine an ic amplifier with the replacement ferrite rod. These were placed in an insulated tube and connected to the main unit with about 200mm of screened cable so that the antenna could be adjusted as need be to get the best signal. A gapped screen was placed inside of the tube around the coil and amplifier.

The voltage-controlled oscillator in the NE561 phase-lock loop ic produces an unmodulated output frequency locked to the received signal. The centre frequency of the vco should be set far enough away from 198kHz so that, in the absence of the received signal, the crystal oscillator will not be able to lock to it.

Both the mixer in the ZXF36L01 and the XOR that acts as the crystal oscillator's phase comparator need to be driven by a square wave. These are obtained by the slightly unconventional connection of the 74x90 decade dividers. This means that the fourth bit has a 20% duty cycle rather than the required 50%.

The 50kΩ potentiometer should be set to give 300mV pk-pk at the signal input of the evaluation board. The 47kΩ resistor sets the mixer drive signal to the correct level.

Output is only a 1.6V pk-pk sine wave so a comparator is used to convert it to a TTL – or CMOS, as appropriate – square wave for the second input to the XOR gate. The output XOR the gate is filtered, both to remove the 4kHz ripple of the gate's action as a phase comparator, and to remove the low frequency phase modulated data signals that are applied to Droitwich.

P F Gascoyne
Wantage
Oxfordshire

Direct conversion AM radio receiver for 30kHz to 700KHz

This receiver takes advantage of the ZXF36L01 IC's local oscillator ability to be driven directly from a microcontroller's output port – i.e. with a square wave.

A highly-stable signal is needed in a direct conversion receiver. In this application, it is easily provided by a simple program in one of the new flash microprocessors that use a crystal oscillator.

Using a microcontroller also allows for such functions as automatic scan tuning in any number of steps, direct readout of frequency on an LCD of LED display, and the ability to receive SSB transmissions by slightly offsetting the frequency away from the carrier. This design also removes the need for any special or hard to source inductors.

Circuit details

Transistor Tr_1 and associated components act as an RF amplifier between the antenna and mixer receiver stage to reduce the possibility of the local oscillator signal being radiated from the receiver's aerial. This amplifier also introduces a useful 6db of gain.

Secondly, through C_3, the stage rolls the response off above about 700kHz, which increases stability. Capacitors C_1 and C_2 roll off the response below 30kHz.

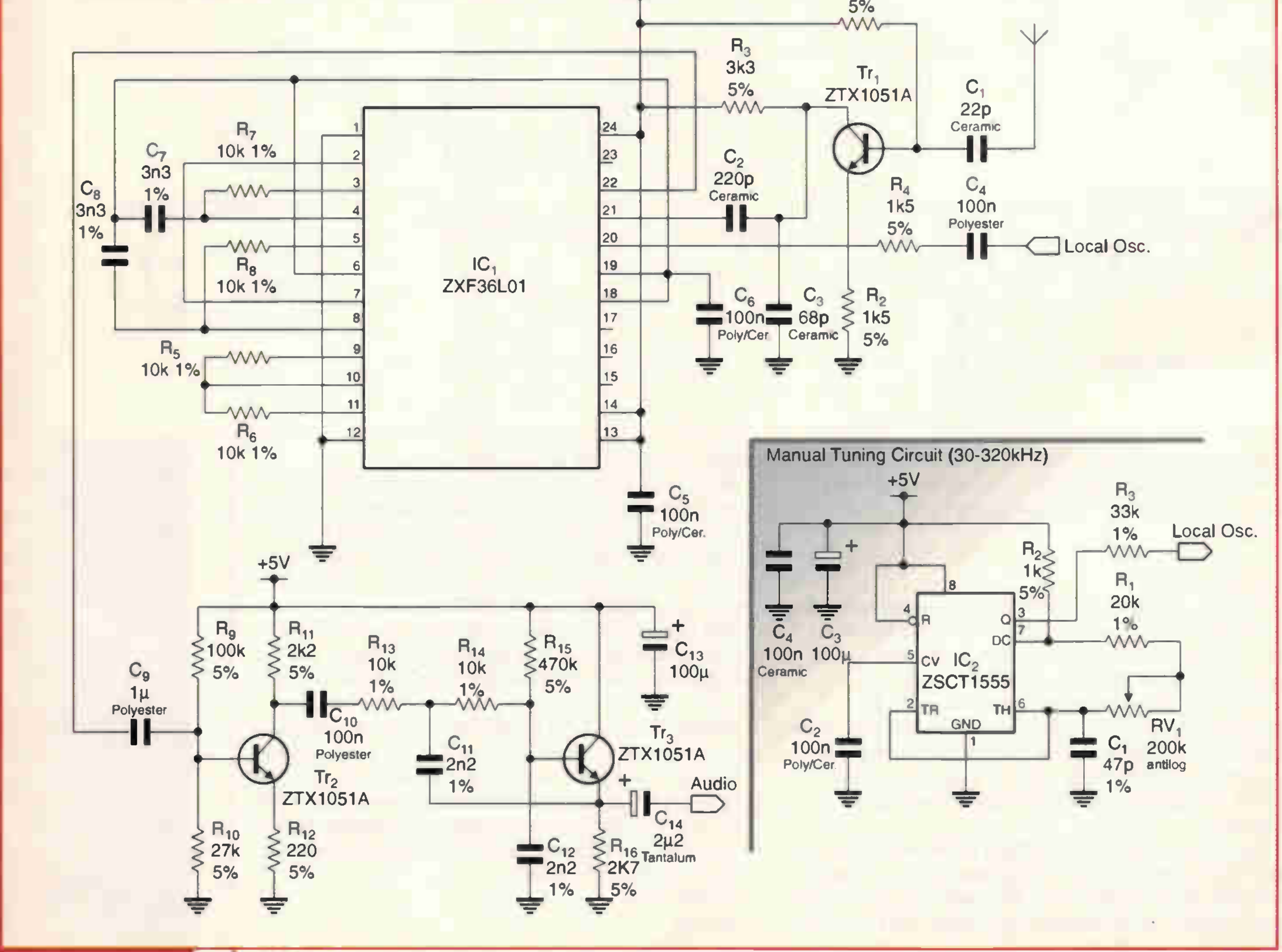
The 50% duty cycle square wave from the microprocessor at the required reception frequency is attenuated by R_3 before being applied to the mixer at IC_1 at pin 20.

Signal emerging at pin 7 contains a multitude of frequencies above the wanted audio. These are passed through IC_1's band-pass filter, setup in notch mode with attenuating skirts but with R_6 and C_8 transposed. This configuration acts as a low-pass filter with a cut-off frequency of 4.8kHz and thus reduces the level of the unwanted signals at the output pm, 22.

Transistor Tr_2 and associated components now form an audio preamplifier which boosts IC_1's output by around 20db before the signal is passed to Tr_3 for further filtering in a second order 7.2kHz low-pass filter.

Audio emerging from C_{14} will now be suitable to drive a power amplifier and speaker but may also benefit from further low-pass filtering if greater selectivity is required. For best results the input impedance of the following stage should be 10kΩ or higher.

Direct conversion AM radio receiver for 30kHz to 700KHz



When you come to implement your chosen microcontroller, make sure that you use the crystal clocking option, as opposed to *RC* or ceramic resonator alternatives. Crystal timing will give the greatest waveform stability and allow the maximum 700kHz to be reached. It may also be advantageous to use a device with as fast a clock as possible.

An easier – but not as effective – means of tuning the receiver without using a microcontroller is shown as an inset to the main diagram. Output from this circuit just feeds the local oscillator input instead of the microcontroller's output. Tuning can now be accomplished manually using RV_1.

Lee Archer
Ashton-in-Makerfield
Lancashire

Ultrasonic receiver

Ultrasonic detectors find many uses both in industry as leak and corona detectors, and in natural studies where they can be used to extend our hearing range into that of bats and insects. Using the ZXF36L01 as a direct conversion mixer and filter simplifies the design of these instruments.

I transposed the Zetex development board into a detector I made some time ago with good results. I did however change the board centre frequency to 1.6kHz from the 10kΩ as supplied. This value allows a reasonable energy to be recovered from swept signals, which will be attenuated with narrow frequency bandwidths.

I also used a variable-frequency oscillator and a digital local oscillator with no problems.

Portable ultrasonic detection circuit

In Fig. 2, the ultrasonic microphone, which may be of the capacitance , ceramic or electret type produces a signal which is amplified by the low-noise preamp. This signal is then mixed with the output of the digital or analogue variable-frequency oscillator.

The notch-pass filter with attenuating skirts selects the resultant audio signal. A frequency of around 1.6kHz was selected for the audio tone. This enables a swept, signal that is a characteristic of bats to be resolved without too great a loss of recovered signal energy. Similarly the Q factor should not be too great if narrow pulsed or rapidly swept signals are to be resolved satisfactorily.

The resolved signal will be of the double side band type with the centre frequency being the null between the two ±1.6kHz side-bands.

Doppler acceleration alarm

Replacing the audio amp with a detect circuit and activating a target with an ultrasonic signal would enable the production of a Doppler acceleration alarm. By adjusting the local oscillator, which would in effect be the acceleration alarm trip set point, an output would be obtained when the

Doppler shifted frequency fell within the pass band of the filter. For example if the energising field was 40kHz and the local oscillator was 40.1kHz and the pass-band was 2kHz a Doppler shift of 1kHz would be required to meet the trip point. With the local oscillator at 40kHz a Doppler shift of 2kHz would be required.

Peter Fry
Holbury
Southampton

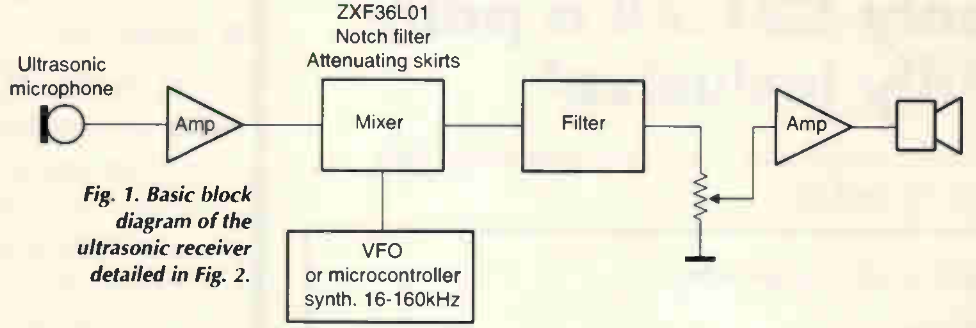


Fig. 1. Basic block diagram of the ultrasonic receiver detailed in Fig. 2.

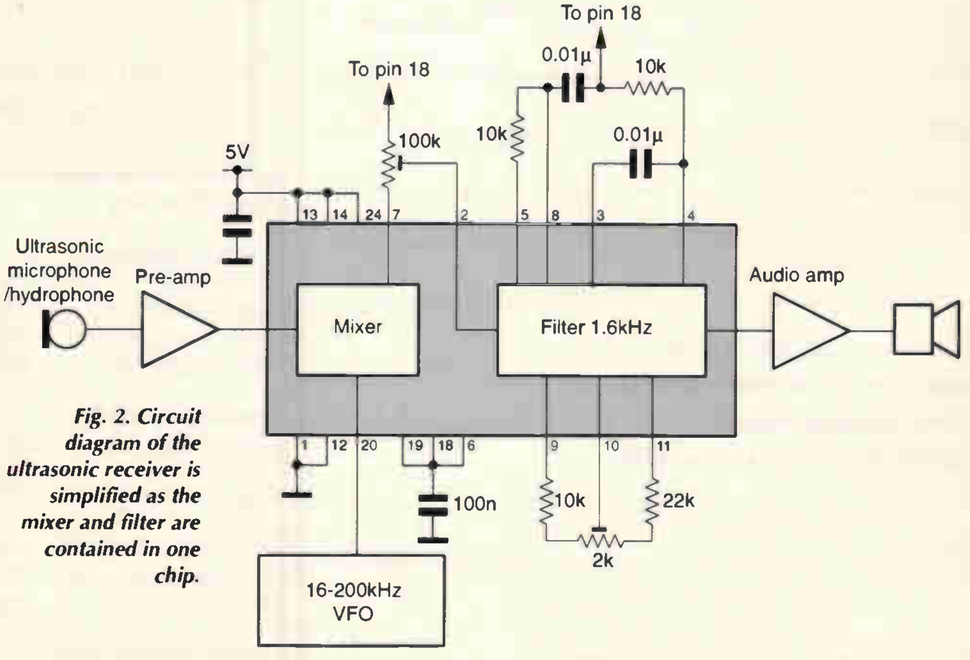


Fig. 2. Circuit diagram of the ultrasonic receiver is simplified as the mixer and filter are contained in one chip.

Electronics World reader offer:

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

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

Please supply the following:

Probes

Total________

Name ________________________________

Address ________________________________

____

____

Postcode Telephone

Method of payment *(please circle)*

Cheques should be made payable to Cumulus Business Media

Access/Mastercard/Visa/Cheque/PO

Credit card no________________________________

Card expiry date Signed

Please allow up to 28 days for delivery

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

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

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

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

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

Specifications

Switch position 1

Bandwidth	DC to 10MHz
Input resistance	1MΩ – i.e. oscilloscope i/p
Input capacitance	40pF+oscilloscope capacitance
Working voltage	600V DC or pk-pk AC

Switch position 2

Bandwidth	DC to 150MHz
Rise time	2.4ns
Input resistance	10MΩ ±1% if oscilloscope i/p is 1MΩ
Input capacitance	12pF if oscilloscope i/p is 20pF
Compensation range	10-60pF
Working voltage	600V DC or pk-pk AC

Switch position 'Ref'

Probe tip grounded via 9MΩ, scope i/p grounded

Solving direct-conversion side-band image problems

The following are design ideas that I had while trying to design a frequency tracker that could work in poor signal to noise ratios and harmonics such as in a guitar tuner. I didn't have the test equipment or enough development boards to fully verify them but they are presented for your interest.

When operating in the direct-conversion mode, two side-bands, separated in frequency by 2× filter frequency, will be resolved. For example, with the local oscillator set to 44kHz and the filter set to 1kHz, an output will be produced when the input is at 45kHz or 43kHz.

The same situation applies if the input is 44kHz and the local oscillator is swept from 43 to 45kHz. This may not confuse manual operators, but if this signal is to be detected and further processed automatically then problems could arise if the system locks on to the 'wrong' side-band.

Using the ZXF36L01in a mixer notch pass with attenuating skirts and the local oscillator under software control, two possible configurations could solve this problem.

The first solution rejects the 'unwanted' sideband while the second processes both side-bands to indicate the centre frequency.

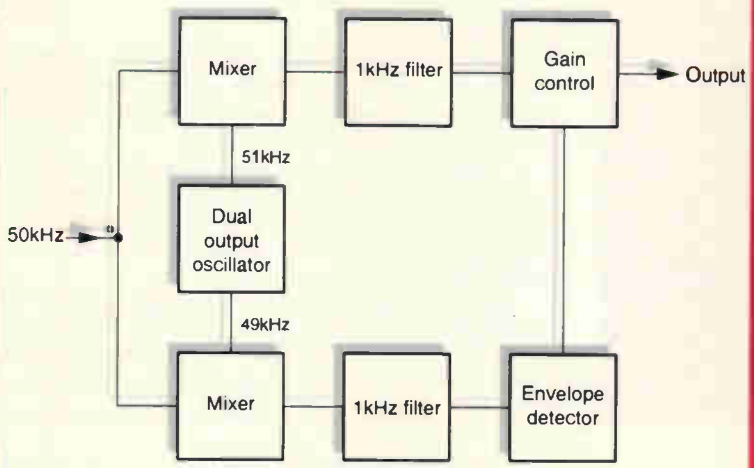


Fig. 1. Direct conversion image rejecting continuous-wave output.

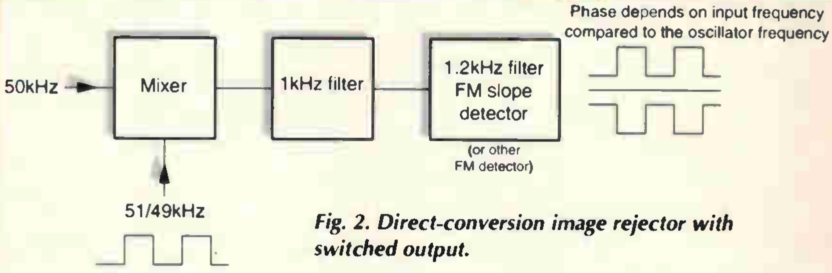


Fig. 2. Direct-conversion image rejector with switched output.

Direct-conversion image-rejecting CW output

In this circuit the local oscillator is fed to two ZXF36L01 devices. Each is configured for notch pass with attenuating skirts both at, say, 1kHz pass.

The local oscillator, which is software controlled, is fed simultaneously to both mixers. The centre frequency +1kHz is fed to one mixer and centre frequency −1kHz to the second. This results in both side-bands being simultaneously detected.

All that now remains is to declare one side-band as the wanted signal and to use the other as the 'pass enabler' the output of the wanted side-band is only enabled to the output when *two* side-bands are present a further interlock the side-band amplitude could be checked for equal height.

The microprocessor will indicate the centre frequency at this point.

Direct-conversion image rejection with switched output

In this circuit two ZXF36L01s are used, the first in a mixer and filter configuration, the second tuned slightly higher to act as a slope tuned FM demodulator. Alternatively, two filters could follow the first such that a better FM detector could be realised.

Via software control, the local oscillator is automatically switched between the upper and lower frequencies, 51 and 49kHz in my example. The first filter will produce an output of a near continuous wave at 1kHz with an input of 50kHz. If the input were to go to 50.1kHz then the output would comprise of two signals alternating between 1.1kHz and 900Hz.

An FM detector fed with this signal would produce a square wave output whose phase could be compared to the oscillator switch signal. This would indicate whether the LO was below or above the desired frequency.

If the local oscillator is arranged to track with the 2kHz difference then there will only be a single point at which a continuous output is obtained as opposed to two if a single non switched signal is used.

Peter Fry
Holbury
Southampton

Acoustic leak monitor

This use of the ZXF36L01 is for acoustic monitoring of leaks. The mixer section reduces ultrasound to audible frequencies, and the filter allows the signal to noise ratio and sensitivity to be increased.

In many industrial plants, there are multi-plate heat exchangers. A typical use is in food industries, where it is necessary to raise and lower the temperature of a product on a short time scale to kill bacteria. Such exchangers work by having an interleaved stack of stainless steel plates so that the heating or cooling fluid passes over one side, and the product over the other. Leakage between the two sections can result in the product contamination and so regular checks are made.

During maintenance, leakage is measured by applying compressed air and checking the pressure decay rate. If a leak is found in one plate the exchanger must be dismantled and each plate checked in turn to find what might be tiny pin-hole leaks.

To help locate leaks, acoustic monitoring is useful. Air leakage through small holes can have characteristic audible or ultrasonic output.

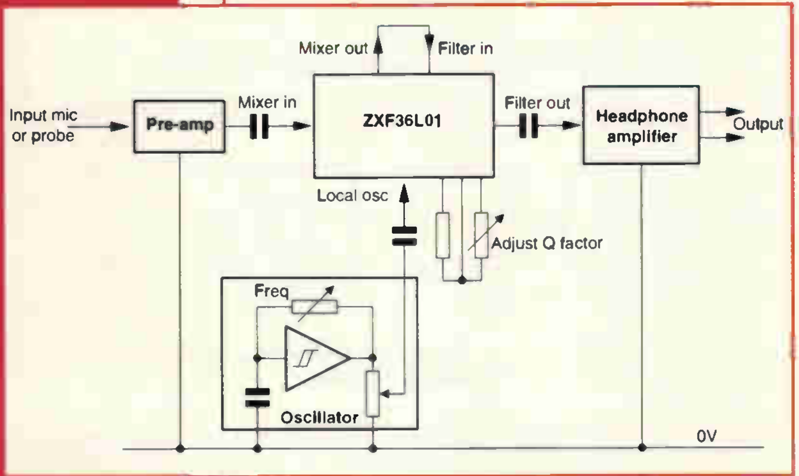
The proposed design speeds up the leak detection by enabling operators to hear and observe these acoustic signal levels.

Circuit details

A block schematic is shown. The signal from a contact probe, microphone, or ultrasonic receiver is matched and adjusted by an appropriate low-noise amplifier then fed to the mixer input of the ZXF36L01.

If a minimal solution is needed, the sensitivity is high enough to allow direct operation from some types of transducer. However, a pre-amplifier allows gain adjustment to maximise dynamic range and noise performance.

The local-oscillator input is fed from a simple feedback *RC* oscillator, which is adjustable from 20 to 200kHz. The circuit produces a near 50% duty cycle and has a level of 25mV peak-to-peak. Ultrasonic signals mix with the oscillator output to produce a difference frequency in the audible range. Typically, a 36kHz signal and a 34kHz oscillator produce a 2kHz output.



The variable-Q band-pass filter is centred at 2kHz – which is where the ear has good sensitivity. When initially searching for leaks the filter is set to a low Q factor so that signals from the mixer above and below 2kHz can easily be heard. Increasing the Q factor and adjusting the local oscillator frequency allows the wanted sound to be 'tuned in'.

Higher Q settings give more selectivity and reduce unwanted out of band signals. Selection of appropriate Q and gain allow the sensitivity to be maximised.

Output is amplified to headphone driving levels by a low-voltage full-bridge device such as the TDA7052A. This is a low component count amplifier with a DC volume control.

There are many other devices that could be specified in this application, some of which have a shut down option. Such a device could be used along with the ZXF36L01 shut down pin for a battery saving feature. Alternatively, a 5V regulator with shut down could be used to provide total automatic switch off.

I haven't tested the design, but the data sheets indicate that the device will function well at the frequencies and Q factors involved.

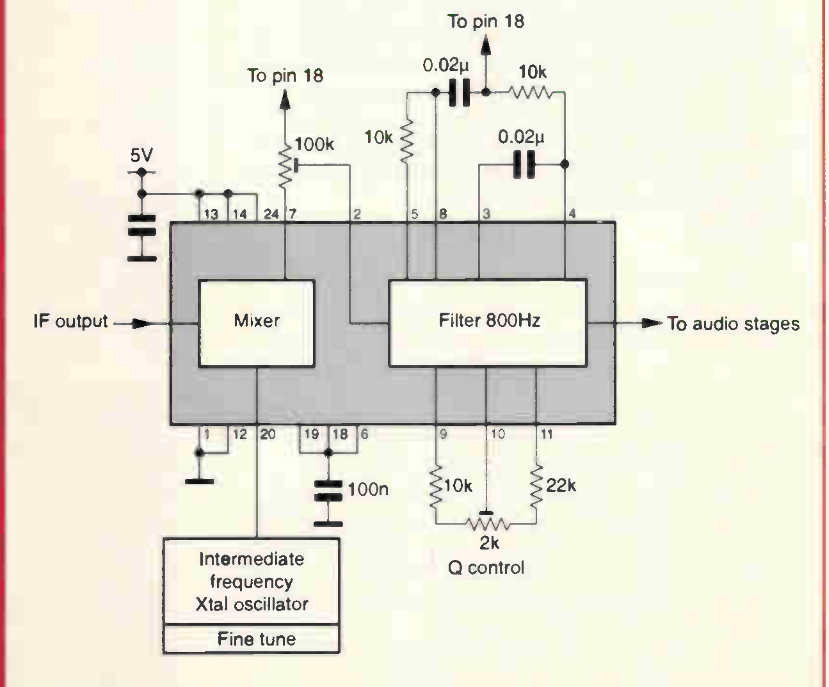
Other applications

The principles here can be applied to other ultrasound monitoring applications. Checking mechanical bearings and engine vibrations in the ultrasound range could give interesting insights. There are also possible medical applications for example, monitoring artificial heart valves and other implants.

Bryan Brooks
Burton-on-Trent
Staffordshire

The ZF36L01 could be used as a CW detector and filter in a communications receiver.

BFO CW/SSB detector and filter



Bringing the Q setting out to the operator would enable a variable Q filter for optimum CW reception. The maximum Q permitted must give a safety margin away from the self-oscillation value. The normal centre frequency of 800Hz could be used depending on preferences.

The same principle could be used for SSB reception. Depending on the audio quality required though, it may be desirable to cascade two filters with offset centre frequencies so that a broader SSB characteristic filter response is obtained.

A fine tune on the IF injection oscillator will enable the signal to e adjusted exactly in the pass-band.

Peter Fry
Holbury
Southampton


Innovative ideas
New product news
Circuit diagrams
Updates on research
Tools for professionals
Current issues
– on your doorstep
Keep up-to-date with an
Electronics World subscription,
delivered direct to your door
every month.
See reverse for details...


OLSON
OLSON IS THE MARKET LEADER FOR HIGH QUALITY MAINS DISTRIBUTION PANELS
POWER FOR THE OFFICE
A WIDE RANGE OF PRODUCTS AVAILABLE WITH RCD, MCB AND RF FILTER PROTECTION
INTERNATIONAL RANGE
For 19" rackmounting systems, designed for vertical or horizontal use. Available with European, American, Australian and IEC sockets.
POWER FOR 19" RACKMOUNT SYSTEMS
FLOOR BOXES
INDUSTRIAL WITH RCD PROTECTION
DATA PATCH PANELS
19" CABLE TIDIES
32 AMP MULTI POWER CABLE MANAGEMENT SYSTEMS
19" VENTILATION PANELS
19" FAN TRAYS
NEW CATALOGUE!
SALESLINE 020 8905 7273
product guide portfolio
24 HOUR DELIVERY SERVICE
VISA
VISA, MASTERCARD & SWITCH CARDS ACCEPTED
OLSON ELECTRONICS LIMITED
OLSON HOUSE, 490 HONEYPOT LANE
STANMORE, MIDDLESEX HA7 1JX
TEL: 020 8905 7273 FAX: 020 8952 1232
E-MAIL: sales@olson.co.uk WEBSITE: www.olson.co.uk

Active RF scope probe

Have you ever stopped to work out just how much the loading from your passive scope probes is affecting your measurements? If you have, you've probably noticed the high price of active probes too. Cyril Bateman's unity-gain oscilloscope probe features low capacitance and provides faithful results up to 100MHz, yet it won't leave you out of pocket.

Many oscilloscopes measure to at least 100MHz, but because of capacitive loading, most test probes inhibit measurement of high-frequency low-level signals.

My Coline M12SW oscilloscope probes have a claimed bandwidth of 250MHz and 1.4ns rise time. When set to divide by ten, the probe applies 18pF capacitive loading to the circuit.

Set to times one though, each probe applies 60pF to the test circuit. The probe's bandwidth reduces to just 10MHz and its rise time increases to 35ns. Square wave signals of 100kHz and above are visibly badly distorted. **Fig. 1**.

While at low frequency the Coline probe exhibits greater than 1MΩ impedance, by 10MHz this reduces to 800Ω when set to divide by ten. Set to divide by one its 60pF capacitance results in an impedance of just 265Ω. Other probes may impose heavier loading. An HP9100 probe for example set to times one, applies a 150pF load to the circuit under test.

Many modern ICs become unstable, or at best peaky, when loaded with such capacitance. One might wonder just what our measurements do represent[1] – the circuit under test or our scope probe?

Measuring low signal levels, you may be forced to set the probe to divide by one in order to obtain an adequate display. The resulting capacitive load then attenuates and distorts the displayed signal.

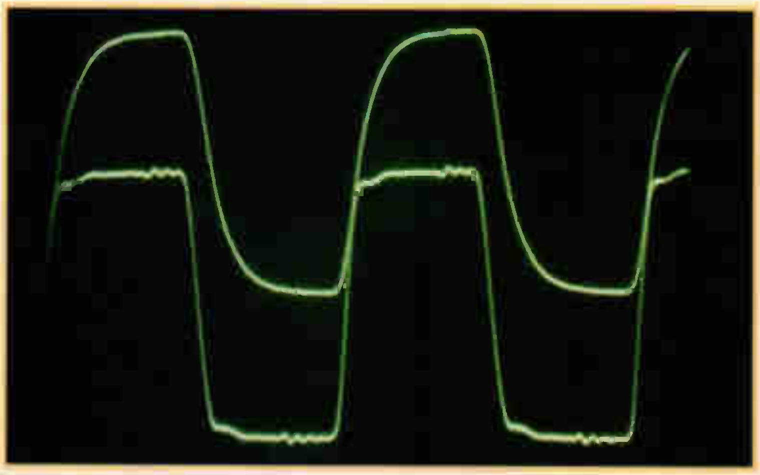


Fig. 1. Two views of the same 5MHz square wave. Top was viewed using a 250MHz probe, set to divide by one, is badly distorted by the probe's reduced bandwidth. Bottom using an identical probe set to divide by ten and with increased oscilloscope sensitivity. The probe's 20pF and 60pF capacitance loading has degraded both waveforms.

To properly measure low-level signals you have to reduce the probe's capacitance to ground. In practice this means using either a 50Ω measurement system or a low capacitance active probe.

Most low-level circuits are not intended for use with 50Ω loading, so for these an active probe is essential. Commercially available active probes however can be extremely expensive.

With my 250MHz Coline probe set to divide by 10 and using an oscilloscope sensitivity of 10mV/cm, I can measure signals down to 0.2V. A low-capacitance active probe with unity gain, a 100MHz range and a maximum input voltage of 2V would provide a useful overlap with the Coline probe for measuring lower-level signals.

In my last article[2] I discussed how to design a high input-impedance, low-capacitance active probe with AC coupling. It provides a flat response from 100Hz to 100MHz into a properly terminated 75Ω coaxial cable. It has a very fast rise time and as a stand-alone probe its performance to 100MHz, equals that of my 250MHz Coline probe set to divide by 10.

This active probe design was based on the Maxim[3] unity-gain MAX4005, which has a very high frequency range and a JFET input. It is supplied complete with an internal 75Ω precision thin-film output resistor.

The 4005 provides a ±0.1dB gain flatness of 60MHz and ±0.2dB to 80MHz, a 350ps rise time and 950MHz bandwidth, **Fig. 2**.

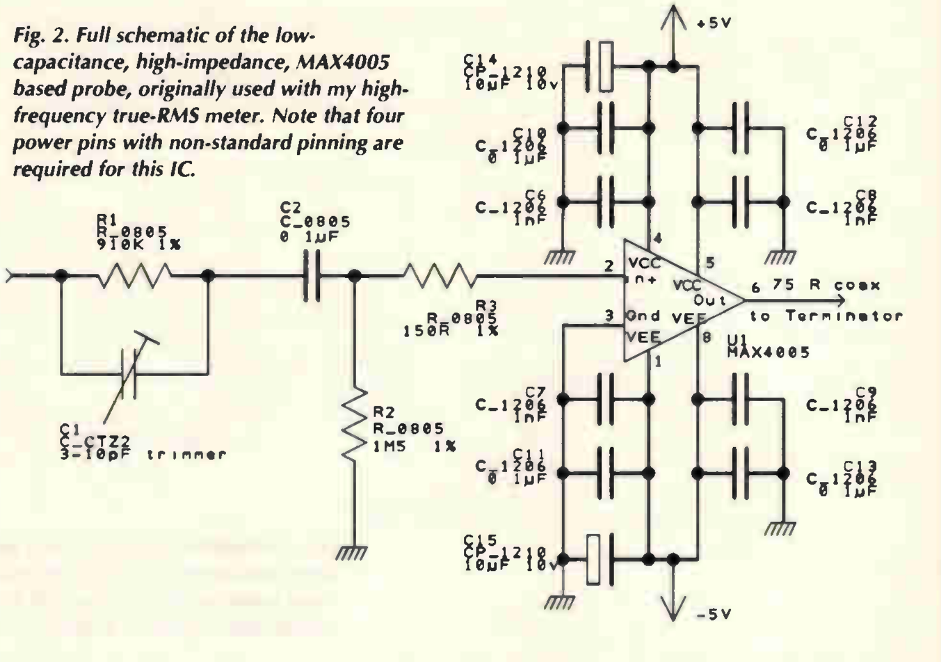
Using this IC, my assembled probe provided flat performance from 100Hz to 100MHz, when terminated in 75Ω. With a coaxial test prod that accommodates Coline oscilloscope probe accessories, it provided some 4pF and 2.4MΩ input impedance and a maximum input capability of 7V pk-to-pk, **Fig. 3**.

However on its own, this probe does not have unity gain. It attenuates its input signal by approximately 10dB to output some 650mV for a 2V input signal.

To provide unity gain requires a 75Ω terminating stage with 10dB gain at the scope input connector to restore signal levels. To measure low level signals, this gain stage should be low noise and have a 0.1dB bandwidth as good as or better than the MAX4005.

This article discusses how to design an active 75Ω matching termination, which mounts directly onto the oscilloscope front panel connector. This terminator provides sufficient low-noise gain to overcome probe and cable losses, resulting in a high impedance, low capacitance, unity gain 100MHz scope probe.

Fig. 2. Full schematic of the low-capacitance, high-impedance, MAX4005 based probe, originally used with my high-frequency true-RMS meter. Note that four power pins with non-standard pinning are required for this IC.



Terminating gain stage

To allow a margin for corrections and calibration, a gain of five is required. Attaining a low-noise gain of five with a flat response from 100Hz to 100MHz is no small design task.

Low frequency and 75Ω impedance combine to require the use of extremely large value coupling capacitors. These become series self resonant at very low frequencies – certainly within the desired pass band. Near self resonance, capacitor impedance is much lower than its theoretical impedance. Above this resonance frequency the capacitor behaves as a DC-blocking inductance.

At some higher frequency, parallel, high impedance resonances occur. At frequencies close to parallel resonance the capacitor then appears as an extremely high impedance – almost open circuit.

When a capacitor is used to block DC but pass the wanted signal, these parallel resonances also effectively block, or attenuate the wanted signal.

For these reasons, while my probe's input is AC coupled, the input circuit of this 75Ω terminator is not. DC output offset for my prototype measured only 1.1mV. Any significant circuit DC offsets could simply be blocked by switching the scope input from DC to AC only.

Choosing an IC

Following an examination of ICs available from main-line distributors, I selected the Maxim MAX4106 for my terminating gain stage design. This is described in the data sheet as a 350MHz ultra-low-noise op-amp, compensated for closed loop gains of 5V/V or greater. It is only available in the small, surface-mounting, SO8 package.

The 4106 has a claimed noise level of 0.75nV/√Hz at 10kHz and 9.5μV RMS integrated from 1 to 100MHz. Its low distortion architecture provides a spurious-free dynamic range of 63dB at 5MHz. Set to a gain of five, it has a ±0.1dB bandwidth of 75MHz, and can slew to 275 V/μs.

As the 4106 is a current-feedback

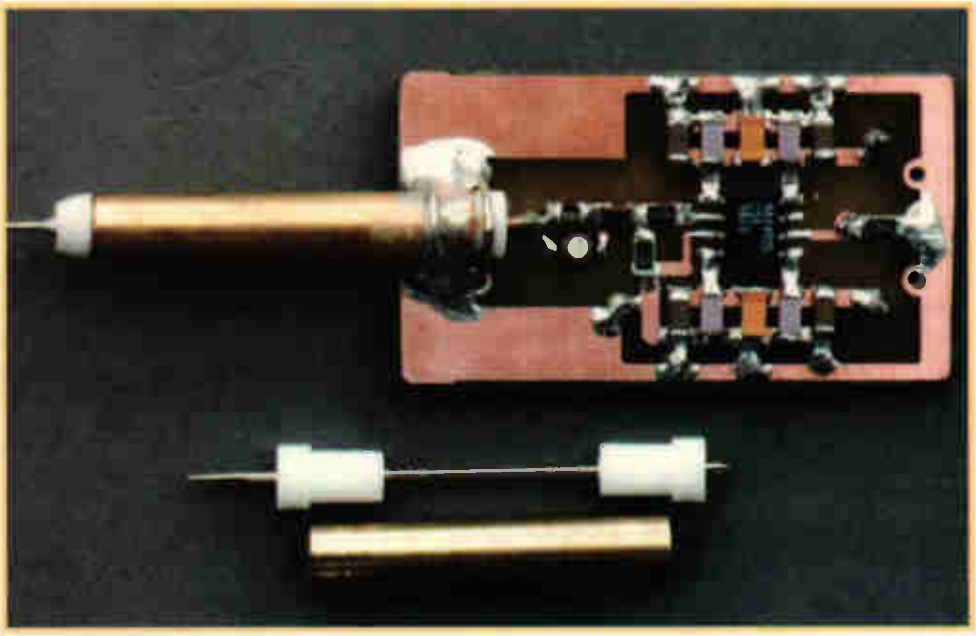


Fig. 3. Assembled and tested probe PCB, fitted with a small coaxial test prod able to accept Coline scope probe accessories. This prod was assembled from two PTFE stand off insulators, a sewing needle and a length of 4mm ID thin-wall brass tubing.

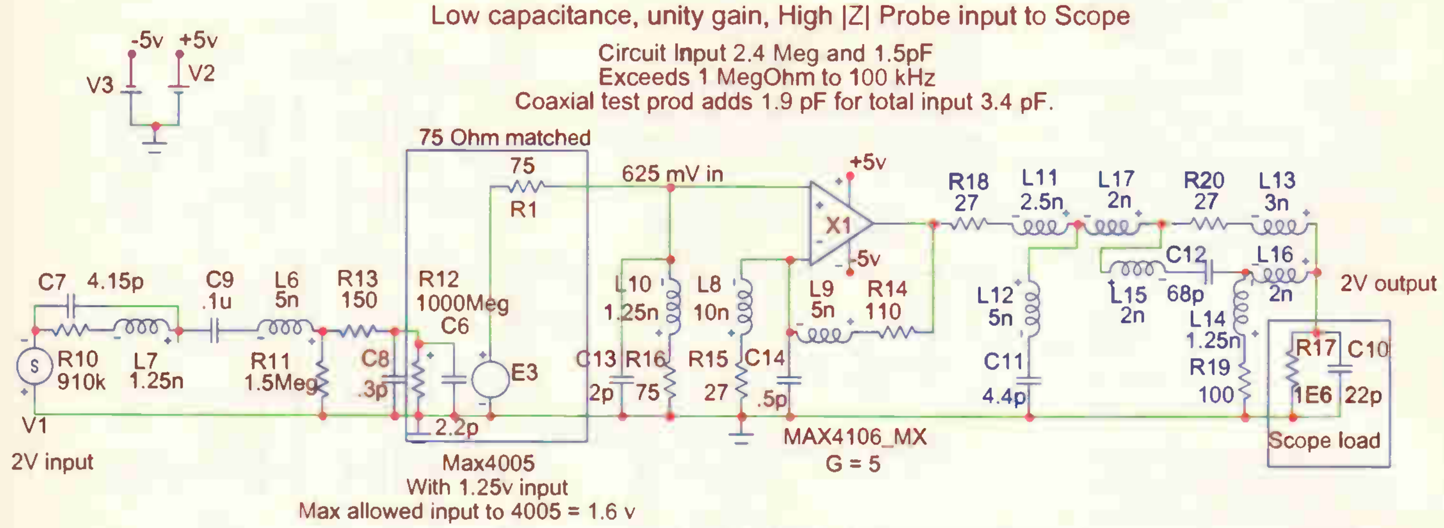


Fig. 4. Simulation schematic used with the MC6 simulator. The MAX4106 has been substituted for the AD8361 true-RMS meter back-end circuitry. The small capacitor, C_{11}, is used with R_{18} to compensate the MAX4106 for the oscilloscope capacitive loading.

design with 20μA bias current, it is essential to use low-value resistors from both MAX4106 input pins to ground. Capacitance to ground for both inputs must be minimised.

Terminator gain-stage design

The Maxim CD ROM includes a macro model for the MAX4106 op-amp. This was inserted into the Microcap MC6 simulation file used to design my low capacitance probe, replacing the AD8361 and INA133 circuitry.

The MAX4106 was set to a gain of five using 27Ω to ground and 110Ω feedback resistors. With due allowance for circuit strays and the IC's 2pF input capacitance, these values eliminate potential in-band feedback loop resonance.

For convenience of assembly and to minimise parasitics, I used a 110Ω size 0805 resistor for feedback with a 27Ω size 1206 from the negative input to ground.

A simple 75Ω input termination resistor to ground – a 1206 sized surface mount device – was also modelled. With a replica 1MΩ oscilloscope input as load, simulations commenced. See the panel entitled 'Frequency-domain simulation' for more details.

Initial results to 100MHz looked good, but suggested some higher frequency resonances could occur. In addition, the output needed buffering for capacitive loads and attenuating to unity gain.

With the addition of these components, my simulation circuit design was complete. Fig. 4

Terminator circuit board

Because space on an oscilloscope front panel is restricted, I wanted to fit this circuit into a small diecast

Frequency-domain simulation

The capacitor, resistor and inductor models built into Spice based simulators assume ideal loss-free components having a constant value, regardless of frequency. For transient or time-domain simulation, Spice automatically provides a facility for amplitude-dependent changes for semiconductors but not for passive components.

Unfortunately with real-life components, almost all parameters are frequency dependent.

The latest simulators still assume ideal passive components in their libraries. Some though, including MC6, provide the facility to override the internal constant-value model using a frequency-dependent expression. Regrettably as far as I am aware, suitable-model libraries are not provided.

A restricted number of component models can be downloaded from Intusoft,[4] and are supplied with their simulators. These offer a limited choice so usually do not exactly fit ones needs. This modelling approach was initiated in 1994 by John Prymak of Kemet.

Kemet[5] now offers a Spice based data sheet for their Ceramic and Tantalum capacitors as a free download. This software provides on-screen plots of capacitor behaviour with frequency, including capacitance, ESR, tanδ, inductance, impedance and series and parallel resonances. For any one frequency of interest, the simulation circuit used and its component values can be displayed on screen. These can then be used in transient analysis and narrow-band frequency sweeps.

Unfortunately these simulation component values cannot easily be extracted for use in wide-band frequency-domain analysis.

The main problem is that this frequency-dependent expression relates to an individual element – a resistor has resistance, capacitance and inductance. It then requires three elements, each with its own frequency expression.

Capacitor models may be considerably more elaborate. It would be convenient if one could download manufacturers' macro models for passive components – better still 'S parameters', as has long been possible for ICs.

box, 50 by 50 by 30mm. This box, with a MACOM panel mounting BNC plug connector, Farnell part 309-461, would fit directly onto my scope input without fouling the controls.

The same box would contain the termination and gain stage, the coaxial interconnect termination and power leads to the probe. Power for both probe and terminator would be provided by tapping into the internal supplies of my scope **Fig. 5**.

Because of the wide bandwidth and slew rate capabilities of the MAX4106, substantial on-board decoupling capacitance would be needed. A 1nF COG, a 100nF X7R size 1206 ceramic and small 10μF 10V tantalum chips were used.

To compensate for the oscilloscope's input capacitance at high frequency, a trimmer capacitor, part of the output attenuator, was required. I choose a Murata 6-50pF COG washable ceramic, Farnell part 108-222. This is a through-hole mounting part, but bending and trimming its mounting tags provides an acceptable surface mounting version, **Fig. 6**.

These decoupling capacitors together with the output trimmer capacitor, occupy much of the final 43 by 38mm PCB design, **Fig. 7**.

To minimise signal path capacitance to ground for this double-sided board, both ground planes were well distanced from the high-frequency signal, feedback paths and the IC body.

Initial performance tests

The probe and termination stage were interconnected using a metre of RG179 B/U coaxial cable. This PTFE-insulated* coaxial cable, available in cut lengths, is easily soldered direct to the PCBs without damaging the cable.

The input trimming capacitor, C_1 in the probe body, had previously been adjusted for a good 1kHz square wave response. Assuming that you're using 1% or better resistors throughout, calibration of the 75Ω terminator stage attenuator resistors should not be needed **Fig. 8**.

The only other adjustment is of the output capacitor, C_2, in the termination stage. This is used to optimise response at high frequencies.

Any minor amplitude error can be compensated by resetting the scope input channel gain.

I fitted a BNC adapter from my Coline M12SW probe on to the active probe's test prod. I then inserted this adapter into a MACOM 50Ω through termination.

Initial square-wave testing showed a good square wave was maintained up to 5MHz – the usable limit of my generator.

In high-frequency sinewave measurements, I used my HP8405A vector voltmeter to monitor input and output levels. The probe/termination combination, with trimmer C_2 set to

*PTFE is an amazing material, but it becomes a serious health hazard if subjected to very high temperatures. Read up on it if you're in doubt. Ed.

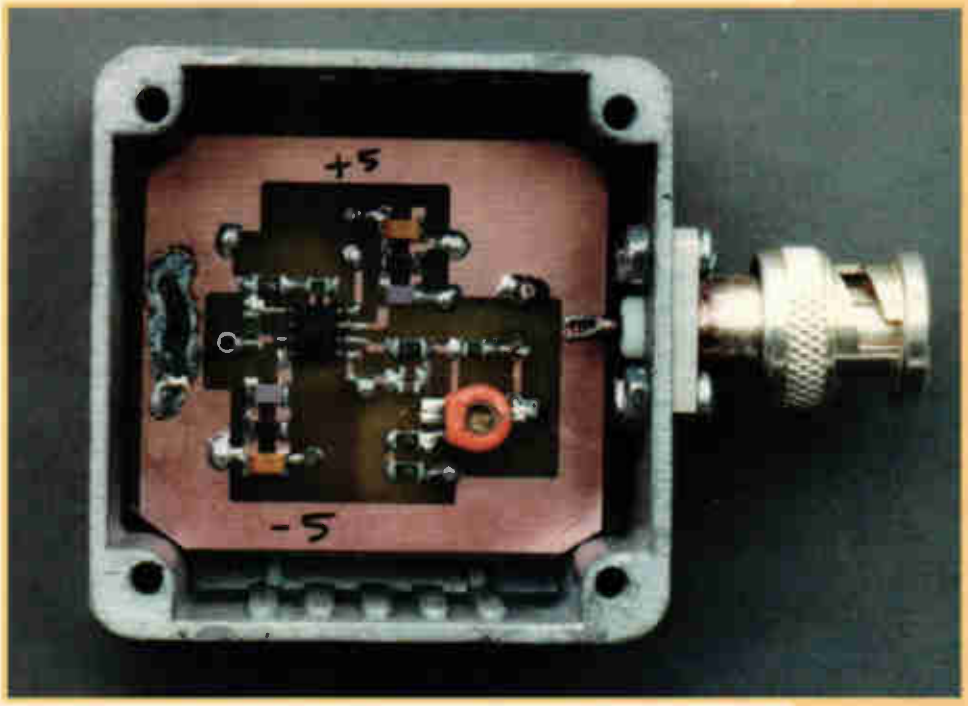


Fig. 5. The 75Ω terminator/gain PCB fits easily into a small die cast box. Provided with a panel mounted plug, it mounts directly onto an oscilloscope front panel without fouling user controls.

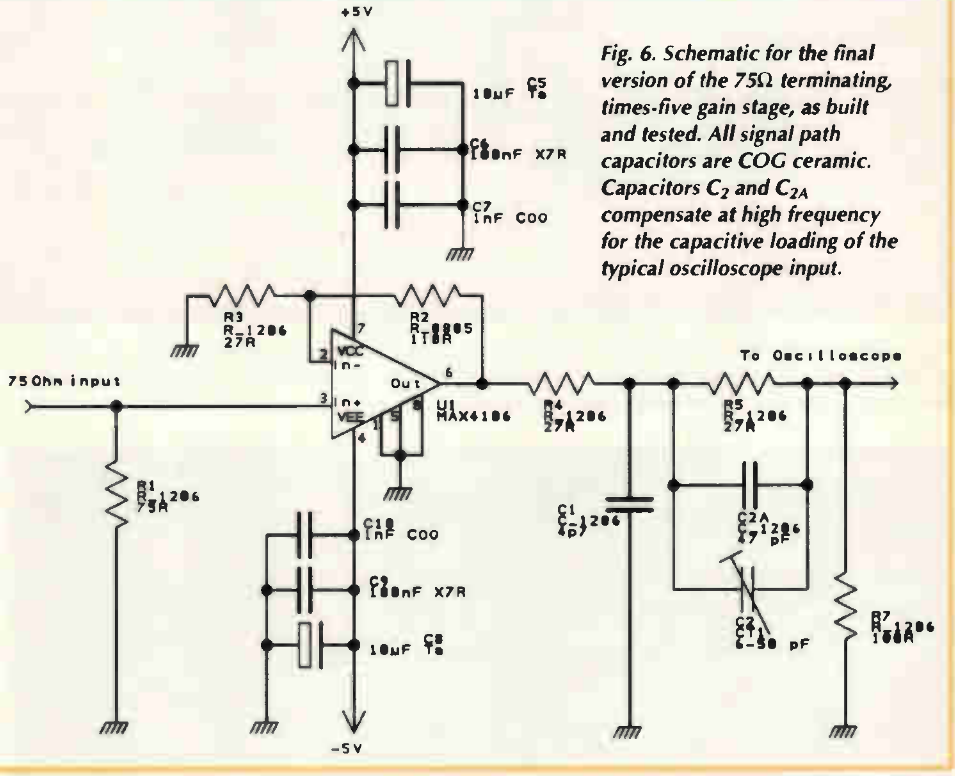


Fig. 6. Schematic for the final version of the 75Ω terminating, times-five gain stage, as built and tested. All signal path capacitors are COG ceramic. Capacitors C_2 and C_{2A} compensate at high frequency for the capacitive loading of the typical oscilloscope input.

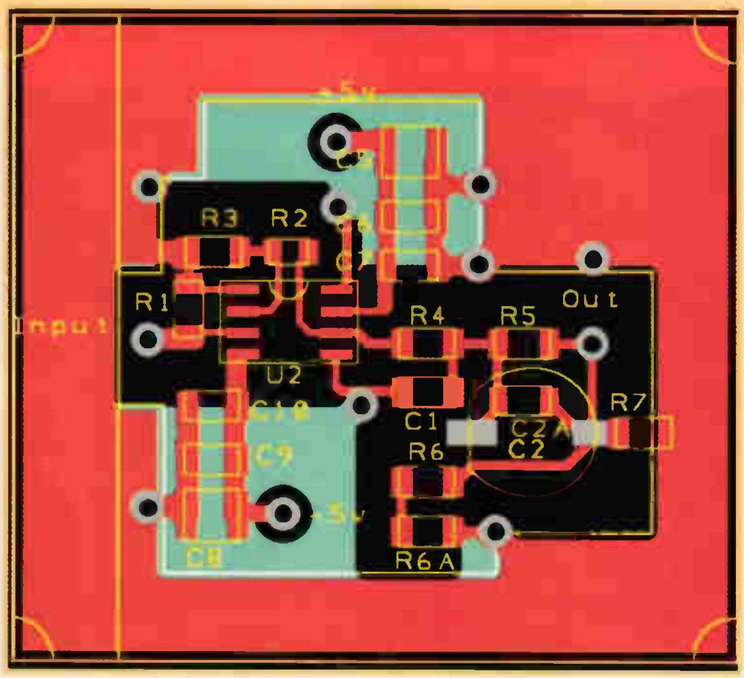


Fig. 7. Final double-sided PCB layout used for the 75Ω terminating, times-five gain stage. By changing R_5, R_6 and R_{6A}, R_7, either a high or low output impedance can be provided. Following performance tests, the high output impedance option has been dropped.

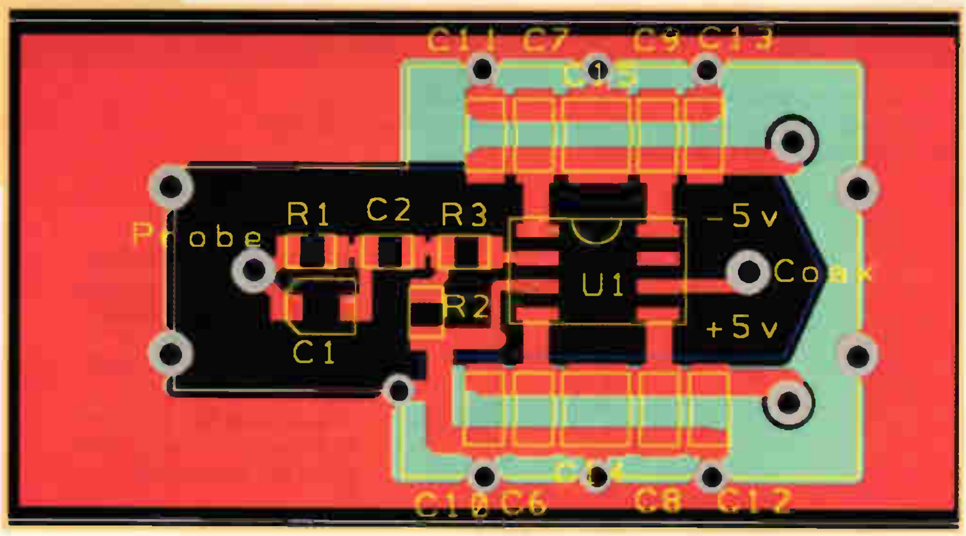
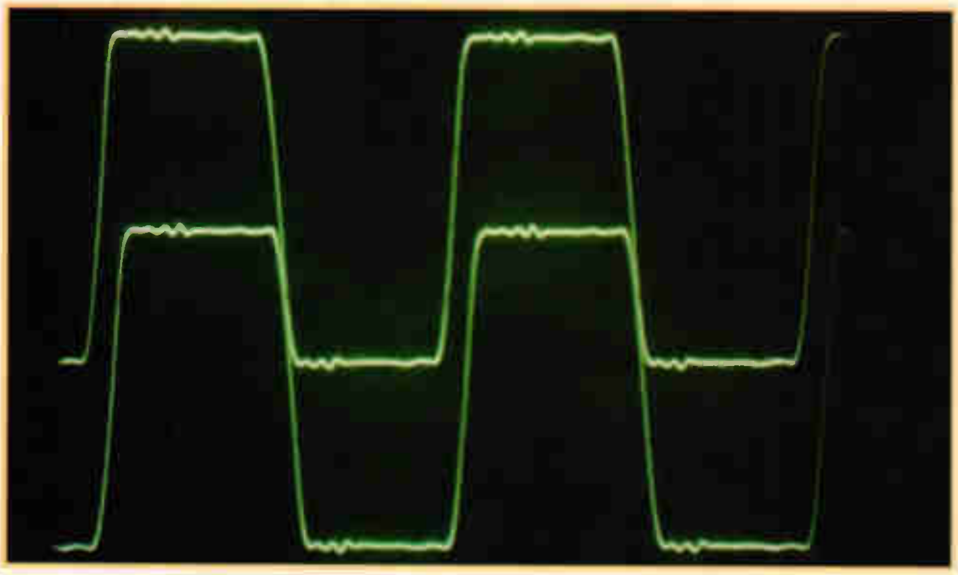


Fig. 8. The small double sided PCB for the low capacitance, high input impedance probe. It connects to the 75Ω terminating gain stage via a 1 metre length of RG179 B/U, PTFE insulated coaxial cable. Note the non-standard orientation of the ±5V supplies.



Measuring equipment used

The HP331A voltmeter and the HP8405A vector voltmeter both have high-impedance low-capacitance inputs. They were used with a 10dB attenuator and MACOM 50Ω through terminator to establish the signal generator output at the MACOM terminator at exactly 0dBm. The HP331A meter is specified to 3MHz, the HP8405A from 1MHz to 1GHz.

My high-|Z| RMS meter could equally well have been used[2]. However the HP331A and HP8405A both provide direct readings in decibels relative to 0dBm. Using these instruments avoided a considerable number of calculations.

maximum, was better than –1.5dB and –3dB set to minimum, at 100MHz.

The all important noise figure, from audio to 3MHz, measured less than 100μV with the probe and terminator screened and the probe prod input shielded, but not grounded, by the Coline BNC oscilloscope-probe adapter.

Viewed on my oscilloscope set to display 5mV/cm, this noise level could just be discerned as a thickening of the scope trace. Reset to display 10mV/cm, no noise was visible.

Final performance tests

Setting output trimmer C_2 to maximum provided the flattest measured response. Some square wave overshoot was evident however when comparing the active probe output with the scope response fed directly from the MACOM 50Ω through termination.

I found the HP8405A vector voltmeter probe loading of 100kΩ and 5pF was depressing the measured response by some 0.5dB at 100MHz. This accounted for the overshoot seen when the vector voltmeter probe loading was removed.

Fig. 9. A 5MHz square wave viewed using the low capacitance active probe, bottom, versus direct scope input from a terminated 50Ω impedance generator, top. As you can see, this active probe design has not visibly degraded the waveform.

I decided to remove output trimmer C_2 and capacitor C_{2A}, replacing both with a 68pF COG fixed capacitor. I then retested the circuit using the 50Ω through-terminated 5MHz square wave. The active probe output into channel B was compared with the 50Ω through terminated waveform in channel A **Fig. 9**.

The previous overshoot was removed. Visually, both channel waveforms were now identical. I then repeated the sinewave measurements, using this 68 pF output capacitor. See **Table 1**.

For the amplitude results, I used an HP331A voltmeter below 1MHz and an HP8405A vector voltmeter for higher frequencies. There's more on this in the panel entitled 'Measuring equipment used'. ■

Table 1

Measured voltage error by frequency in decibels, with 0dBm, 223.6mV input.

Frequency (Hz)	Trimmer min. 53pF (dB)	Fixed 68pF COG (dB)	Trimmer max. 97pF (dB)
100	0	0	0
1k	0	0	0
10k	0	0	0
100k	0	0	0
1M	0	0	0
10M	0	0	0
25M	–0.2	–0.2	0
40M	–0.35	–0.3	0
50M	–0.6	–0.4	0
60M	–0.8	–0.5	0
70M	–1.1	–0.8	0
80M	–1.8	–1.2	–0.6
90M	–2.7	–1.9	–1.2
100M	–3.0	–2.2	–1.6
120M	–4.0	–3.0	–2.2

Results for 60MHz are depressed approximately 0.1dB due to the 100kΩ and 5pF load of my HP8405A vector voltmeter probe. This loading increases with frequency and by 100MHz depresses measured value by 0.5dB. Corrections have not been applied in the above table.

References

1. Are you measuring your circuit or your scope probe? http://www.ednmag.com/ednmag/reg/1999/072299/15ms512.htm
2. Bateman, C., 'Measuring RF millivolts', *Electronics World*, October 2001, p. 778.
3. 950MHz FET-Input Buffer with 75Ω Output, http://www.maxim-ic.com
4. Modelling a Capacitor, http://www.intusoft.com/caps.lib
5. Kspice185_32.exe. J.Prymak. http://www.kemet.com
6. Bateman, C., 'Measure AC millivolts to 5MHz', *Electronics World*, p. 281 April 2000.

Calibration notes

Originally, the terminator PCB was designed to provide both low and high output impedances, simply by changing a couple of components.

I initially built and photographed the high output-impedance version mentioned in the body of the article. For this, R_7 is omitted, R_6 and R_{6A} are 100KΩ, R_5 is 91kΩ, **Fig. 10**.

This version worked extremely well and was easily calibrated. However obtaining accurate high-frequency performance data was almost impossible. My original plan was to use my oscilloscope display. However on checking, this was flat only to 40MHz, and its sensitivity was almost 3dB down at 100MHz.

The high frequency loading using high-impedance low-capacitance probes also seriously influenced results. Consequently I abandoned this version and show only the low output-impedance variant in my figures. For this, R_6 and R_{6A} are omitted. Resistor R_7 is 100Ω and R_5 becomes 27Ω.

Calibration is much simplified. Capacitor C_1 in the probe is adjusted at low frequency. The preferred method is to apply 0dBm at 1kHz or lower frequency and note the voltage output using a high-impedance meter.

Apply 0dBm at 1MHz or higher and adjust C_1 in the probe to attain the noted reading. A suitable meter has been described in *Electronics World*[6].

Alternatively, should no suitable RF voltmeter be available, apply a good 1kHz square wave at 500 to 600mV pk to pk from the oscilloscope calibrator. Adjust C_1 in the probe to display the best possible square wave.

If you can source and measure 100MHz using a high input-impedance, low-capacitance RF voltmeter[2], adjust C_2 in the terminator to read 1 to 2dB down at 100MHz relative to the output with 0dBm input at 10MHz.

If you aren't able to perform the 100MHz measurement, good performance will be assured if you simply replace trimmer C_2 and capacitor C_{2A} with a fixed 68pF COG ceramic capacitor.

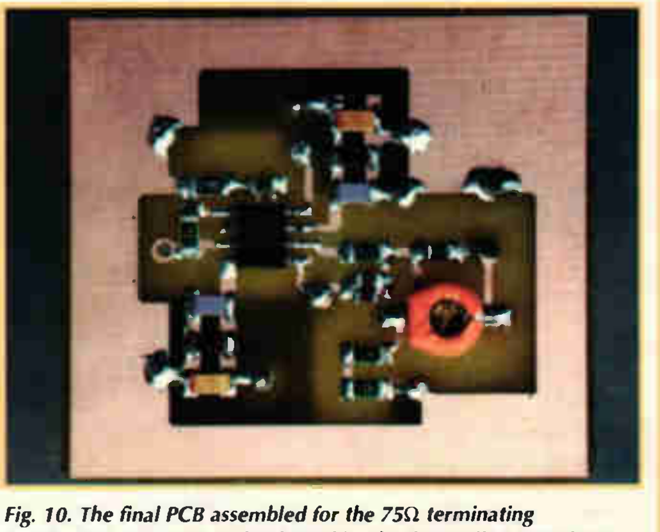


Fig. 10. The final PCB assembled for the 75Ω terminating terminating gain stage is dominated by the decoupling capacitors and the 6-50pF trimmer capacitor. By changing the values of three resistors, this board can provide either a high or low output impedance capable of driving a standard 1MΩ oscilloscope load.

The mosfet exposed

With the aim of helping you better predict a mosfet-based circuit's performance, Bryan Hart shows how the shape of a mosfet's drain characteristics can be explained via a first-order model. He then shows how to use that model to analyse and design some typical mosfet circuits.

A curve-tracer, whether commercially manufactured, or home-produced to a design such as that described recently by Ian Hickman[1], is capable of producing instant graphical information about the DC performance of a semiconductor device.

However, a display of a set of curves, by itself, has its limitations. An analogy is a map without a compass. In the case of experimentally observed device characteristics, a 'compass', is a simplified circuit model based on the physical electronics of the device's operation.

This article show how the shape of the drain characteristics of a mosfet can be explained by reference to a first-order model. The model is then used to analyse and design some typical circuit schemes.

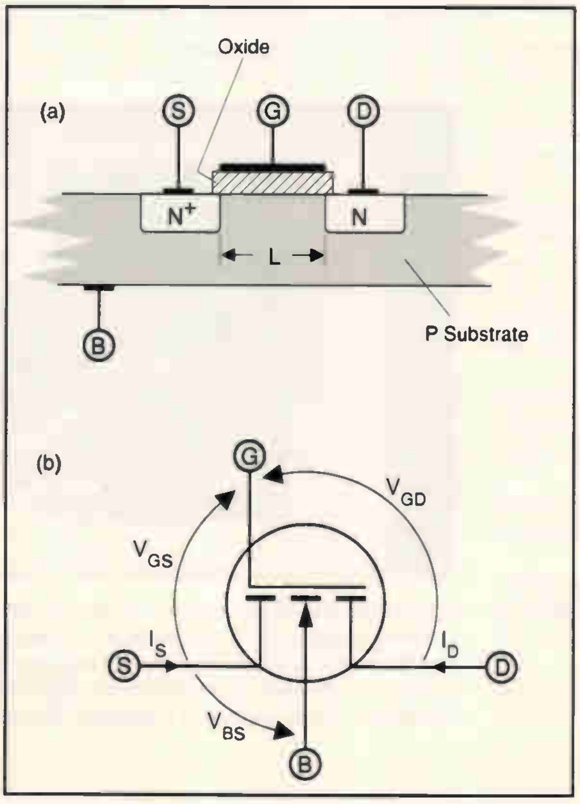


Fig. 1. Schematic cross-section of an n-channel enhancement-mode mosfet, (a), and its symbolic representation, (b).

The model reviewed

The mosfet chosen for discussion is an n-channel enhancement-mode device. This is the most widely used type and it's the easiest to understand.

A schematic cross-section of its physical structure is shown in **Fig. 1a)**. The space, L, between the source, S, and drain, D, defines the length of the channel that forms under the gate G when it is suitably biased: the gate width is a direction perpendicular to the paper is W.

Figure **1b)** shows a standard circuit symbol with the reference directions for terminal voltages and currents marked on it. Substrate B is normally biased so that there is no current flow between it and the source and drain. That is why the substrate does not appear in the DC model[2] of **Fig. 2a)**, which is suitable for the usual case of operation in what is known as the 'strong-inversion region'.

The 'boxed' diodes D_F, D_R have the ideal piecewise-linear characteristics of Fig. **2b)** and the voltage generators V_F, V_R the characteristics in Fig. **2c)**. Parameter V_{TH} is the threshold voltage, which is dependent on substrate doping.

Current generators I_F, I_R have a square-law voltage dependence, as indicated in Fig. **2d)**. Thus, for,

$$V_F(=V_{GS}-V_{TH})>0,$$
$$I_F=KV_F^2 \qquad \text{1a}$$

Similarly, for,

$$V_R(=V_{GD}-V_{TH})>0$$
$$I_R=KV_R^2 \qquad \text{1b}$$

Consequently,

$$I_D=-I_S=(I_F-I_R)=K(V_F^2-V_R^2) \qquad \text{1c}$$

The parameter K is given by,

$$K=\frac{C\mu}{2}\times\frac{W}{L} \qquad \text{1d}$$

In this, C is the gate capacitance per unit area and μ is the effective mobility of electrons in the channel.

For a given processing technology the product $C\mu$ is a constant, but the chip designer has control of the geometrical ratio *W/L*. From a user's standpoint, *K* is readily determinable from terminal measurements, as outlined later. For a p-channel enhancement-mode mosfet all the elements comprising the model of Fig. 2a) are reversed, as are the directions of voltages and currents.

Equations (1a) to (1d) reveal all we need to know about the DC performance of this first-order model. As shown in **Fig. 3**, there are four possible operating regions, or modes, because D_F, D_R can each be independently forward or reverse biased.

The numbering shown for these regions is arbitrary. Regions 1 and 3 are the most interesting for digital applications where they refer, respectively, to the open and closed conditions of a switch. Region 2 is used for linear amplification. In Region 4, the mosfet operates in the reverse mode.

I will now look at each region in turn to show how the model provides a basis for an explanation of the observed mosfet drain characteristics in the common-source connection.

Region 1. Here, D_F and D_R are both off, as V_{GS} and V_{GD} are both less than V_{TH}, so I_F=I_R=0. In this 'cut-off' region I_D=0 regardless of the sign of V_{DS}. In a refinement to the model of Fig. 2a), D_F and D_R can be assumed to have a finite reverse current to allow for the small leakage current that flows in practical devices when $V_{DS}\neq 0$.

Region 2. In this case, D_F is on and D_R is off so,

$$I_D=I_F=KV_F^2=K(V_{GS}-V_{TH})^2 \qquad 2$$

Figure 4 shows an appropriate circuit model.

Following an example set by early workers[3] in this field, it is convenient to represent the drain characteristics in dimensionless form as it makes them universally applicable. To do this two parameters are defined, namely *n*, the gate-drive factor, and I_{DO}, a drain reference current. Thus,

$$n=\left(\frac{V_F}{V_{TH}}\right)=\frac{(V_{GS}-V_{TH})}{V_{TH}} \qquad 3$$

and,

$$I_{DO}=KV_{TH}^2 \qquad 4$$

Physically, I_{DO} is the value of,

I_D for $V_{GS}=2V_{TH}$, or $n=1$

From equations (2), (3) and (4),

$$\frac{I_D}{I_{DO}}=n^2 \qquad 5$$

On a graph, **Fig. 5a)**, of *y*, which is I_D/I_{DO}, versus *x*, which is V_{DS}/V_{TH}, the drain characteristics, for *n*=1, 2, etc., comprise a series of unequally-spaced horizontal lines.

The description 'current saturation' is appropriate for this region in view of the constancy of I_D with

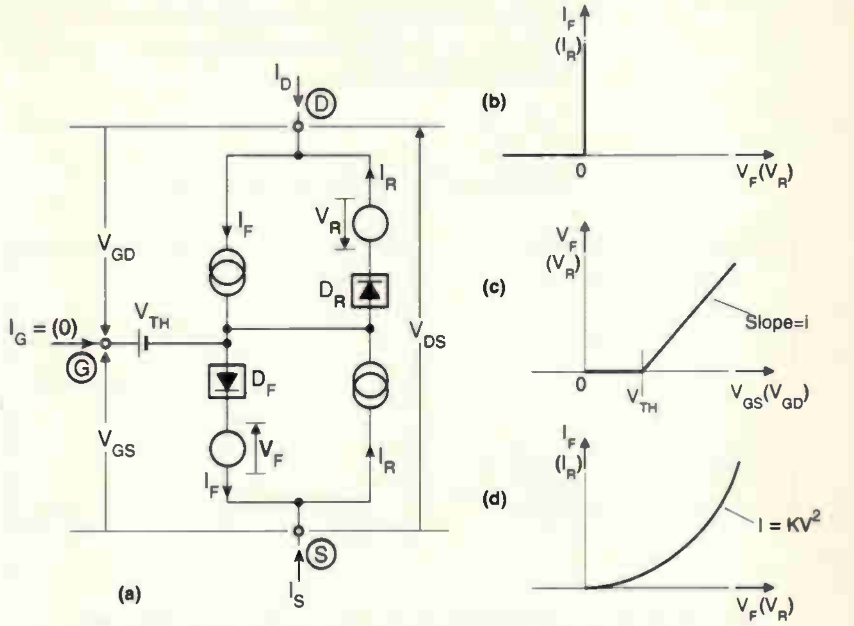


Fig. 2. In a) is a DC model of the mosfet and 2b), 2c), and 2d) are the characteristics of its constituent elements.

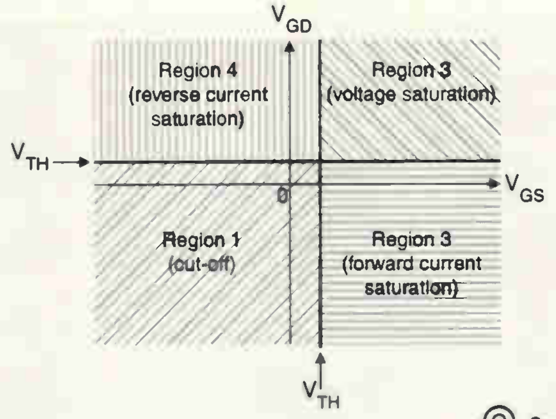


Fig. 3. A mosfet can be described as having four operating regions.

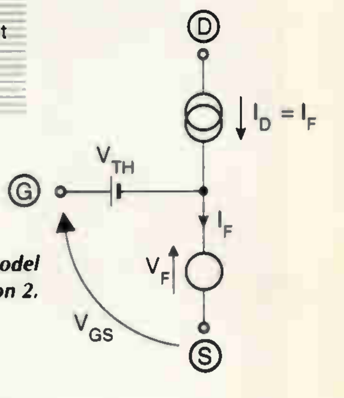


Fig. 4. A simplified model for a mosfet's Region 2.

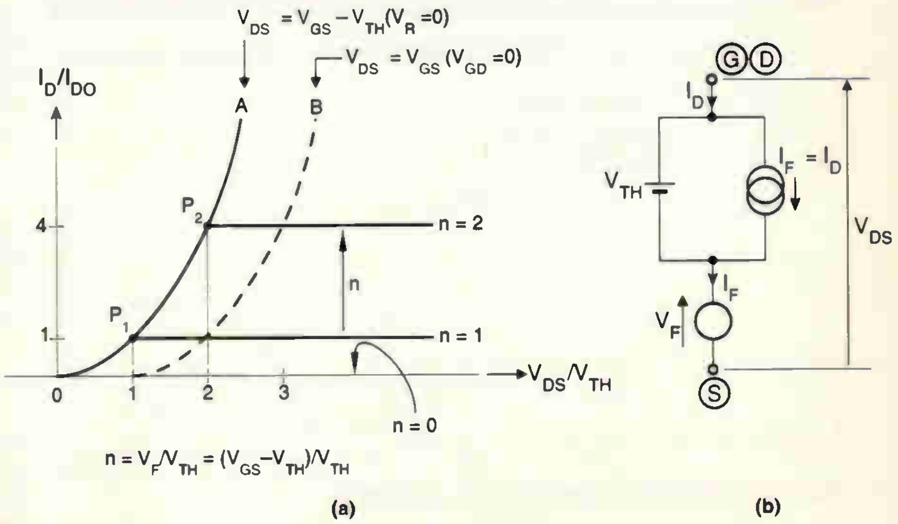


Fig. 5. Output characteristics for Region 2, a), showing boundary curves A and B discussed in the text. Diagram 5b) is a simplified mosfet model for a gate-drain strap.

V_{DS}. The boundary curve for Region 2 is obtained for the condition V_R=0, or in circuit terms $V_{DS}=V_{GS}-V_{TH}$. From equation (3), this means,

$$n=\frac{V_{DS}}{V_{TH}}$$

Substituting this value in equation (5) yields,

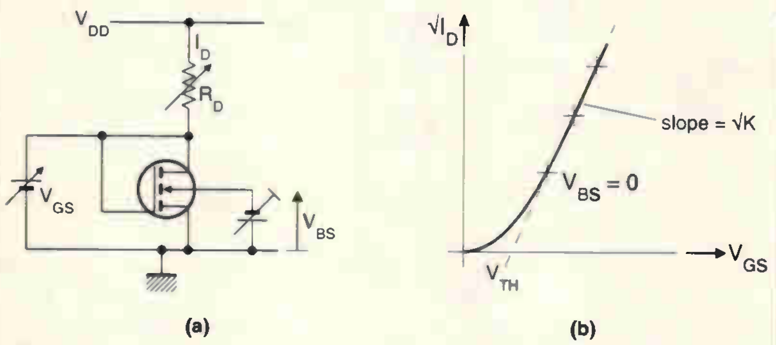


Fig. 6. Parameter measurement set-up, a). A typical plot, for finding K and V_{TH} is shown in b).

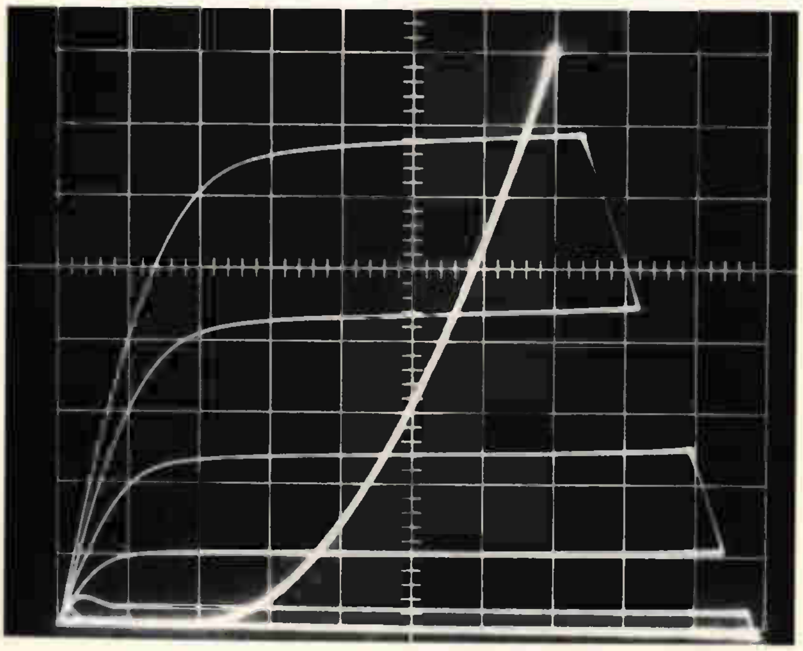


Fig. 7. Curve-tracer characteristics for CD4007A sample, with the curve for V_{DG}=0 superimposed.

Horizontal scale	*V_{DS}=1 V/div*
Vertical scale	*I_D=0.5mA/div*
V_{GS} steps, 1V	*V_{BS}=0*

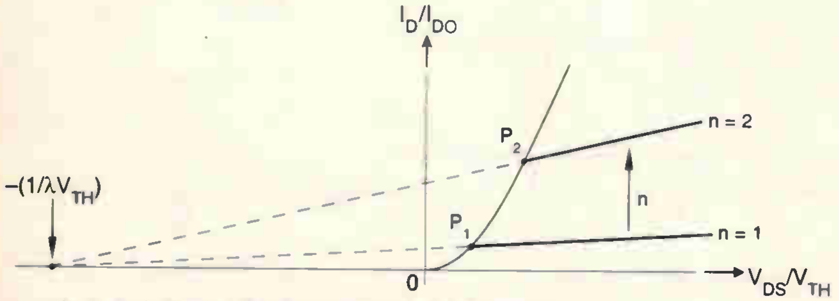


Fig. 8. Definition of the channel-modulation parameter, λ.

$$\frac{I_D}{I_{DO}}=\left(\frac{V_{DS}}{V_{TH}}\right)^2 \qquad 6$$

This equation describes the parabola $y=x^2$, the relevant part of which is curve A in **Fig. 5a)**. Illustrative points P_1 and P_2 refer to x=1 and x=2 respectively.

Suppose, now, that the mosfet has a gate-drain strap. That connection scheme is used in some analogue IC designs and in measurements to determine the basic parameters K and V_{TH}. A simplified model is shown in Fig. **5b)**.

Substituting the condition $V_{DS}=V_{GS}$ in equation (3) gives,

$$n=\frac{V_{DS}-V_{TH}}{V_{TH}}$$

and putting this value in equation (5) gives,

$$\frac{I_D}{I_{DO}}=\left(\frac{V_{DS}}{V_{TH}}-1\right)^2 \qquad 7$$

This describes curve B in Fig. 5a). It is curve A shifted horizontally to the right by one x-axis unit.

Figure 6a) shows an experimental set-up to find K and V_{TH}. When the best straight line is drawn through a plot of $\sqrt{I_D}$ versus V_{GS} in Fig. 6a), the slope gives $\sqrt{K}$ and the extrapolated intercept on the V_{GS} axis gives V_{TH}.

Experiments indicate that if $V_{BS}<0$ and $|V_{BS}|>>0.8$V, then K remains constant but V_{TH} increases by an amount $\Delta V_{TH}\approx\gamma\sqrt{|V_{BS}|}$, in which the parameter γ is dependent on substrate doping. Typically, $2>\gamma>0.5$.

A plot of $\sqrt{I_D}$ versus V_{GS} for a sample mosfet from the long-established CMOS unit type CD4007A gave $K=150\mu A/V^2$ and $V_{TH}\approx1.7$V with V_{BS}=0. **Figure 7** shows the first-quadrant drain characteristics, obtained using a Tektronix 575 curve tracer. On these is superimposed, by double photographic exposure, a characteristic for the condition V_{DG}=0, corresponding to curve B in Fig. 5b).

It is evident that the practical characteristics in Region 2 are not strictly horizontal but have a small positive slope, which is not predicted by the simple model under consideration. Viewed on a compressed V_{DS} scale, the characteristics can be approximated by straight lines radiating from a common point of intersection on the negative V_{DS} axis at,

$$V_{DS}=-\frac{1}{\lambda}$$

The reason for this is a shortening in the effective channel length, with increase in V_{DS}, that is similar to the base-narrowing effect in bipolar junction transistors. The upshot is that the characteristics can be represented by the expression,

$$I_D=K(1+\lambda V_{DS})V_F^2=K(1+\lambda V_{DS})(V_{GS}-V_{TH})^2 \qquad 8$$

The model of Fig. 2a) *is* still applicable if K is replaced by a voltage-dependent parameter, $K'=K(1+\lambda V_{DS})$.

In dimensionless form – see **Fig. 8** – equation (8) becomes,

$$\frac{I_D}{I_{DO}}=n^2\left[1+\lambda V_{TH}\times\frac{V_{DS}}{V_{TH}}\right] \qquad 9$$

A low-frequency incremental model for Region 2 is shown in **Fig. 9**. It is based on equation (8), from which the mutual conductance, g_{fs}, and the output resistance, r_{ds}, can be found by differentiation. For the usual practical case $1 \gg \lambda V_{DS}$,

$$g_{fs} = \frac{i_d}{V_{gs}} \approx 2\sqrt{(KI_D)} \qquad 10$$

and,

$$r_{ds} = \frac{V_{ds}}{i_d} \approx \frac{1}{\lambda I_D} \qquad 11$$

Region 3. In this region, D_F and D_R are both on so $V_{DS}(=V_F-V_R)$ can fall to a low value. This suggests the description 'voltage-saturation' for this region in preference to the often-used, but arguably confusing, word 'triode'.

$$I_D=I_F-I_R=K(V_F^2-V_R^2) \qquad 12$$

and

$$V_R=V_F-V_{DS} \qquad 13$$

Hence,

$$I_D=K[V_F^2-(V_F-V_{DS})^2] \qquad 14$$

In dimensionless form this becomes,

$$\frac{I_D}{I_{DO}} = n^2 - \left[n - \frac{V_{DS}}{V_{TH}}\right]^2 \qquad 15$$

This equation provides an expression for the drain characteristics in Region 3. This region occupies part of two quadrants of the I_S, V_{DS} plane because you can have either $V_F>V_R$ or $V_R>V_F$.

Consider, first, the condition $V_F>V_R$. Then $I_F>I_R$ and operation is in the first quadrant of **Fig. 10**. It is bounded by the vertical axis and curve (i) which is curve A, of Fig. 5a), re-labelled for convenience. It is specified by equation (6). The same result emerges when $V_{DS} \div V_{TH}$ is substituted for n in equation (15).

To interpret equation (15), graphically, make the following substitutions,

$$y = \frac{I_D}{I_{DO}}; \; y_1 = n^2; \; x = \frac{V_{DS}}{V_{TH}}; \text{ and } x_1 = n$$

Then equation (15) becomes,

$$(y-y_1) = -(x-x_1)^2 \qquad 16$$

For various values of n, and hence, x_1 and y_1, this describes a family of downward-facing parabolas, the relevant parts of which are the sections for $x \le n$: for $x>n$. Equation (16) is no longer valid.

Each parabola has a vertex at x_1, y_1 on the boundary curve and passes through the origin. Curve (ii), in Fig. 10, is one such curve for an arbitrary value of $n(>0)$. The tangent, at x=0, to a parabola defines the incremental conductance, G_O, for V_{DS}=0 and a given V_{GS}.

The range over which this tangent can be taken as a good approximation to the parabolic curve can be assessed by substituting $V_F=(V_{GS}-V_{TH})$ in equation (14) and simplifying. Then,

$$I_D=K[2(V_{GS}-V_{TH})-V_{DS}]V_{DS} \qquad 17$$

For the range $(V_{GS}-V_{TH}) \gg V_{DS}$,

$$R_{DS} \approx R_O = \frac{1}{G_O} = \frac{1}{[2K(V_{GS}-V_{TH})]} \qquad 18$$

The existence of this relationship leads to the description 'ohmic' for operation in the vicinity of V_{DS}=0, though the word is sometimes (mis)used also to describe the whole of Region 3.

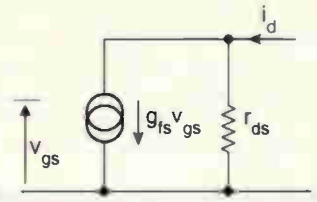


Fig. 9. Small-signal low-frequency equivalent circuit for Region 2.

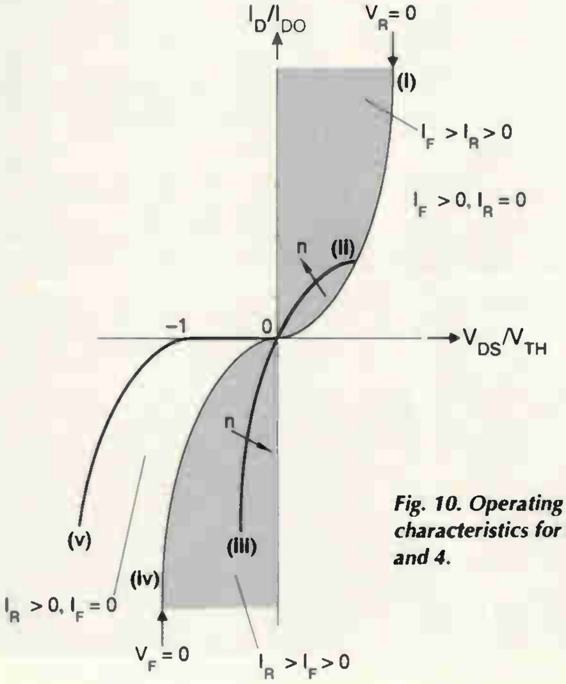


Fig. 10. Operating characteristics for Regions 3 and 4.

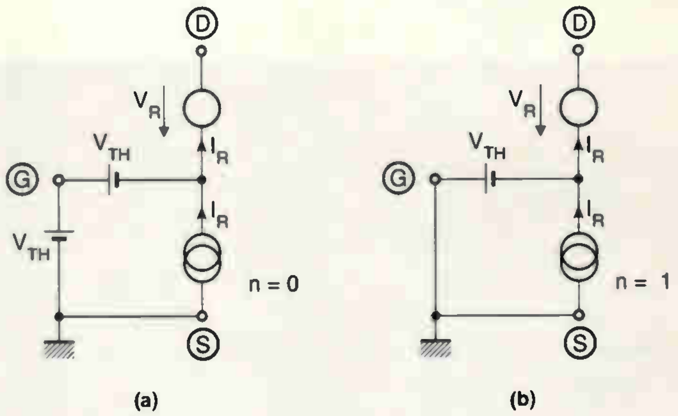


Fig. 11. Model for curve (iv), left, and, model for curve (v) of Fig. 10, right.

Consider now the condition $V_F>V_R$. Equations (15) and (16) still apply so curve (iii) in Fig. 10 is a smooth continuation through the origin, into the third quadrant, of curve (ii).

The boundary for Region 3 in the third quadrant is curve (iv), for V_F=0, corresponding to n=0. Putting V_F=0 in equations (12) and (13), gives $I_D=-KV_{DS}^2$, so curve (iv) can be regarded as curve (i) rotated about the origin through an angle of 180°. **Figure 11a)** shows a simplified model for n=0.

Region 4. Operation to the left of curve (iv) in Fig. 10 counts as in Region 4. The model in Fig. 11b) refers to curve (v), which represents the limit condition V_{GS}=0, corresponding to n=−1 and $I_D=-K(|V_{DS}|-V_{TH})^2$.

Curves, not shown, for non-integral values of n in the range $0>n>-1$ lie between (iv) and (v). These curves have the same shape as (iv) because the gate and drain of the mosfet are effectively strapped together, either directly, for the condition $n=-1$, or via a battery – equivalent to the particular value of V_{GS} used – for the case $0>n>-1$. Thus, any change in V_{DS} is seen as a change in V_{GS}.

If you connect the mosfet to the curve-tracer with the drain and source electrodes interchanged, curves similar to those of Fig. 9 are obtained provided V_{GD} is the parametric variable instead of V_{GS} : in that case,

$$n = \frac{V_{GD} - V_{TH}}{V_{TH}}$$

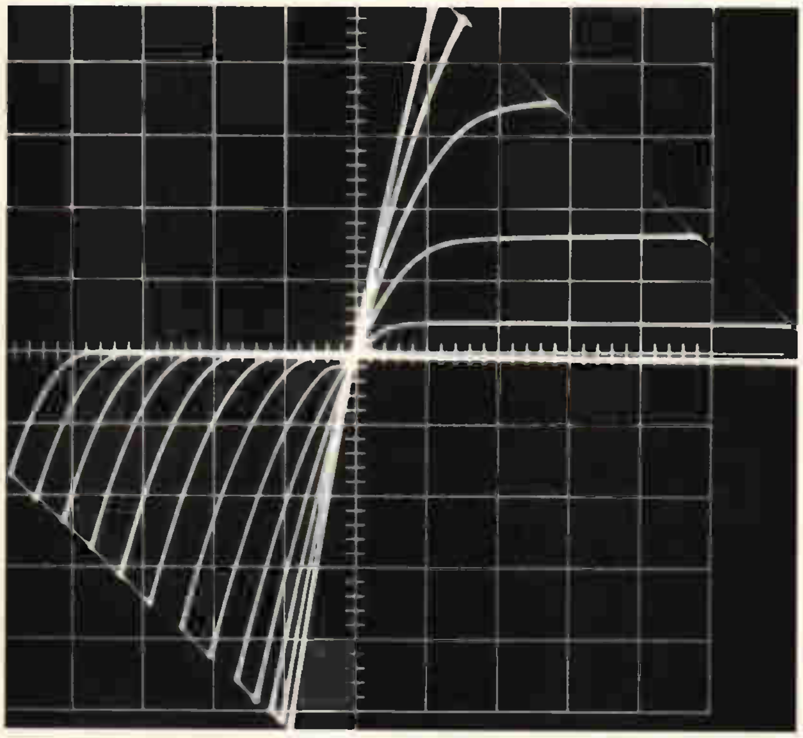


Fig. 12. Curve-tracer output characteristics, for CD4007A, in Regions 3 and 4.
Vertical scale I_D=0.5mA/div
Horizontal scale V_{DS}=1V/div
V_{GS} *steps, 1V* V_{BS}=–5V

Figure 12 shows a curve-tracer plot for the CD4007A sample referred to previously. The curve on the extreme left in the third quadrant is for $n=-1$. This is further along the negative V_{DS} axis than might have been expected from the value of V_{TH} indicated in Fig. 7. That is because the source-substrate bias necessary to observe the curves, namely –5V, increased the magnitude of the threshold voltage above its value at $V_{BS}=0$.

Figure 13 shows an expanded view of the drain characteristics in the vicinity of the origin. These exhibit the linearity predicted by equation (18) over the V_{DS} range observed. Practical applications of the mosfet model are considered next.

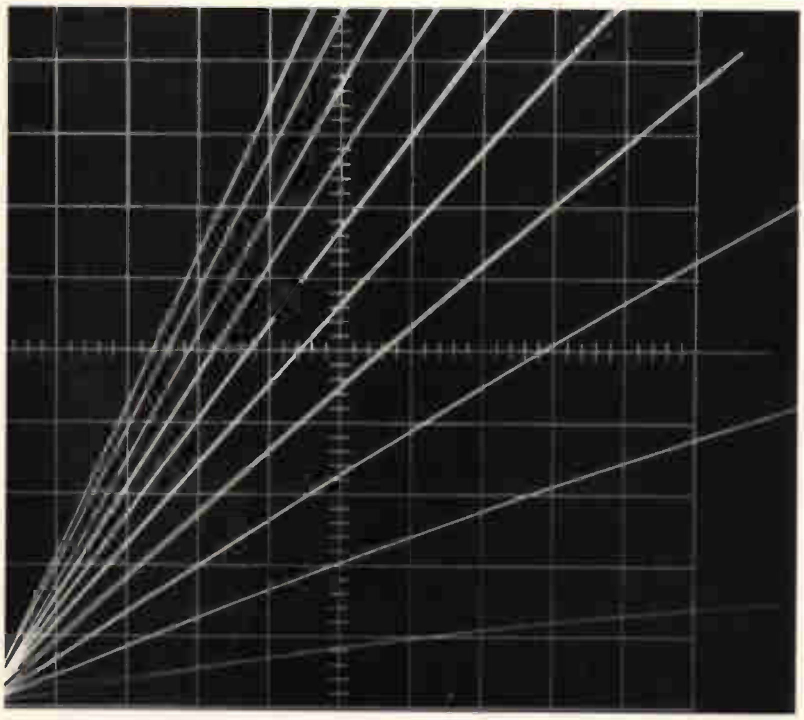


Fig. 13. Showing linearity of drain characteristics near the origin.
Vertical scale I_D=50μA/div
Horizontal scale V_{DS}=20mV/div
V_{GS} *steps, 1V.*

Application examples

The three examples that follow illustrate the use of the mosfet model, Fig. 2a) and its derivatives in circuit analysis and design.

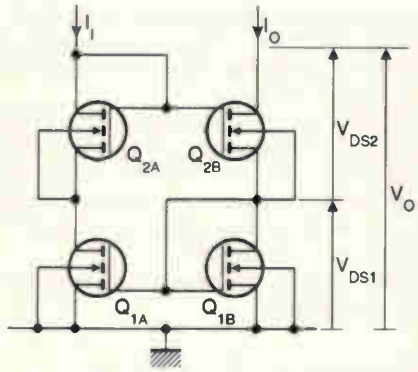


Fig. 14. A 1:1 current-mirror configured using mosfets.

The first is a four-mosfet 1:1 current-mirror, **Fig. 14**. This is similar in device configuration to the four-BJT version[4]. Transistors Q_{1A} and Q_{1B} comprise the principal mirror components. Transistor Q_{2B} increases the incremental output resistance above that obtained using a simple two-mosfet mirror: Q_{2A} is included to balance the drain-source voltages of Q_{1A}, Q_{1B} so they operate under the same DC bias conditions.

Assuming all the devices have identical characteristics and operate in Region 2, it follows that,

$$I_O = I_1 \qquad 19$$

With its drain-gate strap, Q_{1B} must operate in Region 2, but how do we guarantee that Q_{2B} does also? The answer to this is provided by inspection of **Fig. 15**, which is based on the model. The boundary line, curve A, for Region 2 operation of Q_{2B} is specified by $I_D=KV_{DS}^2$ so, at a given current, $I_D=I_1$,

$$V_{DS2} = \sqrt{\frac{I_I}{K}} \qquad 20$$

Curve B, for Q_{1B}, is given by,

$$I_O=K(V_{DS}-V_{TH})^2$$

so, at the same current, I_1,

$$V_{DS1} = V_{TH} + \sqrt{\left(\frac{I_1}{K}\right)} \qquad 21$$

Hence,

$$V_{O1} = V_{DS1} + V_{DS2} = V_{TH} + 2\sqrt{\frac{I_1}{K}} \qquad 22$$

Location P, is one point on curve C, with co-ordinates I_1, V_{O1}, which shows the lower boundary line, for constant-current output of the current-mirror.

Rearranging equation (22), this curve is specified by,

$$I_O = \frac{K}{4}(V_O - V_{TH})^2 \qquad 23$$

This describes a parabola with its vertex on the horizontal axis at $V_{DS}=V_{TH}$. The boundary line is the right-half section of this parabola. A routine small-signal, low-frequency, circuit analysis of Fig. 14, making use of the equivalent circuit of Fig. 9, shows that the incremental output resistance is,

$$r_O \approx (g_{fs} r_{ds}) r_{ds} \qquad 24$$

This discussion explains the shape of the output characteristics, **Fig. 16**, of an experimental circuit constructed from unselected samples of CA3600E – a version of the CD4007A more suitable for linear applications.

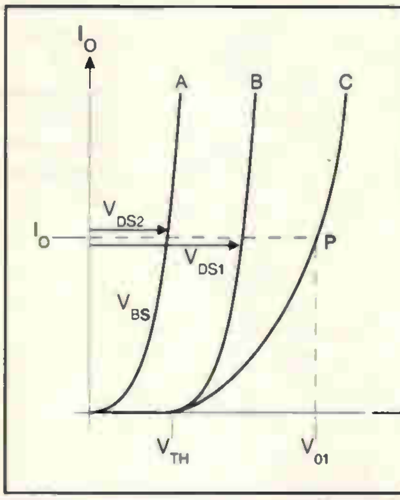


Fig. 15. Curve C is the lower boundary for Region 2 operation of Q_{2B} in Fig. 14.

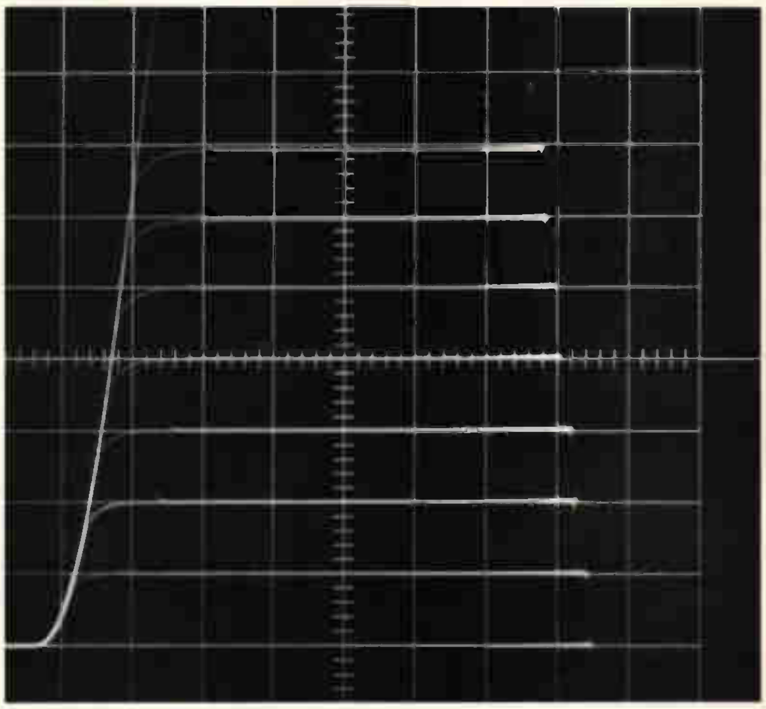


Fig. 16. Experimental characteristics for circuit of Fig 14. (Q_{1A}+Q_{1B}) are part of one CA3600E and (Q_{2A}+Q_{2B}) part of another.
Vertical scale I_D=0.2mA/div
Horizontal scale V_{DS}=2V/div
I_1 steps, 0.2mA

Voltage-controlled resistance

The second application concerns a mosfet used as a voltage-controlled resistor. In the attenuator circuit of **Fig. 17a)**, V_I, V_O, V_{GS} are respectively the input, output and control voltages. Transistor Q operates in the ohmic region if $(V_{GS}-V_{TH})>>V_O$. Then the drain-source resistance R_O is given by the equation (18), and the attenuation factor, α, is given by,

$$\alpha = \frac{R_O}{R + R_O} \qquad 25$$

The condition $(V_{GS}-V_{TH})>>V_O$, which might be restrictive in some applications, can be relaxed by use of a well-known circuit modification that is elegant in its simplicity. In Fig. **17b)**, feedback resistors $R_X(>>R)$ are added and V_C is the new control voltage.

By inspection,

$$V_{GS} = \frac{V_O + V_C}{2} \qquad 26$$

Substituting this, and $V_O=V_{DS}$, in equation (17) gives,

$$R_O' = \frac{1}{K(V_C - 2V_{TH})} \qquad 27$$

R_O' is now effectively constant over a typical output range of several volts.

The third application involves the model in the calculation of the '1' output level in single-polarity mosfet logic. **Figure 18a)** shows an NMOS logic-inverter stage in which Q_1 is the drive mosfet and Q_2 the load mosfet. Fig. **18b)** is applicable for calculating V_O when Q_1 is passing a leakage current I_L in its 'off' state.

$$V_F = (V_{DD} - V_{TH} - V_O) \qquad 28$$

and,

$$I_L = K V_F^2 \qquad 29$$

Hence,

$$V_O = V_{DD} - V_{TH} - \sqrt{\frac{I_L}{K}} \qquad 30$$

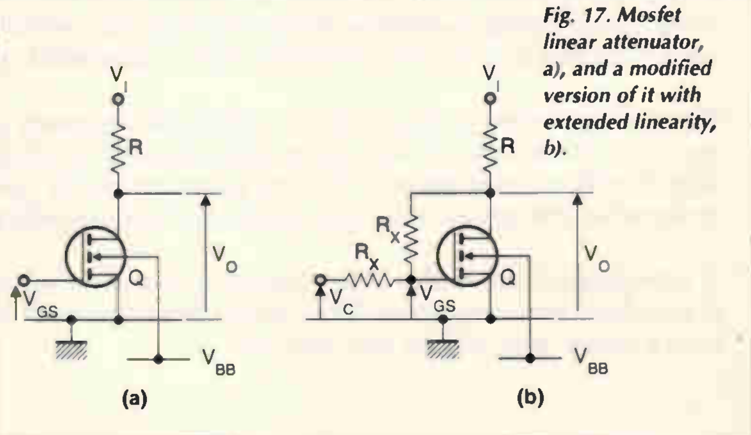


Fig. 17. Mosfet linear attenuator, a), and a modified version of it with extended linearity, b).

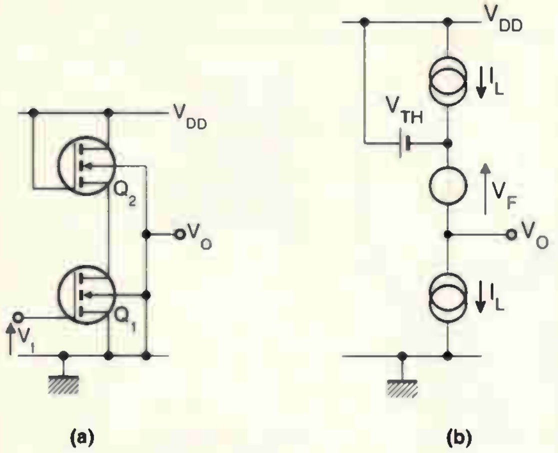


Fig. 18. An NMOS inverter stage, a), and a model of it, b), when Q_1 is off.

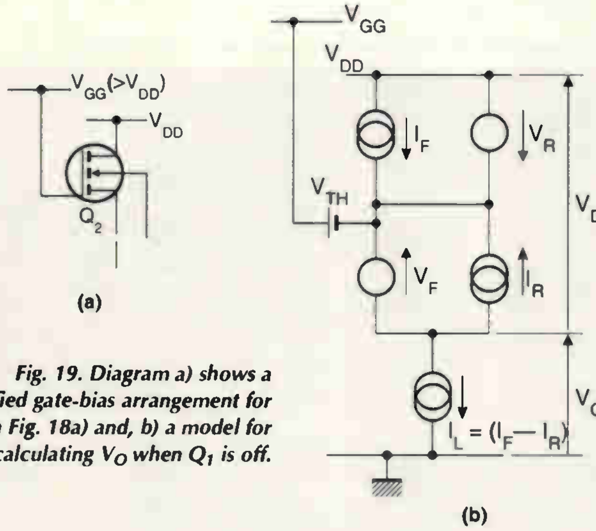


Fig. 19. Diagram a) shows a modified gate-bias arrangement for Q_2 in Fig. 18a) and, b) a model for calculating V_O when Q_1 is off.

The reduction in V_O from an ideal value V_{DD} results in a significantly smaller 'on' drive for a subsequent stage. This problem can be overcome by connecting the gate of Q_2 to a separate supply rail $V_{GG}(>V_{DD})$, as shown in Fig. 19a).

From the new equivalent circuit of Fig. 19b),

$$I_L = (I_F - I_R) = K(V_F^2 - V_R^2) \qquad 31$$

and,

$$V_R = (V_{GG} - V_{TH} - V_{DD}) \qquad 32$$

Substituting $(V_{DS}+V_R)$ for V_F in equation (31), expanding and rearranging gives,

$$V_{DS}^2 + 2V_{DS}V_R - \frac{I_L}{K} = 0 \qquad 33$$

If $2V_R >> V_{DS}$, the first term in the equation is negligible in comparison with the second; with the result that,

$$V_{DS} \approx \frac{I_L}{2KV_R} \qquad 34$$

Thus,

$$V_{DS} \approx \frac{I_L}{2K(V_{GG} - V_{TH} - V_{DD})} \qquad 35$$

provided,

$$(V_{GG} - V_{TH} - V_{DD})^2 >> \frac{I_L}{K} \qquad 36$$

Equations (35) and (36) provide selection criteria for V_{GG} in order to obtain a low value of V_{DS} and, hence, a value for V_O close to V_{DD}.

The inconvenience of using a second supply rail to minimise V_{DS} can be avoided by replacing Q_2 by a depletion-mode mosfet operating with V_{GS}=0 but that involves extra chip-processing steps because of the two different mosfet types used. The analysis is similar to that described above but for the depletion model of the mosfet the polarity of the battery V_{TH} in Fig. 2a) is reversed.

A neater solution still is to use CMOS, but that may not be suitable for high voltage interface-circuit design. ■

References

1. Ian Hickman, 'Versatile Transistor Curve Tracer', *Electronics World*, August 2000, pp. 602-607.
2. B.L.Hart, 'A first order d.c. model of the MOSFET', *IJEEE*, October 1997, pp. 326-330.
3. R.D.Middlebrook, 'A Simple Derivation of Field Effect Transistor Characteristics', Proc IEEE, August 1963, pp. 1146-1147.
4. B.L.Hart and R.W.J.Barker, 'D.C. matching-errors in the Wilson current source', *Electronic Letters*, 1976 Vol. 12, No 15, pp. 389-390.

Letters to the editor

Letters to "Electronics World" Cumulus Business Media, Anne Boleyn House,
9-13 Ewell Road, Cheam Road, Surrey SM3 8BZ
e-mail j.lowe@cumulusmedia.co.uk using subject heading 'Letters'.

Wireless designing

Compliments to Joe Carr on a great first installment of 'Designing Radio Receivers' in the August issue. I would like to add some small insights into the architectural decision of whether to choose either low-side or high-side LO injection with a super-heterodyne receiver.

Depending on the distance between your IF and RF, the associated system bandwidth and the external RF environment that the receiver will be placed in, the incorrect choice of which 'side' to inject the LO signal on can be disastrous to the overall design from the consideration of the receiver's spurious response. Interference from undesirable signals such as harmonics of the desired RF signal mixing with harmonics of the LO driving the receiver's mixer(s) can cause spurious or unwanted frequencies to fall within the receiver's IF band degrading receiver sensitivity.

Through the use of a power series expansion on the non-linear device's transfer function, in this case a mixer, or a decent commercially produced spur search program, many of these un-desired receiver responses can be located (Intermodulation, Half-IF and Able-Baker to name a few).

Knowing the frequencies that these mixing products can produce, can often help determine what is the appropriate LO injection 'side' to choose for a particular radio system to reduce, and/or eliminate, these spurious responses from landing in the receiver's IF band.

Looking forward to an exciting continuation of articles on receiver design from the ground up.

Jeffrey Kitcheos PE
Field Applications Engineer
Analog Devices
Hoffman Estates
Ilinois

DAB debate

Dave Kimber's editorial on DAB in the August issue makes interesting reading. I had always understood that the problem of co-channel interference between transmitters carrying the same multiplex on a given frequency – or strictly group of frequencies, since it is a spread spectrum system of sorts – would be addressed largely by the use of many, relatively low-power, transmitters so that those 75km away would have little chance of coming significantly into the equation. That situation may, therefore, improve (we can but hope...) when the installed base of transmitters grows to nearer the intended final density.

The business of spectrum re-use for different local multiplexes, however, seems more serious if listeners near the edge of each local station's coverage area are to be able to hear the stations at all.

Do the broadcasters have any comment on this? Will the roll-out of the higher-frequency DAB band – around 1300MHz – address this problem? That band is not even supported by all the current-production DAB tuners!

DAB sound quality continues to disappoint, due entirely to the MPEG 2 data reduction used. Readers interested in finding out more about this can read about it on my web site: www.musaeus.co.uk/dab

Richard Black
via e-mail

Since my leader, 'Has DAB really arrived?' appeared in the August issue, Videologic has swapped my tuner for the latest version with up-to-date software. I can now receive the Birmingham multiplex, although the signal strength seems inadequate for a portable or car receiver at my location.

On the basis of the advice I received and the information available to me at the time I made the reasonable inference that co-channel interference was the cause of my reception problem, but this has turned out to be incorrect.

As a result, I withdraw my comments about interference to the Birmingham multiplex, and I apologise for any confusion caused.

I still have concerns about digital broadcasting though, and would like to see a serious public debate about both the engineering and programme aspects of it. *Electronics World* would seem to be an appropriate medium for part of this debate.

One consequence of my article was that I had an interesting discussion with someone from the Radio Authority.

Dave Kimber (G8HQP)

Pseudo-random bits

I have just bought the July 2001 issue and I was delighted to find the article by Ian Hickman titled 'Pseudo-random bits'.

Ian's article touches on another aspect of exclusive circuitry, so-called linear circuitry that illustrates the extraordinary diversity of applications for these gate circuits.

Ian says: "It is possible that feedback arrangements exist that can generate two different non-maximal length sequences. No doubt one of you will already have the answer."

LFSRs are digital-sequential circuits and can be analysed by the methods applicable to digital sequential circuits. The method is essentially the same for both asynchronous and synchronous circuits. Ian might be interested in an article on my web site that gives an example of the method of analysis and the results for a circuit that exhibits multiple loops. The link is: http://users.senet.com.au/~dwsmith/relay.htm.

David Warren-Smith CPEng MSc
Elizabeth Downs
South Australia

Phono preamp for the CD era

I do not object to opinions that differ from mine. I specifically object to Mr Self's obnoxious manner in expressing that difference. I am certainly not the first to so fault Mr Self; he has an unenviable reputation in that regard, a fact of which I suspect he is well aware.

I quoted no noise performance specification at all, so I have no idea why he states that I quoted one of –82dB ref 5mV at 1kHz. I guess I would worry, too, about an amp better than noiseless, but I made no such quote and no such claim.

I was specifically referring to the amplification headroom, as it seemed Mr Self was doing. Now, apparently, he claims he really was talking about noise headroom. It's certainly tough to hit a moving target. The noise issue has been run into the ground.

As a practical matter, the preamp's noise performance is more than adequate. No one who has listened to it has been able to hear any noise unless their ear was placed immediately in front of the speaker. Even there, there was no more audible noise than heard coming from my Krell preamp.

The preamps that I have measured that used the single-stage topology did no better than 0.4dB maximum deviation from the RIAA curve, compared with 0.1dB for my design. I did a little better than this when I briefly played around with such designs, but it seemed that they were noticeably more sensitive to component variations.

To claim an op amp-based design is simpler than my discrete design ignores the internal circuit complexity of the op amp. From the designer's standpoint, the op amp is certainly more straightforward, but the number of devices in the signal path is unlikely to be any less and is probably greater. I actually have no qualms about op amp-based designs, but many people do. I designed my preamp with those kind of potential objections in mind.

Dr Norman Thagard
Via e-mail

In response to Mr Thagard's letters in the May and September issues, I am very sorry that he has taken such offence at my brief enquiry as to why he designed his preamplifier the way he did. It is, I am afraid, unrealistic to publish a design in a journal like *Electronics World* and expect it to receive uncritical adulation.

When I published my last preamplifier design, I positively invited people to say if they could do better; the idea is to foster healthy competition rather than aggrieved correspondence.

The implication of Mr Thagard's reply in May is that his PSpice simulations are superior to my mathematical model. This model is a spreadsheet based on the philosophy of NatSemi's Application Note AN-104. Both are useful, and both are inferior to measuring the real thing.

I therefore fired-up both techniques and compared the results with real-life measurements of my 5534 single-stage design as used in Preamp '96; see *EW* July 1996. See **Table** below.

The two theoretical methods differ by 1.48dB in their noise output. I suggest that this is due to differences in the input noise specs for the 5534. The parameters for the mathematical modelling are taken from the manufacturer's data sheet, while the PSpice model comes from the TI macromodel library and is not in a format that allows direct comparison of e_n and i_n. The real-life measurement is in the middle of the two theoretical results, which I think demonstrates we are not far from the truth.

Note that extracting noise results from PSpice – in my version at least – is not at all straightforward, requiring a rather complex macro.

The comparison was done over the bandwidth 400-22kHz because in practical noise measurements high-pass filtering is needed to exclude the magnetic hum pickup of a real MM cartridge.

In each case, removing the cartridge resistance causes the noise to drop by less than 0.4dB, so it is clearly making only a minor contribution.

Mr Thagard quotes a noise performance of –82dB ref 5mV in (1kHz), which according to my calculations and simulations, represents a noise figure of –0.4dB, i.e. the system is quieter than one with a noiseless amplifier. This is a little worrying.

To return to the noise headroom issue, in his last letter Mr Thagard says that if the second stage of a two-stage RIAA preamp is given enough gain, then there is no extra headroom limitation in the first stage. This is of course true, but neglects the point that the second stage will then generate considerably more noise, which will not be low-pass filtered by the RIAA HF roll-off.

The two-stage philosophy means that you must amplify, attenuate, then amplify again; this introduces the unwelcome headroom/noise trade-offs. The one-stage version simply amplifies as much as required and no more.

Mr Thagard also says that a two-stage preamp is "much more likely to accurately track the RIAA curve than the single-stage design". I cannot see why this should be so; after all, we are only setting up a few time-constants. It is true this requires more calculation in the one-stage case, but the mathematics was clearly set out by Stanley Lipshitz in 1979. Possibly I should have described the algorithm fully in my previous articles.

I am still uneasy about the philosophy of this design, which uses considerable complexity but underperforms a twenty-year old op-amp. It may be good enough for listening to, as Mr Thagard insists, but I'm afraid that it seems too complicated to me. If you can make something better, simpler, and cheaper at the same time, then you don't call that process overdesign. ■

Doug Self
London

Table. Investigation of the 5534 op-amp.

	Noise out Full model	Noise out R_{cart}=0	Difference	Noise ref 5mV_{in} Full model	
MathModel	–93.34 dBu	–93.73	0.39 dB	–79.40 dB	Freq-variable e_n, i_n
PSpice	–91.86 dBu	–92.15	0.29 dB	–77.92 dB	TI library model
Measured	–92.3 dBu			–78.4 dB	Preamp '96

NEWPRODUCTS

Please quote *Electronics World* when seeking further information

Transceiver for DS3, E3, STS-1

TDK Semiconductor has expanded its DS3/E3/STS-1 product family with multi-channel line interface units. The three devices operate with data rates of 34Mbit/s (DS3), 45Mbit/s (E3) and 51Mbit/s (STS-1). Primary product applications for the multi-ports include DSLAMs, T3/E3 digital multiplexers, SONET Add/Drop multiplexers, PDH equipment, DS3-to-fibre optic and microwave modems, and ATM WAN access for routers and switches. The 78P7202L (dual port), 78P7203L (triple port) and 78P7204L (quad port), are extensions of the 78P7200L single-chip IC. Each of the multi-ports is a line interface transceiver for E3, DS3 and STS-1 applications.

TDK Semiconductor
Tel: 001 714 508 98821
www.tdksemiconductor.co.uk

Octal voice codec

IDT has announced an octal codec capable of processing eight individual analogue voice

channels. The high channel count is the highest density available, said IDT, making it ideally suited for communications equipment in the enterprise/carrier-class network, wireless infrastructure and access network markets. Applications include voice routers, voice-over-Internet-protocol gateways, multi-service access switches, residential integrated access devices and digital loop carrier voice switches. Also included in the family are two quad codecs. All three devices include AC impedance matching, tone generation, transhybrid balance, frequency response correction, gain setting, and selectable microprocessor interface or general communications interface. Integrating these features within the CODEC, rather than in an external Asic or digital serial port, gives the designer flexibility, said IDT. It also reduces parts, saves board space and cuts costs.

IDT
Tel: 01372 363339
www.idt.com

SMT power inductor has low DC resistance

Pulse has announced two surface mount power inductors for use with Volterra's low-voltage power delivery semiconductors. With a profile height of 0.125in. (3.17mm), the SMT power inductors are designed for high-current, low-voltage, low-profile DC-to-DC power converter applications which use latest generation microprocessors. The low DC resistance, which offers improved circuit efficiency, and the high-current capability, is the result of the squared-toroid core design. The package used by Pulse for these devices is a flat-top, self-leaded design with a fixed clip, said to be ideal for easy pick-and-place applications and higher current ratings.

Pulse
Tel: 01483 401700
www.pulseeng.com

Low-power Bluetooth transceiver

Specialist distributor Telecom Design Communications stocks a Bluetooth RF transceiver from Conexant. The CX72303 meets Bluetooth class 2 and 3 standards for the version 1.1 specification of the wireless system. The single-chip transceiver has a voltage supply of 1.8V, a 14mA maximum transmit (Tx) and receive (Rx) current consumption and a one to ten metre operating range. RF sensitivity is –86dB. Integrated within the chip are a voltage-controlled oscillator, synthesiser, power amplifier, and low-noise amplifier.

TDC
Tel: 01256 332800
www.tdc.co.uk

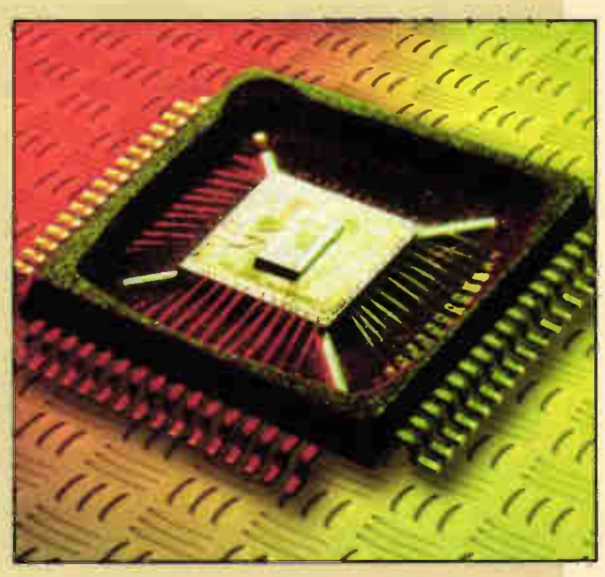
Credit card-sized AC/DC supply

Measuring less than the size of a

Twin-die flash microcontroller

Hitachi's latest flash microcontroller uses a multi-chip package to add on-chip EEPROM to the device. Based on the H8/300H CPU core, the H8/3664N is shipped with 512 bytes of embedded EEPROM in a second die within the package. The device offers 16-bit performance and a range of peripherals. The addition of on-chip EEPROM makes the device suitable for applications that require non-volatile storage of initialisation or calibration information, such as meters or motion control systems, security systems and communication systems where passwords or other addressing information must be stored. In addition to the embedded EEPROM, the H8/3664N also has 32kbytes of on-chip single supply flash memory. This allows reprogramming of the memory without any additional circuitry and provides for end of line production programming, said the supplier. The on-chip I^2C interface makes the device appropriate for many consumer applications, such as radios and stereos, where I^2C is the *de facto* communications standard, and set-top boxes, where it can be used for handling housekeeping and I/O functions. Other peripherals include two 8-bit timers, a high speed USART, eight channels of 10-bit a-to-d converter and 37 I/O pins. Samples are available in a 64-pin Quad Flat Pack package.

Hitachi
Tel: 01628 585 163
www.global.hitachi.com



credit card, the new medically approved GSM15 from Condor DC Power Supplies will suit medical equipment applications, such as monitors or pumps, where an ultra small power supply is needed. The family of 15W AC-to-DC supplies is available with 5, 12, 15, 24 and 28V outputs and a wide input range of from 90 to 264V AC. Leakage current under normal conditions Class 1 grounding is 25µA with Class 2 grounding at 132V AC and rising to 84µA with Class 1 grounding at 264V AC. EMC meets BN6 1000 level 3 and conducted emissions meet EN55011. It will achieve 15W with convection cooling and 18W is possible with 150LFM of air. It is protected against short circuit and overload with an on-board AC line fuse as standard.
Condor
Tel: 01769 540744
www.condorpower.com

Electro-optic moulded interconnectors

CPE-Europe is offering a moulded interconnect technology that is claimed to simplify the assembly process for electro-optics, electromechanical modules and sensors. It is based on moulded (plastic or ceramic) substrates that create electro-mechanical features. By selectively creating copper tracks (down to 50µm track or gap) on the three-dimensional form, the substrate can simplify assembly and increase reliability of the electronic functions. This new service is now available in the UK and Europe through CPE-Europe.
CPE-Europe
Tel: 01604 620215
www.cpe-europe.com

Very-low-power static RAM

The BS616LV4010 low-power 4Mbit by 16 SRAM manufactured by BSI is available from Memotech. Available in either 216k by 16 or 512k by 8 formats, the device is fabricated

using a six-transistor memory cell design. Its data retention mode is designed to allow data to remain valid at a minimum power supply voltage of 1.5V. Supplied in TSOP II or BGA packaging styles, the part's V_{cc} range is quoted as 2.7 to 3.6V, with a typical standby current of just 1µA. The SRAM is available in commercial, 0 to +70°C, or industrial –40 to +85°C, temperature ranges. A 5V version of this SRAM is also available.
Memotech
Tel: 01223 370060
www.memotech.co.uk

Zero-profile solderless socket

Tyco Electronics is offering the Holtite socket (part of the Augat brand), which is designed for high-density systems and standard or non-standard devices with zero profile above the PCB. The sockets press in to the existing plated through hole, requiring no soldering. To address thermal issues associated with certain components, it is designed to maximise heat dissipation around the device. The sockets use a precision-machined four-finger contact.
Tyco Electronics
Tel: 0208 954 2356
www.cpe-europe.com

Highly-integrated transmit IC for dual-band cellular phones

Maxim Integrated Products has introduced three baseband-to-power amplifier complete dual-band cellular phone transmit ICs. They are designed for dual-band, dual-mode, and single-mode N-CDMA, TDMA, GAIT, and W-CDMA cellular phones.
The MAX2361 series has a high integration level, which dramatically reduces component count and size, said Maxim.
Maxim
Tel: 0118 930 3388
www.maxim-ic.com

DWDM network analyser

Telecom testing specialist Conformance Standards Ltd (CSL) is offering a network analyser for dense wavelength division multiplexing (DWDM)

from Digital Lightwave. The DCA 425 is a portable system for installation and maintenance of DWDM systems. It combines the functions of an optical power meter, spectrum analyser and bit-error-rate analyser. Features include measurement of optical channel signal to noise (QSNR) and protocol analysis of DWDM signals at STM-64 rates. It can monitor four fibre inputs with wavelength spacing as low as 50GHz.
CSL
Tel: 01452 385025
www.cslcomms.com

Data acquisition for use under Matlab

Amplicon Liveline, distributor for UEI PowerDAQ products in the UK, is offering a Matlab driver for its PowerDAQ family of acquisition and control plug-in boards for the PCI-bus. Matlab has a good reputation for data-analysis among scientists and engineers. To assist users

Brick fuses rated up to 250V

Cooper Electronic Technologies has introduced a series of 250V surface-mount fuses complying with EIA/ISS-722 environmental standards. Maximum AC rating is set at 250V and DC rating is 125V. All components are capable of replacing glass tube equivalents for off-line current protection, said the firm. The 1025TD (time delay) and 1025FA (fast acting) fuses have been designed to North American standards with UL and CSA agency listing, the 1025T (time delay) and the 1025F (fast acting) developed to European IEC standards with Semko and VDE approval. The 1025TD is capable of carrying 200% of its rated current for a minimum one second and the 1025F has been designed to open at 200% of its rated current in 5 seconds maximum.
Cooper
Tel: 01509 882606
www.cooperet.com

working with real-world data rather than simulations, The MathWorks developed the Data Acquisition Toolbox, which interfaces with data acquisition and control hardware. Users can create sophisticated applications based on M-files, complete with graphical-user interfaces, as well as conduct experiments directly from the Matlab command line. This combination can be used to automate the process of collecting data, performing analysis, and either display results or create a response signal and send it out through the same I/O board.
Amplicon
Tel: 01273 570220
www.amplicon.co.uk

Low-noise precision voltage references

Analog Devices has introduced a family of low-noise precision voltage references that it claims achieve the lowest noise performance for a given supply current in 5V systems. The ADR42x family is based on the firm's XFET technology, designed specifically for low noise, linear temperature coefficient performance and to solve many of the inherent problems that limit the use of band-gap and buried-zener references. These parts, said Analog Devices, achieve five times better noise performance than a band-gap reference at the same supply current. Typical applications would include digital voltmeters, precision instrumentation, high-resolution data acquisition systems, industrial process control systems and optical network control circuits. The ADR42x family has four members, each with noise of 1.75μV pk-to-pk at a supply current of 0.6mA. Output voltages 2.048, 2.50, 3.00 and 5.00V. Temperature coefficient is 3ppm/°C. Packages are either 8-pin small outline or mini-SOIC and the devices are specified over the industrial temperature range. A-grade devices cost $2.25 in 5000 units.
Analog Devices
Tel: 0032 11 300 635
www.analog.com

Single-chip, two-channel transceiver

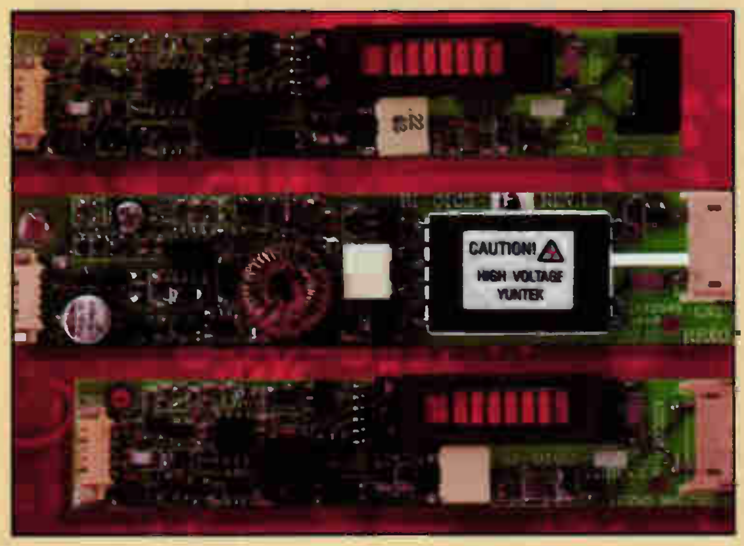
Exar Corporation has announced the XRT73LO2, a standards-compliant 3.3V, two-channel transceiver line interface unit for E3, DS3, and STS-1 applications. This is the final device in Exar's transceiver product family, which includes single, dual, triple and quad-channel devices. It is aimed at multi-port E3/DS3/STS-1 applications such as digital cross-connect systems, ATM switches, routers, and add/drop multiplexers. The device includes equaliser and clock recovery circuits allowing reliable use over a wide range of cable lengths. On-chip transmit clock duty cycle correction guarantees pulse template compliance, said the firm. Each channel can be configured independently to run at either of the three data rates via either hard wire connections or a 4-pin serial interface. Over coaxial cable data rates range from 34.368Mbit/s using E3, through 44.736Mbit/s of DS3, to 51.84Mbit/s using STS-1. The 80-pin TQFP operates at the industrial temperature range of –40 to 85°C.
Exar Corporation
Tel: 0033 49364 775
www.exar.com

Co-planar board mating interfaces

Samtec has a range of interconnects allowing printed circuit boards to be mated in the same plane. On 1.27mm pitch, headers and sockets are available for a variety of applications. Surface mount and through-hole headers and shrouded headers mate with right-angle sockets with pin outs on 1.27 mm or 0.64mm for high density. For 2mm pitch applications, surface mount (MMT & MMS Series) and through-hole (TMM, TMMH & CLT Series) headers and sockets are available for parallel board connection. Surface mount and through-hole shrouded headers (TSH Series) are available. 2.54mm pitch surface mount co-planar board mating is available (TSM/SSM Series) as well as through-hole (TSW/BCS Series) applications. Surface mount and through-hole shrouded headers (TSSH Series) are available for blind mating. For micro pitch applications, Samtec also has a mini-edge card system (MECI) on 1mm pitch, and for 0.8mm pitch applications, high speed edge-mount connectors (QTE/QSE Series) are also available.
Samtec
Tel: 01236 727113
www.samtec.com

REO Components catalogue

A new catalogue from REO Components with a product range from wire-wound potentiometers to purpose designed switch-mode power supplies is now available. The mini catalogue is a compilation of some of the their more popular stock items.
REO Components
Tel: 01588 676167
www.reocomponents.com



LCD backlight inverters

BF Group has launched a range of LCD backlight inverters for driving monochrome STN, passive colour STN and active-matrix TFT LCD. The inverters are suitable for consumer, office automation, industrial, medical markets and POSI P01/Kiosk applications. Aimed at single-tube, dual-tube and quadruple-tube CCFL backlit displays, the display inverters can cater for a wide range of tube current, drive frequency, running voltage and kick-off voltage parameters. The inverters are fitted with either a simple voltage-controlled dimming system, or the more complex pulse-width modulation method that allows dimming ratios of up to 2000:1 to be achieved. Custom designs can also be carried out to meet any CCFL backlighting system requirement for use in an LCD, said the firm.
BF Group
Tel: 01444 413777
www.bfgroup.co.uk

Please quote *Electronics World* when seeking further information

Detection switch with 1.4mm profile

Matsushita Electric Works' latest detection switch measures 3.4 by 3.5 by 1.4mm. The ABC2 switch's coil spring and contact have been integrated to provide contact force and reliability. Contacts are gold-coated for reliability. The switch can be operated from both horizontal and vertical directions. Mounting can either be conventional surface mount or the switch body can be recessed into the PCB for a low profile. In addition, the device's 1.0mm over-travel and positioning boss is intended to simplify installation

Matsushita
Tel: 01908 231555
www.memotech.co.uk

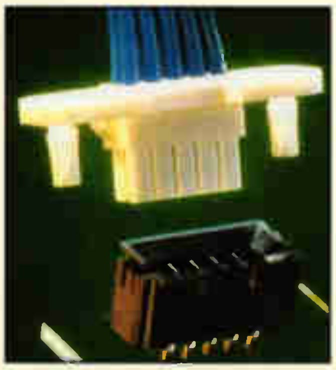
VCXOs for WDM

NDK Europe has unveiled a series of voltage-controlled crystal oscillators (VCXO) for wavelength division multiplexing (WDM). The devices have a frequency range of 50 to 780MHz, with frequency drift of either 20, 50 or 100ppm.

NDK Europe
Tel: 020 8390 8344
www.ndk.com

Solderless power connector

Molex's line of Mini-Fit-CPI connectors are dual row, vertical



headers which feature a compliant pin interface with 'eye of the needle' press-fit pins that require no soldering. They are suitable for high current requirements in telecoms and networking equipment, including backplanes. The connectors feature phosphor bronze terminals that can handle up to 8A per terminal depending on circuit size and will not twist in PC board holes, said the supplier. They can be applied to PC board thicknesses of 0.094in and up. Blind mating capability can simplify wire-to-board and board-to-board assembly. Available with tin or gold-plated contacts and with 4 to 24 circuits, these connectors are intermateable with Molex's Mini-Fit, Jr and Mini-Fit BMI receptacles.

Molex
Tel: 01252 720751
www.molex.com

Side-actuated SM switch

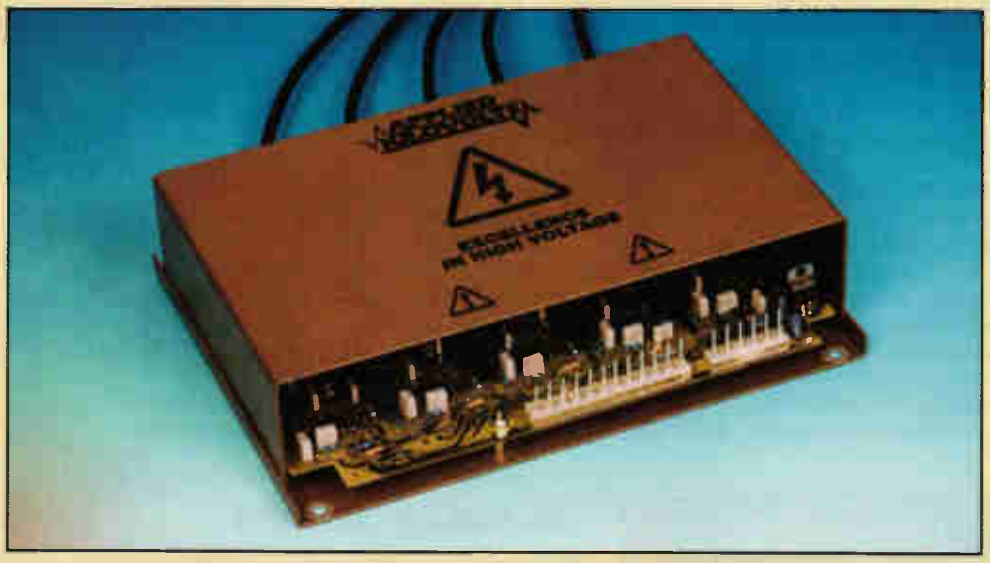
The latest surface mount side-actuated tactile switch from ITT Industries, Cannon measures 4.6 by 3.5 by 1.42mm. Available in a single-pole, single-throw configuration with normally-open contact, the KMS switch features a sharp tactile feedback. Typical applications are likely to be mobile phones, pagers,

keyless entry systems and automotive electronics. The switch has a large hard plastic actuator, robust construction, four solder terminals and a ground terminal on the switch cage. Technical specifications include a maximum contact voltage of 50V DC, min/max current ratings of 1mA/50mA, and bounce of less than 3ms. Life expectancy is 100k operations and contact resistance is less than 100mΩ.

ITT Industries
Tel: 00331 60245151
www.ittcannon

Resistor array integrates eight devices into one package

The MNR18 chip-resistor array from Rohm integrates eight resistors with values up to 1MΩ



Five-channel 5kV miniature power supply

Applied Kilovolts has expanded its range of high-voltage power supplies with a multi-channel, five output HP5x5. This supply has five separately controlled 5kV outputs each capable of 300μA. The module is available with any combination of polarities (e.g. 3 positive and 2 negative) in a case measuring 216 x 155 x 52mm. The module is based on the high precision standard HP5 and is powered from 24V. It needs five 0 to +10V signals to control the output voltages and reads back the actual voltages by 10V monitor signals. Line and load regulation of all outputs is 50ppm and it has a peak-to-peak ripple on each output of 150mV. As an added feature, the output voltage range (and monitor signal) on any channel can be reduced by changing one resistor. This will give increased resolution on this channel. The supply was developed for compact scientific instruments where a large number of high voltages are needed for lens voltages, beam deflection, focusing, astigmatism correction and multi-element electron guns. Applications include mass spectrometers, ion beam and electron gun surface science instruments and multiple high-voltage testing.

Applied Kilovolts
Tel: 01273 439440
www.memotech.co.uk

Visit our website www.distel.co.uk

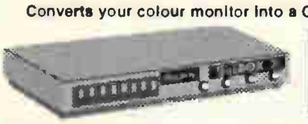
THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

THE AMAZING TELEBOX

Converts your colour monitor into a **QUALITY COLOUR TV!!**



TV SOUND & VIDEO TUNER
CABLE COMPATIBLE*

The **TELEBOX** is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors 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 £49.95 code (B)
See www.distel.co.uk/data_my00.htm for picture + full details

FLOPPY DISK DRIVES 2½" - 8"

All units (unless stated) are ***BRAND NEW*** or removed from often brand new equipment and are fully tested, aligned and shipped to you with a full 90 day guarantee. Call or see our web site ***www.distel.co.uk*** for over 2000 unlisted drives for spares or repair.

3½" **Mitsubishi MF355C-L**. 1.4 Meg. Laptops only	£25.95(B)
3½" **Mitsubishi MF355C-D**. 1.4 Meg. Non laptop	£18.95(B)
5¼" **Teac FD-55GFR** 1.2 Meg (for IBM pc's) RFE	£18.95(B)
5¼" **Teac FD-55F-03-U** 720K 40/80 (for BBC's etc) RFE	£29.95(B)
5¼" **BRAND NEW Mitsubishi MF501B** 360K	£22.95(B)
Table top case with integral PSU for HH 5¼" Floppy / HD	£29.95(B)
8" **Shugart 800/801** 8" SS refurbished & tested	£210.00(E)
8" **Shugart 810** 8" SS HH *Brand New*	£195.00(E)
8" **Shugart 851** 8" double sided refurbished & tested	£260.00(E)
8" **Mitsubishi M2894-63** double sided *NEW*	£295.00(E)
8" **Mitsubishi M2896-63-02U** DS slimline *NEW*	£295.00(E)
Dual 8" cased drives with integral power supply 2 Mb	£499.00(E)

HARD DISK DRIVES 2½" - 14"

2½" **TOSHIBA MK1002MAV** 1.1Gb laptop(12.5 mm H) *New*	£79.95
2½" **TOSHIBA MK2101MAN** 2.16 Gb laptop (19 mm H) *New*	£89.50
2½" **TOSHIBA MK4309MAT** 4.3Gb laptop (8.2 mm H) *New*	£105.00
2½" **TOSHIBAMK6409MAV** 3.1Gb laptop (12.7 mm H) *New*	£190.00
2½" to 3½" conversion kit for Pc's, complete with connectors	£14.95
3½" **FUJI FK-309-26** 20mb MFM I/F RFE	£59.95
3½" **CONNER CP3024** 20 mb IDE I/F (or equiv.) RFE	£59.95
3½" **CONNER CP3044** 40 mb IDE I/F (or equiv.) RFE	£69.00
3½" **QUANTUM 40S** Prodri ve 42mb SCSI I/F, New RFE	£49.00
5¼" **MINISCRIBE 3425** 20mb MFM I/F (or equiv.) RFE	£49.95
5¼" **SEAGATE ST-238R** 30 mb RLL I/F Refurb	£69.95
5¼" **CDC 94205-51** 40mb HH MFM I/F RFE tested	£69.95
5¼" **HP 97548** 850 Mb SCSI RFE tested	£99.00
5¼" **HP C3010** 2 Gbyte SCSI *differential* RFE tested	£195.00
8" **NEC D2246** 85 Mb SMD interface. *New*	£199.00
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 drives in stock - Shipping on all drives is code (C1)

IC's -TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK

10,000,000 Items EX STOCK

For ***MAJOR*** SAVINGS

CALL OR SEE OUR WEB SITE www.distel.co.uk

VIDEO MONITOR SPECIALS

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

Mitsubishi **FA3415ETKL** 14" SVGA **Multisync** colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including IBM PC's in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE**. Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Fully guaranteed, in EXCELLENT little used condition.
Tilt & Swivel Base £4.75 **Only £119** (E) Order as **MITS-SVGA**
VGA cable for IBM PC included.
External cables for other types of computers available - **CALL**

Ex demo 17" 0.28 SVGA Mitsubishi Diamond Pro monitors, Full multisync etc. Full 90 day guarantee. Only £199.00 (E)

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

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with <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 H12¾" x 15½" D. **Only £99.00** (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with **standard composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burns). In attractive square black plastic case measuring W10" x H10" x 13½" D. 240 V AC mains powered. **Only £79.00** (D)

KME 10" 15M10009 high definition colour monitors with 0.28" dot pitch. Superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13½" x 12" x 11". Good used condition. **Only £125** (E)

20" 22" and 26" AV SPECIALS

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

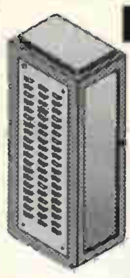
20"....£135 22"....£155 26"....£185 (F)

We probably have the largest range of video monitors in Europe, All sizes and types from 4" to 42" call for info.

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.

19" RACK CABINETS



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

Top quality 19" rack cabinets made in UK by **Optima Enclosures Ltd.** Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting ,plus ready mounted integral 12 way 13 amp socket switched mains distribution strip make these racks some of the ***most versatile we have ever sold.*** Racks may be stacked side by side and therefore require only two side panels to stand singly or in multiple bays. Overall dimensions are: 77½" H x 32½" D x 22" W. **Order as:**

OPT Rack 1 Complete with removable side panels.	£345.00 (G)
OPT Rack 2 Rack. Less side panels	£245.00 (G)

Over 1000 racks, **shelves, accessories 19" 22" & 24" wide 3 to 46 U high. Available from stock !!**

32U - High Quality - All steel RakCab

Made by **Eurocraft Enclosures Ltd** to the **highest possible spec,** rack **features all steel construction** with **removable** side, front and back doors. Front and back doors are **hinged for easy access** and all are lockable with **five secure 5 lever barrel locks.** The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members **to take the heaviest of 19" rack equipment.** The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A **mains distribution panel** internally mounted to the bottom rear, provides 8 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. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)

Sold at LESS than a third of makers price !!

A superb buy at only £245.00 (G)

42U version of the above only £345 - CALL

12V BATTERY SCOOP - 60% off !!

A special bulk purchase from a cancelled export order brings you the most **amazing savings** on these ultra high spec 12v DC 14 Ah rechargeable batteries. Made by **Hawker Energy Ltd, type SBS15 featuring pure lead plates** which offer a far superior shelf & guaranteed 15 year service life. **Fully BT & BS6290 approved.** Supplied **BRAND NEW** and boxed. Dimensions 200 wide, 137 high, 77 deep. M6 bolt terminals. Fully guaranteed. Current makers price over £70 each ***Our Price £35 each*** (C) ***or 4 for £99*** (E)

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*

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.

Web ref = LK33 ***ONLY £99.00 or 2 for £180.00*** (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 3½" disks with concise books c/w QBasic .	£14.95
Windows for Workgroups 3.11+ Dos 6.22 on 3.5" disks	£55.00
Wordperfect 6 for DOS supplied on 3½" disks with manual	£24.95

shipping charges for software is code B

TEST EQUIPMENT & SPECIAL INTEREST ITEMS

MITS. FA3445ETKL 14" Industrial spec SVGA monitors	£245
FARNELL 0-60V DC @ 50 Amps, bench Power Supplies	£995
FARNELL AP3080 0-30V DC @ 80 Amps, bench Suppy	£1850
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
IBM 53F5501 Token Ring ICS 20 port lobe modules	£750
IBM MAU Token ring distribution panel 8228-23-5050N	£95
AIM 501 Low distortion Oscillator 9Hz to 330KHz, IEEE	£550
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	£6500
Marconi 2022C 10KHz-1GHz RF signal generator	£1550
Marconi 2030 opt 03 10KHz-1.3 GHz signal generator,New	£4995
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	£675
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
View Eng. Mod 1200 computerised inspection system	£POA
Sony **DXC-3000A** High quality CCD colour TV camera	£995
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	£9500
Emerson AP130 2.5KVA industrial spec.UPS	£2100
Mann Tally MT645 High speed line printer	£2200
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram	£945
Siemens K4400 64Kb to 140Mb demux analyser	£2950
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
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 MS9001B1 0.6-1.7 uM optical spectrum analyser	£POA
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
CLAUDE LYONS 12A 240V single phase auto. volt. regs	£325
CLAUDE LYONS 100A 240/415V 3 phase auto. volt. regs	£2900

DISTEL on the web !! - Over 16,000,000 items from stock - www.distel.co.uk

DISPLAY -ELECTRONICS-

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

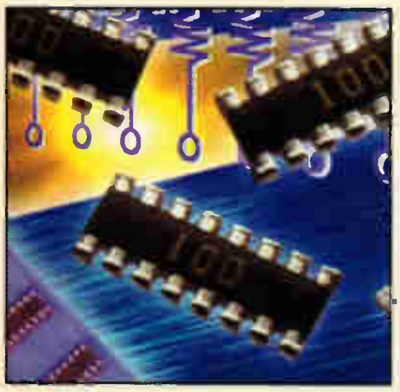
LONDON SHOP
Open Mon - Sat 9:00 - 5:30
215 Whitehorse Lane
South Norwood
On 68A Bus Route
Nr. Thornton Heath & Selhurst Park SR Rail Stations

NEW DISTEL©
Visit our web site
www.distel.co.uk
email = admin@distel.co.uk

ALL ☎ ENQUIRIES
0208 653 3333
FAX 0208 653 8888

SWITCH VISA EST. 26 YEARS

Please quote *Electronics World* when seeking further information



into a single surface mount package. The array effectively integrates eight conventional 0402 resistors into a 16-pin IC-style device with dimensions of 3.8 x 1.6 x 0.5mm. Resistance values range from 10Ω to 1MΩ and all devices have a tolerance of ±5 per cent. It is rated for a maximum continuous working voltage of 25V per element and is designed to operate across an extended temperature range from –55 to 125°C. Supplied in tape-and-reel format, the MNR18 resistor array features a solderplated, convex electrode design which aids mounting alignment and preventing the formation of solder bridges during reflow.
Rohm
Tel: 01908 282666
www.rohm.co.uk

2.4GHz spread-spectrum radio transceiver

AeroComm has released its line of LX 2.4GHz frequency-hopping spread-spectrum (FHSS) transceivers, available in Europe from Low Power Radio Solutions. Unlike radios designed from chip sets, LX transceivers are agency-approved, ready-to-use modules designed for integration into larger volume OEM products. There are also RF development tools and support. Manufacturers can choose short-range, low power consumption versions for battery-powered or piconet applications, and higher power radios coupled with repeaters for miles of range. All LX transceivers have identical dimensions, connectors and software requirements, and so modules are interchangeable for changing design needs. The modules support RF data rates up to 244kbit/s. The range's power output starts at 3mW for local uses (within 15m), and reaches 150mW for kilometres of range in outdoor applications or for large industrial facilities. For longer distances, or when obstacles block the communication path, a repeater can be employed to extend range. All transceivers are available with integral strip dipole antennas for applications not permitting external antennas. Or, radios with antenna connectors are available for use with a variety of agency external antennas.
Low Power Radio Solutions
Tel: 01993 709418
www.lprs.co.uk

MSOP-packaged DSL driver

The LT1969 is a customer premises equipment line driver for ADSL/VDSL/xDSL applications. It consists of a dual, high output power (±300mA), low distortion (THD =–72dBc at 1MHz) high-speed (gain bandwidth product=700MHz) op-amp that features adjustable supply current and two-bit digital power control. Packaged in a low profile (1mm thick) thermally enhanced MSOP 10-pin package, the LT1969 occupies only 15mm^2 of board area. The LT1969's adjustable supply current allows a designer to trade off power consumption versus output power and distortion for optimum DSL line driver performance, said the supplier. The 2-bit digital programmability allows the LT 1969 to be programmed for up to four driver conditions. A wide output swing, 14.3V with +6V supplies into a 25Ω load, allows the device to operate on low voltage supplies, either ±5V(10V) or ±6V(12V).
Linear Technology
Tel: 01276 677676
www.linear-tech.com

Dual-mode RF chip set

Zarlink Semiconductor (formerly Mitel Semiconductor) has a new RF chip set for cellular hand sets operating in dual-mode TDMA/AMPS networks that are installed primarily in North America. The MGCMO2 and MGCTO4 devices have a complete intermediate frequency receiver, baseband interface and transmitter in a two-chip solution. The MGCMO2 is an IF receiver and baseband interface chip. The device integrates Zarlink's existing MGCRO1 IF receiver and MGCMO1 baseband interface chips into a single 49-pin 7 by 7mm ball-grid array (BGA) package. The MGCTO4 transmit circuit provides the transmit function in dual-band, dual-mode TDMA/AMPS and CDMA/AMPS mobile telephones. The chip is in a 5by 5mm micro lead frame (MLF) package. Total chip set area is 75mm^2 of board space. The chips are now sampling. The chip set is priced at about $5 in high volumes. To support customer evaluation and ease of design, Zarlink offers an evaluation board featuring both devices, plus a reference design.
Zarlink Semiconductor
Tel: 01793 518128
www.zarlink.com

Snap-in Al capacitors

BCcomponents has added to its family of snap-in aluminium electrolytic capacitors in the shape of the 197 PGP-SI, a general-purpose power capacitor targeting consumer applications such as audio-visual equipment, domestic appliances and PCs. The capacitance range is 56 to 1800μF, and its voltage range is 160 to 450V, depending on case size. The category temperature range is –40 to +85°C and the product's load life and useful life at 85°C is 2000 hours, while its useful life at 40°C is 25 000 hours.
BCcomponents
Tel: 0031 40259 0724
www.bccomponents

Please quote *Electronics World* when seeking further information

Integrated colour sensors

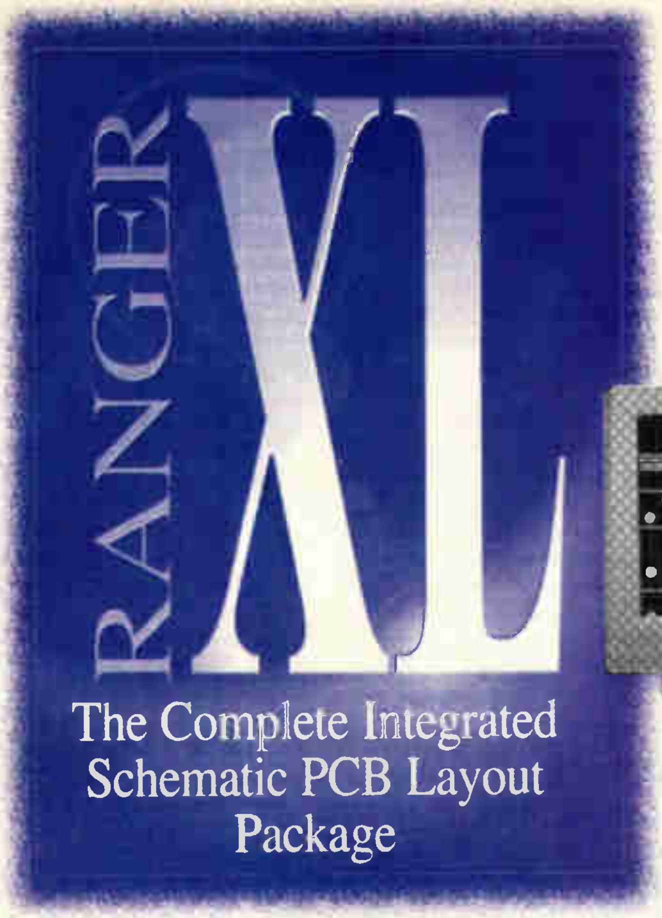
From Pacer are the new range of integrated colour sensors from Texas Advanced Optoelectronic Solutions (TAOS). Designated the TSL X257 series, the new devices consist of three individual optoelectronic sensors that provide on-board conditioning plus colour filters. Each of the three new colour sensors is designed to detect one of three primary colours: red, blue or green. The TSLR257 detects red light; the T5LB257 blue light and the T5LG257 detects green light. All three TAOS colour sensors are built on the TAOS light-to-voltage converter platform with a colour filter deposited on the detector chip. Colour identification applications for the sensors include CRT-screen test and set up, colour tone scanning applications on printed materials, paints and cosmetics, process control, medical diagnostics such as body fluid analysis as well as dental, fabric and fashion applications. Colour filtering applications include fluorescence and mark detection, optical band pass filters as well as medical diagnostic applications. The devices are mounted in side looking plastic packages. Future devices will include linear array colour detectors and single packaged devices with three primary colour detection plus reference photodiode.

Pacer
Tel: 0118 984 5280
www.pacer.co.uk

DC-to-DC power modules

Lambda has unveiled its range of PG-10 DC-to-DC surface-mounted power modules. Using synchronous rectifier circuit technology, the PG-10 achieves 88 per cent efficiency on the 5V output model. Measuring 28.0 by 8.7 by 37.7mm, the module is aimed at next generation telecom infrastructure applications and similar high-speed digital systems. The PG-10 offers a choice of output voltages selectable from a range of 1.2V to 5V with power output ratings from 4.2W to 10W. The DC-to-DC converter supports parallel operation and features output alarm signal and on/off control. By cutting down waste heat at source the PG-10 only requires convection cooling, eliminating the need for a heat sink. The power module has full overcurrent and overvoltage protection and complies with safety standards including UL1950 and CSA950. The device is designed to operate over the temperature range of –40°C to 85°C.

Lambda
Tel: 01271 856600
www.lambda-gb.com



Too good for words

The New Ranger XL Series

Ranger 2 for Windows	£60
NEW Ranger 2XL	£500
NEW Ranger XL from	£950
FREE Website Download Demo	

SEETRAX CAE

Advanced Systems & Technology for PCB Manufacturers

Old Buriton Lime Works, Buriton, Petersfield, Hants. UK GU31 5SJ
Tel: (44) 01730 260062 Fax: (44) 01730 267273

CIRCLE NO.121 ON REPLY CARD

Features

- 10Hz - 2.5GHz frequency
- 3 input ranges
- 8 digit LCD display
- Auto power off
- Period measurement
- Data hold and relative
- Memory, min/max/average
- 4 gate times per range
- Optional rf antenna available

2.5GHz frequency counter for £99 inc VAT and delivery

Vann Draper Electronics Ltd

The test and measurement specialists

www.vanndraper.co.uk

Equipment from Grundig, Digimess, Kenwood, Hameg, Tektronix, Hitachi, Fluke, Avo and more

Vann Draper is offering the FC2500 2.5GHz frequency counter to readers of *Electronics World* at a special discount. The FC2500 normally sells at an already low price of £116.33 but is available to readers for only £99 fully inclusive of VAT and delivery.

An optional telescopic antenna (AT-20) for rf measurement is available for just £6.95 fully inclusive.

The FC2500 is supplied complete with operating instructions and a 12 month guarantee.

Date sheets for all products are published on our web site at www.vanndraper.co.uk

To order your counter simply post the coupon to:

Vann Draper Electronics Ltd, Stenson House, Stenson, Derby DE73 1HL
Or Tel: 01283 704706 Fax: 01283 704707 Email: sales@vanndraper.co.uk

Key Specifications

Frequency range	: 10Hz - 2.5GHz
Display	: 8 digit 0.5" liquid crystal display
Measurements	: Frequency, period, data hold, rel, memory, min/max/ave
Gate times	: 4 gate times per range
Sensitivity	: 76MHz - 2.5GHz <50m>
Frequency accy	: +/- 4PPM + 1d
Power requirements	: 4 x 1.5V AA batteries (not supplied), or 9V 300mA adapter
Size and weight	: 173 x 80 x 35mm, 340g inc. battery

Use this coupon for your order

Please supply me:

............FC2500 freq counter(s) at £99.00 inc VAT and del

............AT-20 antenna(s) at £6.95 inc VAT and del

Name.......................................

Address.......................................

....

....

....

Tel No.......................................

Total £.......................................

Cheques payable to Vann Draper Electronics Ltd or debit my Visa, Mastercard or Switch card:

Card type.......................................

Card No.......................................

Expiry date.......................Switch Iss No.......................

Signature.......................................

Overseas readers can still obtain this discount but carriage charges vary according to country. Please telephone or fax

CIRCLE NO.122 ON REPLY CARD

Please quote *Electronics World* when seeking further information

Spectrum analyser gets remote control

IFR Systems' 2399 portable spectrum analyser is now available with remote control and diagnostics capability. Introduced in January of this year, the analyser is used in a wide range of applications including mobile communication service workshops, base station installation, repair and maintenance plus broadcast TV and education. Remote monitoring is made possible with Easy Span, a software program developed by IFR. Test and field engineers using the 2399 can easily access instruments located anywhere in the world via a direct connection or through a dial-up modem using RS-232. This capability means the 2399 can be used by anyone needing remote operation and data collection to perform remote diagnostics. Using RS-232 as the communications medium simplifies the operation and is less expensive than using the GPIB protocol and PCMCIA cards. The 2399 covers a frequency range of 9kHz to 2.9GHz. New features include semi-automated measurement capabilities, a fast processor, large memory capacity and TFT LCD display with a 640 by 480 pixel active display.

IFR Systems
Tel: 01438 772087
www.ifrsys.com

Small surface mount crystals

Advanced Crystal Technology has further reduced the size of its surface-mount crystals with the ACT200. Measuring 8.0 by 3.8 by 2.5mm, the 32.768kHz ACT200 is compatible with existing PCBs, yet occupies 50 per cent less volume. Suitable for many personal, portable domestic and mobile applications, the ACT200 also requires very low drive level at 1μW maximum. Frequency tolerance to ±5ppm, combined with low frequency temperature coefficient at –0.034ppm/°C, create a stable reference throughout the industrial temperature range –40°C to +85°C. By retaining the footprint of previous generation 32.768kHz watch crystals, the ACT200 is drop in compatible with existing designs, while the reduced dimensions allow designers to save weight and space. The ACT200 is suitable for automatic placement from tape and reel. It is able to withstand peak soldering temperature up to 260°C, and therefore compatible with the majority of reflow profiles. ■

ACT
Tel: 0118 979 1238
www.advancecrystaltechnology.com

Quad-output dc-to-dc converters

Power-One announces its new IMX35 Series of quad-output DC-to-DC converters. The IMX35 is ideal for use in stationary or mobile applications, including use in the areas of telecom, datacom, transportation, and industrial automation. The design is based upon a flyback converter topology, using all surface-mount components and planar magnetics.

There are six IMX35 quad-output models available. Models with four separate, electrically-isolated outputs of (5V @ 1.35A ea.), (12V @ 0.65A ea.), or (15V @ 0.55A ea.), have input voltage ranges of 9-36V DC. Models with an 18-75V DC input range are available with outputs of (5V @ 1.4A ea.), (12V @ 0.7A ea.), or (15V @ 0.6A ea.). All outputs can be parallel and series connected providing substantial flexibility, giving output variants from 5 up to 60V DC. Other input ranges as well as double and triple output voltages are also available.

Other IMX35 features include industry-standard pin out, fixed-frequency operation, input voltage enable/shutdown, overvoltage and short circuit protection, adjustable output voltages (80-105% of nominal), and thermal protection. IMX35's are available in either an open-frame 2.87in x 1.88in x 0.35in (72.8mm x 47.8mm x 8.9mm) package or in a rugged full-case version with 3.00in x 2.50in x 0.41in (76.2mm x 63.5mm x 10.5mm) dimensions.

The IMX35 also contains input and output filtering to provide immunity to EMC as well as exceptionally low ripple and noise. The IMX35 with an input voltage range of 18-75V DC is priced at $91.00 in quantities of 100. IMX35 design complies with international safety standards of IEC/EN 60950, UL 60950, and CAN/CSA C22.2 No. 950-95.

Power One
Tel: 01425 474 752
www.power-one.com

Single-ended MOSFET Class-A amplifier

Shown here is a single-ended MOSFET design with clean class-A sound. As an experimental prototype, the circuit was only designed to provide about 3W of output power, but it can be scaled up to any reasonable output power, the main practical limitation being the heat dissipation.

Unlike the more usual three-stage designs, this amplifier only uses two stages. P-channel MOSFETs Q_1-Q_2 form a differential amplifier that provides fast, symmetrical drive to the output MOSFET via current mirror, Q_3-Q_4.

Transistors Q_1 and Q_2 were selected from a batch of about 20 devices for similar gate threshold voltages. The yield is usually at least two pairs having less than 5% difference.

This differential amplifier is operated at a relatively high tail current, around 30mA, for good linearity and speed. Transistors Q_6 and Q_8 form a constant-current generator setting the drain current of the output MOSFET, Q_5, to about an amp.

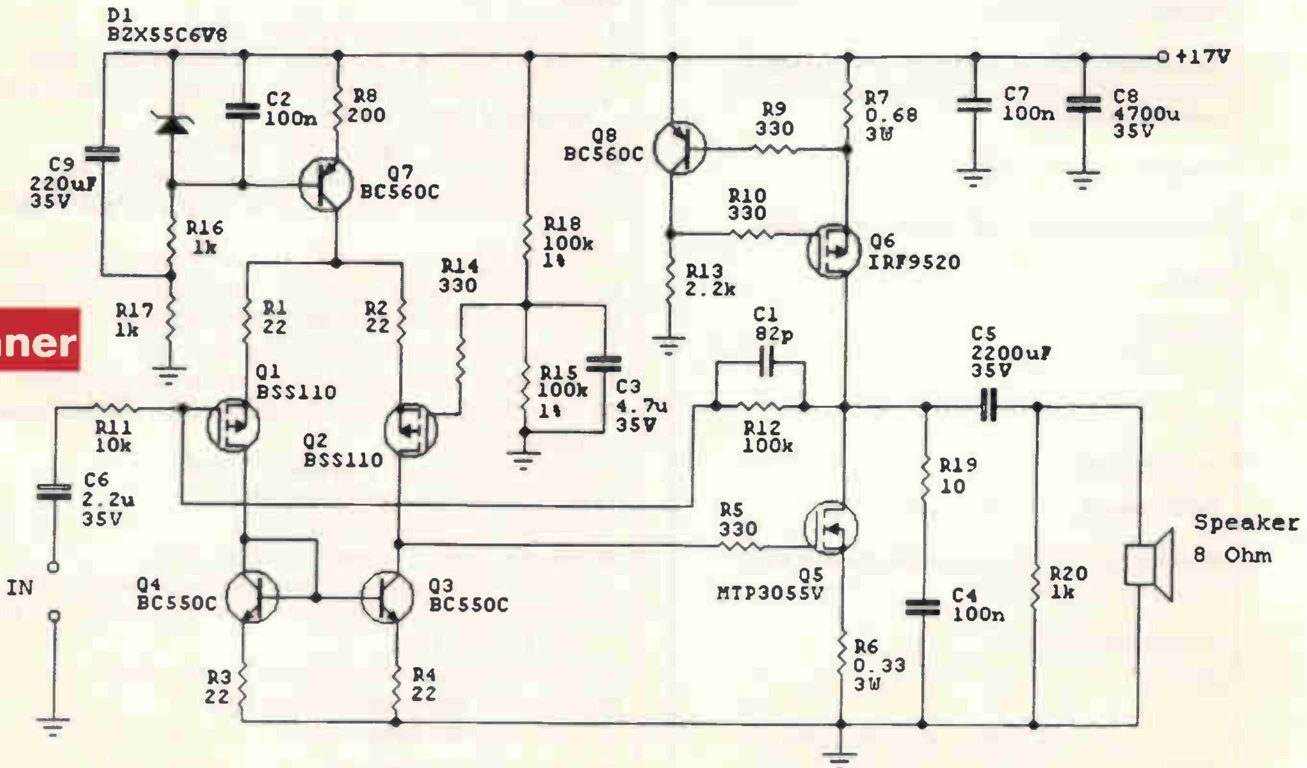
Note that the less usual shunt feedback topology is used. In this way, the problems associated with the limited CMRR due to the difference in the characteristics of Q_1 and Q_2 can be completely eliminated. As a result, distortion is greatly reduced.

One major benefit of having only two stages is that the amplifier is extremely stable. The square-wave response looks virtually identical when the load is changed from 8Ω resistive to 1F capacitive loading. There is no sign of ringing or other instability.

As a result of using the shunt-feedback topology, the amplifier inverts. This, if necessary, can be compensated for by driving it from an inverting pre-amplifier.

Laszlo Gaspar
Biggleswade
Bedfordshire

£100 winner

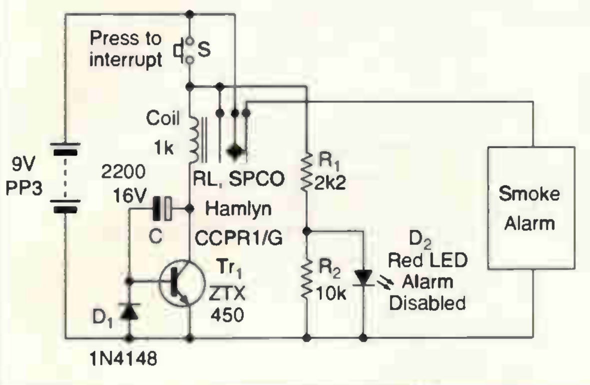


Class-A power amplifier has only two stages. Output power is 3W, but there's no reason why you can't scale up the design.

Smoke alarm interrupter

Using just eight components, this simple circuit could save lives. Batteries are frequently removed from smoke alarms in kitchens to stop alarms caused by cooking fumes. However, the absence of an alarm can have tragic consequences in the event of a genuine emergency.*

The circuit supplies power to the alarm via the normally closed contacts of relay *RL*. Pressing the alarm interrupt push button switch *S* applies 9V to the relay coil, the other end of which is held initially near 0V by the integrator Tr_1 and *C*.



This timer disables a smoke alarm for a short period after the button is pressed to prevent the annoyance of false triggering.

With the relay energised, its contacts change over, disconnecting the smoke alarm and latching the relay after *S* is released. The 'Alarm Disabled' warning LED lights and the voltage across the relay coil decreases as *C* charges.

After approximately eight minutes – a pause generally long enough for the fumes to disperse – the relay drops out. Most smoke alarms will then beep to indicate the application of power.

After the relay has dropped out, *C* discharges via *RL*, R_1, D_1 and D_2. When the LED extinguishes, discharge continues via R_2. Note that the interrupt period is a function of four parameters: battery voltage, the value of *C*, the relay drop-out voltage and the gain of Tr_1. Consequently, the quoted eight minutes is a nominal figure.

The circuit consumes power only during the interrupt period; the average current is less than 9mA.

Keith Cummins
Chale Green
Isle of Wight
F63

*If you modify a smoke alarm, or use it in a manner other than that prescribed by its maker, you may void your fire insurance and also any maker guarantees and approvals associated with with the alarm. But I agree with Keith that adding this circuit is a lot more sensible than removing the battery! Ed

One-chip scope calibrator

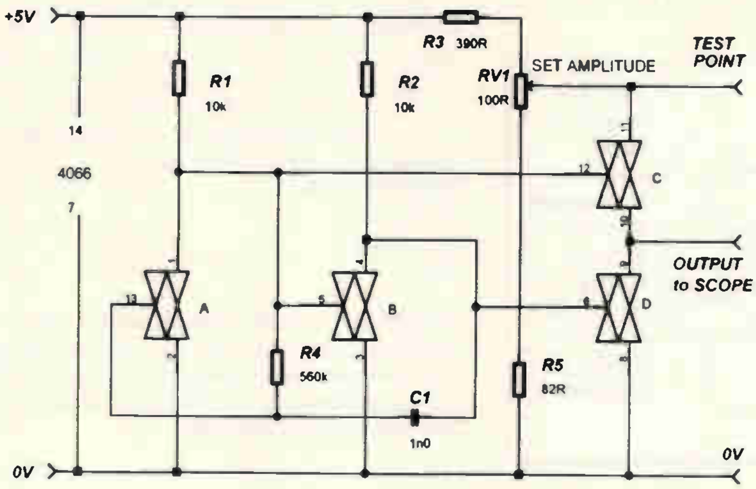
This simple circuit uses a single 4066 CMOS quad switch to generate a 1kHz square wave with precise amplitude. CMOS switches *A* and *B* form an astable multivibrator running at 1kHz and having complimentary outputs.

The outputs drive two switches, *C* and *D*, which are connected across a precise voltage set by RV_1. The square wave output is taken from the centre point between switches *C* and *D*.

The voltage at the 'test point' can be set, for example, to 1.00V using a conventional digital multimeter. Providing that the output load is greater than 100kΩ, – most 'scopes have an input resistance of 1MΩ – then the peak-to-peak amplitude will be within 0.5% of the test point value.

Other amplitudes could be obtained by changing the value of R_3 and R_5 or by replacing R_5 with a switched potential divider or precision multi-turn potentiometer.

Simple oscilloscope calibrator using a single 4066 CMOS quad switch to generate a 1kHz square wave with precise amplitude.



John Lawrence.
Prestatyn
Denbighshire
F64

Voltage-to-frequency converter with polarity indicator

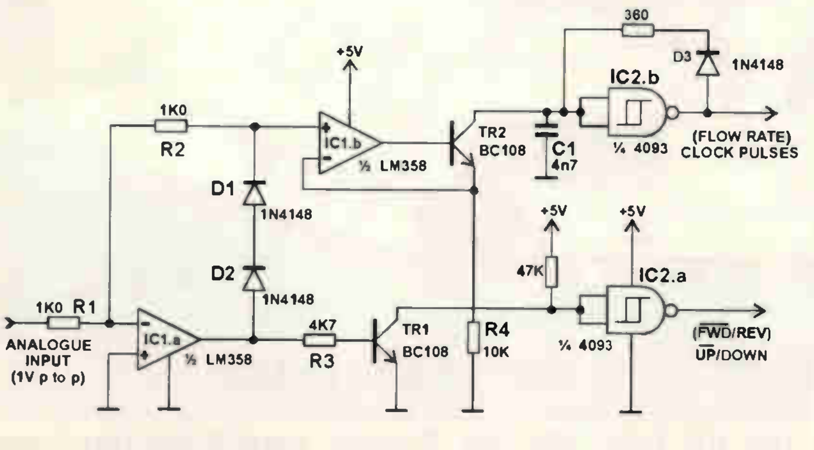
While developing a piece of test equipment for medical ultrasound systems, the need arose for a voltage-to-frequency converter with rather unusual features.

The circuit had to provide output pulses with a frequency zero hertz for zero input, and a logic-level output to indicate the polarity of the input signal. This was required to control the count rate and direction of an eight-bit, up/down counter. Other possible uses may be associated with stepper motor control, for example.

The solution is shown in the accompanying circuit, which requires a supply current of little more than 1mA. It produces a peak output pulse frequency approaching 20kHz for an input range of ±0.5V. The pulse duration is approximately 2μs, determined by the recharge time of C_1. Using a rail-to-rail op-amp as IC_1 and standard CMOS for IC_2 allows single supply operation over a wide supply-voltage range.

Diodes D_1, D_2 and IC_{1a} form a conventional full-wave rectifier stage, with IC_{1b} acting as a high impedance buffer.

Voltage-to-frequency converter with voltage polarity indicator.



Incorporating the extra diode, D_2, requires the output of IC_{1a} to exceed 1V whenever the input signal goes negative. This condition turns Tr_1 on, producing a logic '1' at the output of IC_{2a}, indicating a 'reverse' count.

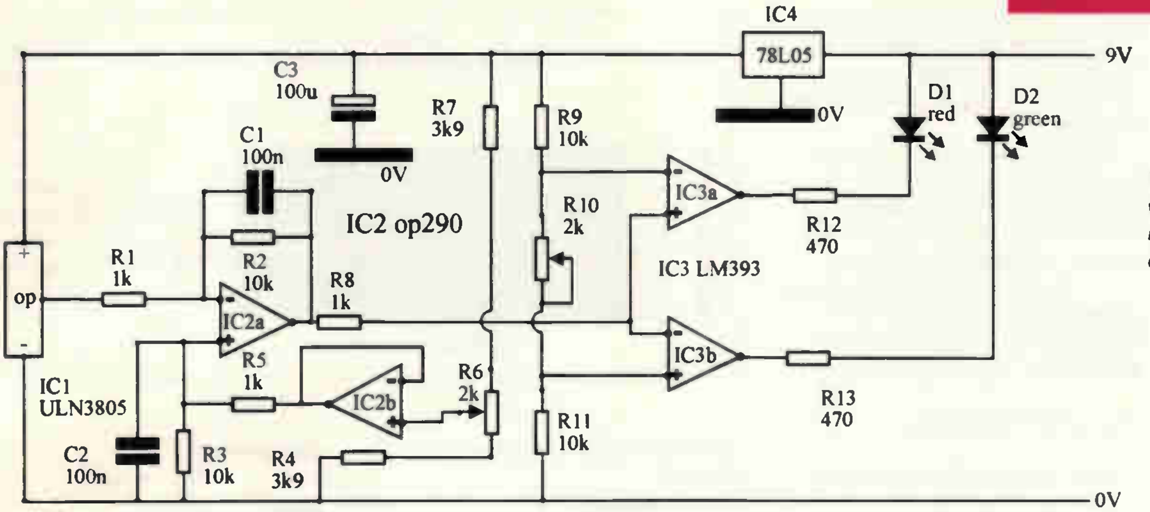
Together, IC_{1b} and Tr_2 form a current source, governed by the potential difference across R_4 – a full-wave rectified version of the analogue input. That current discharges C_1, until it reaches the lower input threshold of IC_{2b} (Schmitt), at which point it is recharged by the high level, which is also the output pulse. As this is so much less than the discharge time the pulse frequency is effectively governed by the modulus of the analogue input signal.

Frequency linearity is better than 95% over an input range from ±2mV to ±500mV, and there is very little distortion in the rectified signal for sine waves up to 100Hz. Obviously the circuit could be adapted for greater input signal bandwidth, and output pulse frequency by substituting faster devices.

Improved linearity could be achieved by reducing the recharge time – replacing IC_{2b} with a high output-current comparator would achieve this. Deriving the comparator threshold levels from a band-gap voltage reference would improve overall stability.

G C Aucott
Leicester
F62

£50 winner



Test a solenoid valve's electrical integrity without disconnecting it.

Magnet sniffer – solenoid valve tester

Solenoid valves are common components in process plant, controlling flows of air, water, hydraulic oil or other fluid media. Generally, they give little trouble. But when they appear to have failed, is it due to an electrical, mechanical or control failure?

Electrical testing is normally the first step in fault diagnosis and this often entails disconnection of the solenoid coil. This is costly and time consuming, often only for the coil to be reconnected again when the fault is confirmed as a mechanical failure. The following test device was designed to avoid this.

The suspect coil or other electromechanical device is approached with the test probe. If the coil is correctly energised, one of the two LEDs will light, depending on the magnetic polarity.

In the case of an AC energised coil both LEDs will light. With familiarity, residual magnetism will be recognised and ignored.

Sensor IC_1 is a linear hall-effect device chosen for low cost and small size. A small piece of ferrite rod is glued on to its operating face. This projects through the case to act as a search probe and should be covered with a heat-shrink sleeve and cap.

Op-amp IC_{2a} is a differential amplifier with a roll off at 160Hz to eliminate any HF interference that may be present. Resistor R_6 and its buffer IC_{2b} are used to null any offset from the Hall-effect sensor. This is generally set to give a no signal output from IC_{2a} of 2.50V.

Op-amp IC_3 forms a comparator, positive signals lighting LED_1 and negative signals lighting LED_2. Resistor R_{10} is a sensitivity control giving symmetrical adjustment of the set point around the 'no field' level from the preceding stage.

Both variable resistors may be presets if desired, depending on your application. No hysteresis was applied around the comparators, giving a dimming effect on weak or diminishing signals.

This is a useful, reliable test instrument with a multitude of uses to ease fault finding on process plant.

Nigel K Goodman *Eng. Tech.*
AMIIE(elec.)
St Leonard's on Sea
East Sussex
F69

Triple capacitive voltage inverter with MAX871

This design idea is based on a customer request for a cheap and not very accurate negative voltage supply of about –2V to –15V with a low output current <5mA. Input voltage is 5V. This application might be used for negative op-amp supply.

Figure 1 shows the typical operation circuit with the flying capacitor C_1 and C_2. Output voltage on pin 1 is $-V_{IN}$. Four additional capacitors C_3 to C_6 and four additional diodes D_1 to D_4 triple the negative output voltage at the OUT pin from $-V_{IN}$ to $-3V_{IN}$. C_5 and C_6 decrease the voltage with every step by $-V_{IN}$.

Without any diode voltage drop C_3

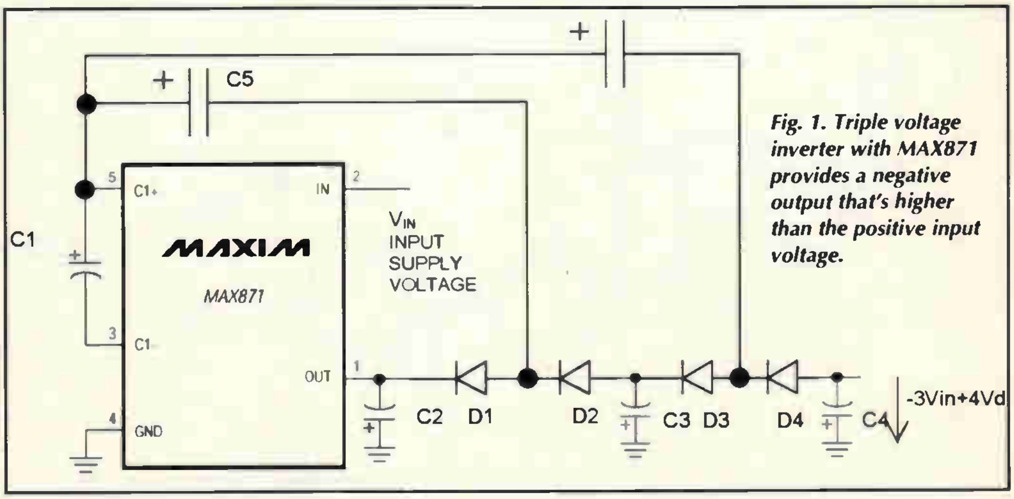


Fig. 1. Triple voltage inverter with MAX871 provides a negative output that's higher than the positive input voltage.

got $-2V_{IN}$ and C_4 charges ideally to $-3V_{IN}$. It is possible to add more of these cascades but with every step the voltage drop of the diodes will reduce the effort.

The schematic of the design idea has been tested with 4.5V and 5V input voltage. **Figure 2** shows load current versus output voltage. The general voltage drop on V_{OUT} is caused by the forward voltage of the external diodes of typically 0.3V to 0.4V per diode, depending on the load current. Output voltage V_{OUT} is,

$$V_{OUT}=-3\times V_{IN}+4\times V_D$$

Voltage V_D is the forward voltage drop of diode D_1 to D_4, while V_{IN} is the input voltage on pin 2. If Schottky diodes are used V_D is typically 0.3V to 0.4V.

Martin Baumbach
Maxim GmbH

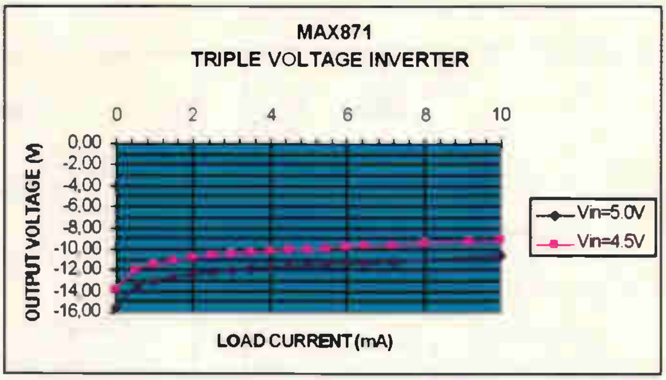


Fig. 2. Load current versus output voltage for the step-up voltage inverter.

Components	
$C_{1\text{-}6}$	470nF ceramic
C_{input}	10µF
$D_{1\text{-}4}$	BAT41

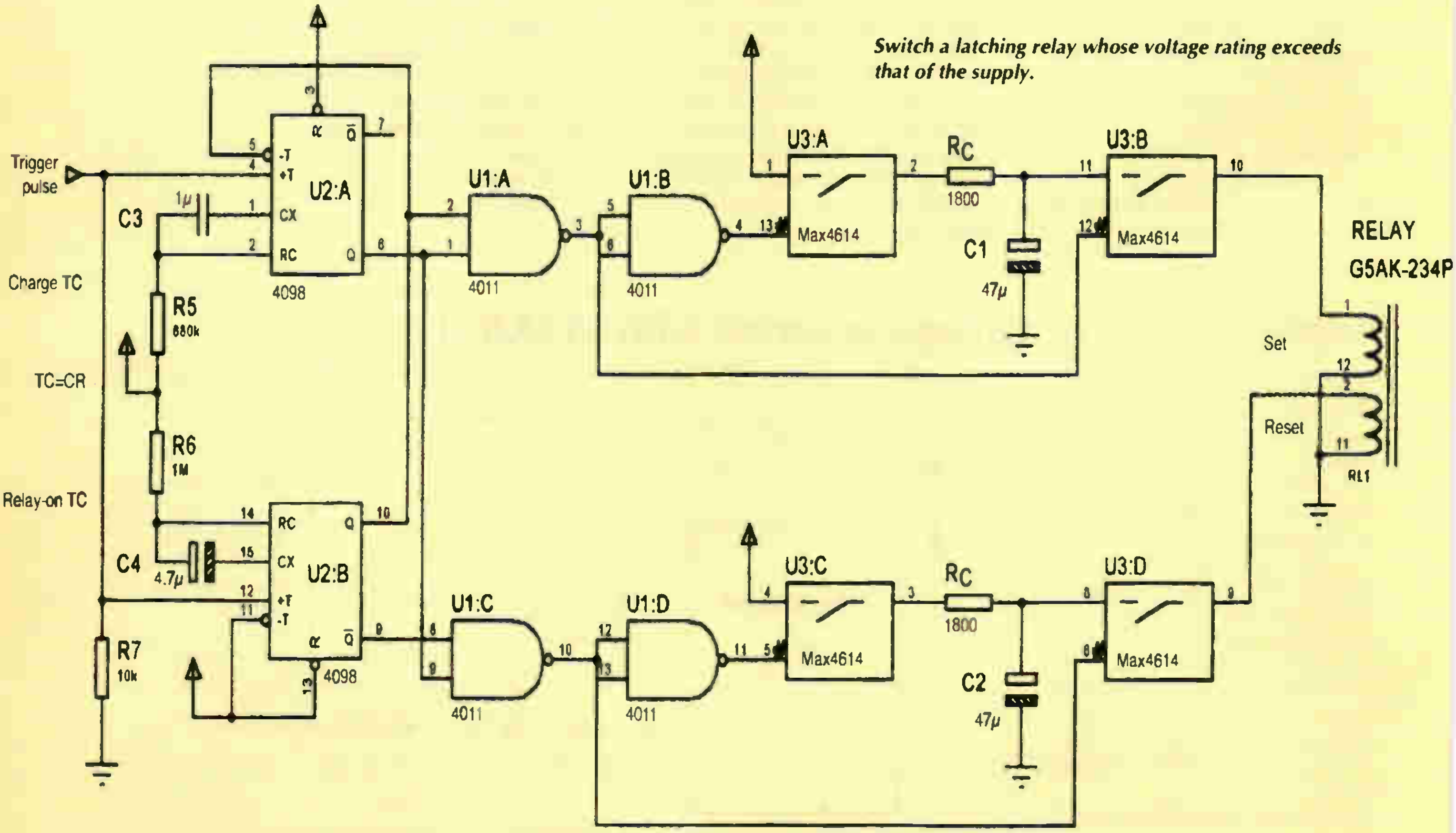
Operate latching relay from any voltage

The circuit allows a relay to be operated from a regulated supply without exceeding its ratings. It does this by using two charge transfer switches to operate the latching relay.

Charge rate – and hence maximum current – is set by the two resistors marked R_C. The subsequent time needed to build up enough charge to operate the relay is set by one section of a dual monostable. The second monostable determines the relay on time and retriggers the first monostable to charge and operate the relay reset coil.

It is possible to modify the circuit by connecting the trigger pulse to the negative trigger ($-T$) of the second monostable, letting the trigger pulse length largely determine the relay on time.

David Flatt
Birkenhead
Merseyside



Switch a latching relay whose voltage rating exceeds that of the supply.

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

CIRCLE NO.123 ON REPLY CARD

The Balance Box

Microphone or line level amplifier for balanced or unbalanced signal lines

Professional portable units operating from an internal PP3 battery or external mains adaptor

★ Precision true floating transformerless balanced input and output at microphone or line level ★ Simple interfacing and conversion between balanced and unbalanced signal lines ★ Low noise and distortion ★ High common mode rejection ★ Switchable gain selection ★ Extensive RFI protection

The Phantom Power Box – The Headphone Amplifier Box - The *OneStop* DIN rail mounting radio frequency interference filter and voltage transient protector for voltage and current loop process signal lines

Conford Electronics **Conford Liphook Hants GU30 7QW**
Information line 01428 751469 Fax 751223
E-mail contact@confordelec.co.uk
Web: www.confordelec.co.uk/

CIRCLE NO.124 ON REPLY CARD

Mail Order Suppliers Of ELECTRONIC COMPONENTS & SURPLUS STOCK

GREENWELD

We stock thousands of products. Low cost electronic components, bargains and great value surplus stock!

- Electronic Components
- Connectors
- Burglar Alarm Systems
- DC & AC Motors
- Video Senders
- Aerial Amplifiers
- Cable
- Tools
- Meters
- Batteries
- Surplus Stock
- & Much, Much More

Send now for our FREE catalogue!

Visit our website: www.greenweld.co.uk

GREENWELD
Greenweld Limited
Unit 24 Horndon Business Park · West Horndon
Brentwood · Essex · CM13 3XD
Tel: 01277 811042 · Fax: 01277 812419
Email: service@greenweld.co.uk
Office Hours: Mon - Fri 08.00 to 17.00 & Sat 08.00 to 12.00

CIRCLE NO.125 ON REPLY CARD

Armscroft Communications
Where the customer really matters!

Visit us on the web at http://www.armscroft.com
Phone: 01452 531648 (after 3.15pm weekdays please); or mobile: 0796 744 1113
Fax: 0870 056 1421 or E-mail: sales@armscroft.demon.co.uk

Wanted! Collins, Drake, Eddystone, Hallicrafters, Hammarlund, National, Racal, Skanti receivers, transmitters and optional extras. WHY? Must be in good condition both electrically and physically. Worldwide customers waiting to buy. Also wanted; broken, damaged, not working examples of Icom, Kenwood, Yaesu etc. Ring us today!

HF RECEIVERS WANTED!!

Rhode & Schwarz	EK07	£850	The best valve receiver ever made!
Rhode & Schwarz	EK047	£1200	Excellent condition
Rhode & Schwarz	ESH2	£4500	(Includes spectrum display unit.)
Rhode & Schwarz	?	£250	FSK/RTTY demodulator. RARE!
Telefunken	E639AW/2	£650	With panadaptor. Very good condition.
Telefunken	E863	£650	Very good condition.
National	HRO-MX	£200	7-coil packs. Excellent.
RCA	AR-88D	£160	Almost mint condition.
Collins	51S-1	£750	Very nice. Ser No. 12***
Collins	51J-2	£450	Nice.
Collins	51J-4	£650	(Includes cabinet.) Nice.
Murphy	B40	£125	Excellent.
Murphy	B41	£150	Like new.
Rees Mace	CAT	£125	Very good condition.
Hammarlund	BC794-B	£300	Mil. version of SP-210X. Nice.
Marconi	CR100	£125	Restored. Call for information.
Marconi	CR150	£175	Vey good condition.
Watkins Johnson	HF1000	£1500	Mint.
Racal	RA1772	£325	Very good condition.
Racal	RA1792	£475	Very nice.
Racal	RA17L	£275	Very nice condition.

More of the same always wanted! Good prices paid for the right equipment which MUST be in good electrical and cosmetic condition.

AMATEUR EQUIPMENT

Yaesu	FT290RII	£250	Mint!
Yaesu	FT101ZD	£225	Very good condition.
Kenwood	TS830S	£300	Good condition.
KW	2000E	£250	Very good condition.!
Dentron	MLA2500	£450	Good condition.
Icom	PS85	£150	Mint..

PLEASE MENTION ELECTRONICS WORLD WHEN RESPONDING TO THIS ADVERT! THANKS

Our stock is always changing and the above listing is correct at the time of writing. Due to the delay between this advert being written and it being published it is likely that our listing will be out of date. Please phone us for our latest stock.

GOOD PRICES PAID FOR THE RIGHT EQUIPMENT. WHY??

Armscroft Communications, 44 Armscroft Road, Barnwood, Gloucester GL2 0SJ

CIRCLE NO.126 ON REPLY CARD

Fully-automatic NiCd charger

The circuit is based on a digital timer controlling a constant-current sink and, being so simple, can easily be modified to charge at different currents and for different periods. It is also small enough to be retro-fitted into cordless drill charger units.

A 4060 forms an oscillator/counter running at 0.16Hz, the frequency being set by R_1, C_1 and VR_1. When the timer has counted 8192 clock cycles (14 hours) Q_{14} goes high shutting down the oscillator and constant current circuit.

An LM358 and transistor provide a good constant current sink – the 358 being chosen because of its ability to work near ground potential. The second half of the 358 is a simple Schmitt oscillator to flash a LED while the battery is charging and, when the battery is charged, to glow constantly.

Because the charger uses a true constant-current circuit, you can charge one or more cells in series, provided that the supply is sufficient and the transistor's dissipation is considered.

Potentiometer VR_2 allows charge current adjustment. This is 150mA for a sub-C/RR cell, such as used in many cordless drills. The regulated 5V supply ensures oscillator stability and provides a voltage reference for the constant current circuit.

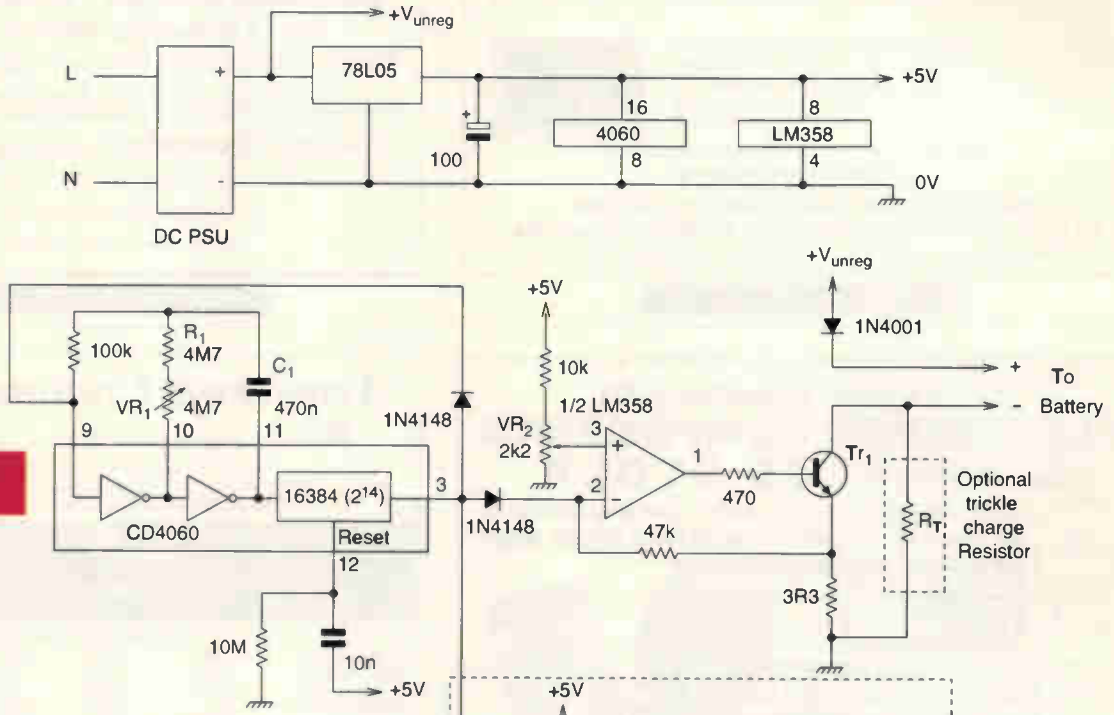
An optional trickle current can be provided by a simple resistor – shown as R_T in the diagram. Note that adding this resistor affects the quality of the constant current circuit.

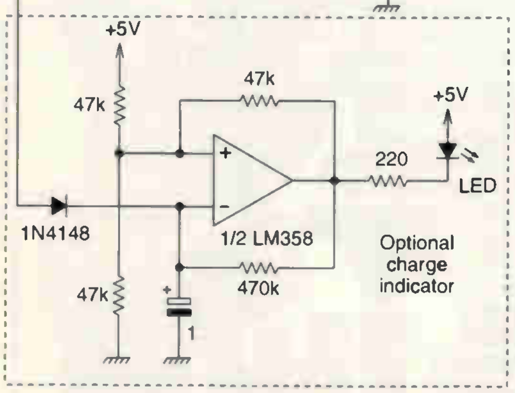
When first testing the circuit, use a 220pF capacitor for C_1. This will result in a full count cycle of about 20s rather than 14 hours. When you are happy that the circuit works replace C_1 with the correct value and calibrate the oscillator by adjusting VR_1 until 6 full clock cycles at pin 9 of the 4060 takes 37s.

The values shown will charge RR (sub-C) cells for 14 hours at 150mA.

Mike Arnold
Sale
Cheshire
F65

This fully automatic NiCd cell charger uses a true constant-current source so you can charge cells in series.





£50 winner

Fan speed reducer

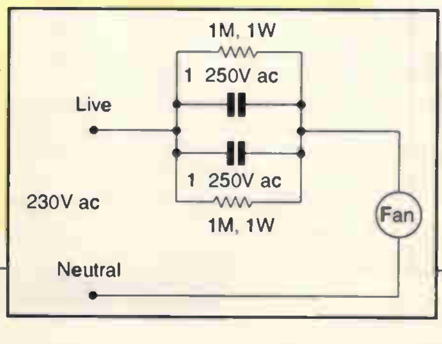
I devised this circuit to run a domestic fan at low speed, for long periods. The capacitor network was placed in series with the motor, to reduce its speed.

The capacitor value required for the desired speed is selected on test, the minimum value required being just enough to start the motor. Resistors are included to discharge the capacitors, in the event that they be left charged up at the instant the on/off switch opens.

Warning: all parts of the circuit are live – and hence potentially lethal – as soon as mains is applied.

Gregory Freeman
Mt Barker
South Australia.
F66

Use capacitors rated for mains use. Ed.



This circuit slows down an extractor fan, making it quieter and reducing its power consumption in return for lower air flow.

Designing radio receivers IV

In the days of valve radio, it sufficed to evaluate a receiver in terms of its static performance. But with today's solid-state electronics and band crowding, it is essential to consider a receiver's dynamic performance. In this fourth and final article on receiver design, Joe Carr explains how it's done.

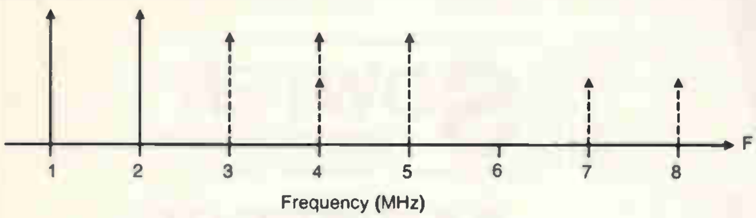


Fig. 1. In a radio receiver, intermodulation products occur when two signals are mixed together – but there are also other sources.

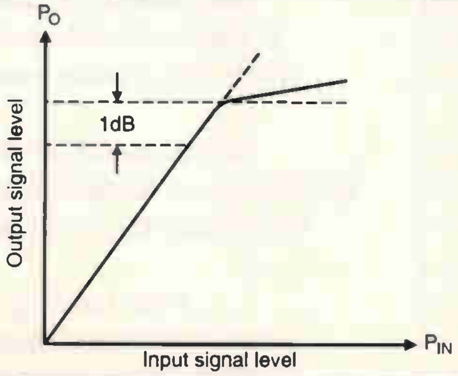


Fig. 2. Any real amplifier saturates given a strong-enough signal. The line's slope represents gain, which is here seen to fall off as the amplifier saturates.

The dynamic performance specifications of a radio receiver are those that deal with how the receiver performs in the presence of very strong signals, either co-channel or adjacent channel.

Until about the 1960s, dynamic performance was somewhat less important than static performance for most users. Today though, the role of dynamic performance is probably more critical than static performance because of crowded band conditions.

There are at least two reasons for this change in outlook. First, in the 1960s receiver designs evolved from tubes to solid-state. The new solid-state amplifiers were somewhat easier to drive into non-linearity than tube designs.

Second, there has been a tremendous increase in radio frequency signals on the air. There are far more transmitting stations than ever before, and there are far more sources of electromagnetic interference – or EMI – than in prior decades.

With the advent of new and expanded wireless services available to an ever widening market, the situation can only worsen. For this reason, it is now necessary to pay more attention to the dynamic performance of receivers than in the past.

Intermodulation products

Understanding the dynamic performance of the receiver requires knowledge of intermodulation products (IP) and how they affect receiver operation. Whenever two signals are mixed together in a non-linear circuit, a number of products are created according to the $mF_1 \pm nF_2$ rule, where m and n are either integers or zero (0, 1, 2, 3, 4, 5...).

If an RF amplifier is overdriven by a strong signal, mixing can occur in either the mixer stage of a receiver front-end, or in the RF amplifier. It can also occur in any outboard preamplifiers used ahead of the receiver.

It is also theoretically possible for corrosion on antenna connections, or even rusted antenna screw terminals to create intermodulation products, or IPs, under certain circumstances. One even hears of alleged cases where a rusty downspout on a house rain gutter caused re-radiated mixed signals.

The spurious IP signals are shown graphically in Fig. 1. The order of the product is given by the sum $m+n$. Given input signal frequencies of F_1 and F_2, the main IPs are:

2nd order:	$F_1 \pm F_2$
	$2F_1$
	$2F_2$
3rd order:	$2F_1 \pm F_2$
	$2F_2 \pm F_1$
	$3F_1$
	$3F_2$
5th order:	$3F_1 \pm 2F_2$
	$3F_2 \pm 2F_1$
	$5F_1$
	$5F_2$

When an amplifier or receiver is overdriven, the second-order content of the output signal increases as the square of the input signal level, while the third-order responses increase as the cube of the input signal level.

Consider the case where two HF signals, F_1=10MHz and F_2=15MHz are mixed together. The second-order IPs are 5 and 25MHz; the 3rd-order IPs are 5, 20, 35 and 40MHz; and the 5th-order IPs are 0, 25, 60 and 65MHz. If any of these are inside the pass band of the receiver, then they can cause problems.

One such problem is the emergence of 'phantom' signals at the IP frequencies. This effect is seen often when two strong signals, F_1 and F_2 exist and can affect the front-end of the receiver, and one of the IPs falls close to a desired signal frequency, F_d. If the receiver were tuned to 5MHz, for example, a spurious signal would be found from the F_1–F_2 pair given above.

Another example is seen from strong in-band, adjacent-channel signals. Consider a case where the receiver is tuned to a station at 9610kHz, and there are also very strong signals at 9600kHz and 9605kHz. The near (in-band) IP products are:

3rd-order:	9595kHz (ΔF=15kHz)	
	9610kHz (ΔF=0kHz)	(On channel!)
5th-order:	9590kHz (ΔF=20kHz)	
	9615kHz (ΔF=5kHz)	

Note that one third-order product is on the same frequency as the desired signal. This product could easily cause interference if the amplitude is sufficiently high. Other third and fifth-order products may be within the range where interference could occur, especially on receivers with wide bandwidths.

Theoretically, the number of IP orders is infinite because there are no bounds on either *m* or *n*. However, in practical terms, because each successively higher order IP is reduced in amplitude compared with its next lower order mate, only the second, third-order and fifth-order products usually assume any importance. Indeed, only the third-order difference frequencies are normally used in receiver specifications sheets because they fall close to the RF signal.

There's a large number of IMD products from just two signals applied to a non-linear medium. But consider the fact that the two-tone case used for textbook discussions is rarely encountered in practice. A typical two-way radio installation is in a signal-rich environment, so when dozens of signals are present the number of possible combinations climbs to an unmanageable extent.

The –1dB compression point

An amplifier produces an output signal that has a higher amplitude than the input signal. The transfer function of the amplifier – indeed, any circuit with output and input – is the ratio of input to output.

For the power amplification of a receiver RF amplifier it is P_o/P_{in}, or, in terms of voltage, V_o/V_{in}. Any real amplifier will saturate given a strong enough input signal, Fig. 2. The dotted line represents the theoretical output level for all values of input signal. The slope of the line represents the gain of the amplifier.

As the amplifier saturates however, as represented by the solid line, the actual gain begins to depart from the theoretical at some level of input signal P_{in1}. The –1 dB compression point is that output level at which the actual gain departs from the theoretical gain by –1dB.

The –1dB compression point is important when considering either the RF amplifier ahead of the mixer – if said exists – or any outboard preamplifiers that are used. It is the point at which intermodulation products begin to

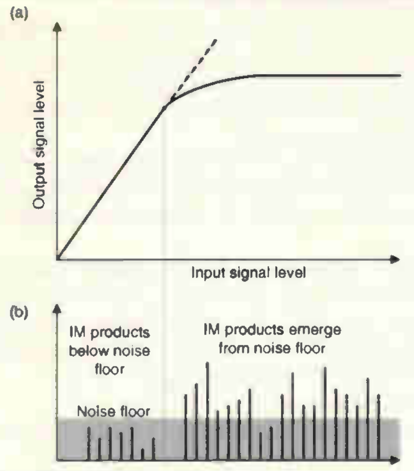


Fig. 3. Normally, intermodulation products that are third order and higher go unnoticed as they remain below the noise floor. The problems start as the receiver approaches saturation.

emerge as a serious problem.

Harmonics are also generated when an amplifier goes into compression. A sine wave is a 'pure' signal because it has no harmonics. All other waveshapes have a fundamental plus harmonic frequencies. When a sine wave is distorted, harmonics arise.

The effect of the compression phenomenon is to distort the signal by clipping the peaks. This raises the harmonics and intermodulation distortion products.

Third-order intercept point

It can be claimed that the third-order intercept point, or TOIP, is the single most important specification of a receiver's dynamic performance. This is because it predicts the performance as regards intermodulation, cross-modulation and blocking desensitisation.

Third-order – and higher – intermodulation products are normally very weak. They don't exceed the receiver noise floor when the receiver is operating in the linear region. But as input signal levels increase, forcing the front-end of the receiver toward the saturated non-linear region, the intermodulation products emerge from the noise, **Fig. 3**.

At this point, the IPs begin to cause problems. When this happens, new spurious signals appear on the band and self-generated interference begins to arise.

Figure 4 shows a plot of the output signal *versus* fundamental input signal. Note the output compression effect that was seen earlier in Fig. 1. The dotted gain line continuing above the saturation region shows the theoretical output that would be produced if the gain did not clip.

It is the nature of third-order products in the output signal to emerge from the noise at a certain input level, and increase as the cube of the input level. Thus, the slope of the third-order line increases 3dB for every 1dB increase in the response to the fundamental signal.

Although the output response of the third-order line saturates similarly to that of the fundamental signal, the gain line can be continued to a point where it intersects the gain line of the fundamental signal. This point is the third-order intercept point (TOIP).

Interestingly enough, one receiver feature that can help reduce IP levels back down under the noise is the use of a front-end attenuator, also called an input attenuator. In the presence of strong signals even a few decibels of input attenuation is often enough to drop the IPs back into the noise, while afflicting the desired signals only a small amount.

Other effects that reduce the overload caused by a strong signal also help. Situations arise where the apparent third-order performance of a receiver improves dramatically when a lower gain antenna is used.

This effect can be easily demonstrated using a spectrum analyser for the receiver. This instrument is a swept frequency receiver that displays an output on an oscilloscope screen that is amplitude-versus-frequency, so a single signal shows as a spike.

In one test, a strong, local VHF band repeater came on the air every few seconds, and you could see the second and third-order IPs along with the fundamental repeater signal.

There were also other strong signals on the air, but just outside the band. Inserting a 6dB barrel attenuator in the input ('antenna') line eliminated the IP products, showing just the actual signals. Rotating a directional antenna away from the direction of the interfering signal will also accomplish this effect in many cases.

Preamplifiers are popular receiver accessories, but can often reduce rather than enhance performance. Two problems commonly occur – assuming the preamp is a low-noise device. The best known problem is that the preamp amplifies noise as much as signals. While it makes the signal louder, it also makes the noise louder by the same amount. Since it's the signal-to-noise ratio that is important, one does not improve the situation. Indeed, if the preamp is itself noisy, it will deteriorate the signal-to-noise ratio.

The other problem is less well known, but potentially more devastating. If the increased signal levels applied to the receiver drive the receiver non-linear, then intermodulation products begin to emerge.

When evaluating receivers, a TOIP of +5 to +20dBm is excellent performance, while up to +27dBm is relatively easily achievable, and +35dBm has been achieved with good design; anything greater than +50dBm is close to miraculous – but nevertheless attainable.

Receivers are still regarded as good performers in the 0 to +5dBm range, and middling performers in the –10 to 0dBm range. Anything below –10dBm is not usually acceptable. A general rule is to buy the best third-order intercept performance that you can afford – especially if there are strong signal sources in your vicinity.

Dynamic range

The dynamic range of a radio receiver is the range – expressed in decibels – from the minimum discernible signal to the maximum allowable signal. While this simplistic definition is conceptually easy to understand, in the concrete its a little more complex. Several definitions of dynamic range are used.

One definition of dynamic range is that it is the input signal difference between the sensitivity figure – 0.5μV for 10dB S+N/N for example – and the level that drives the receiver far enough into saturation to create a certain amount of distortion in the output. This definition was common on consumer broadcast-band receivers at one time. It was especially common on automobile radios, where dynamic range was somewhat more important due to mobility.

A related definition takes the range as the distance in decibels from the sensitivity level and the –1dB compression point. Yet another definition, the blocking dynamic range, is the range of signals from the sensitivity level to the blocking level (see below).

A problem with the above definitions is that they represent single signal cases, so do not address the receiver's dynamic characteristics. There is both a 'loose' and a more formal definition that is somewhat more useful, and is at least standardised.

The loose version is that dynamic range is the range of signals over which dynamic effects – like intermodulation – do not exceed the noise floor of the receiver. For HF receivers, the recommended dynamic range is usually two-thirds the difference between the noise floor and the third-order intercept point in a 3kHz bandwidth.

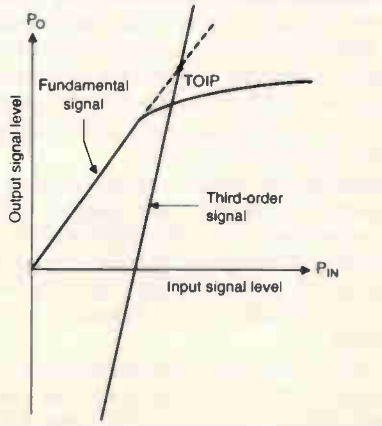
There is also an alternative definition: dynamic range is the difference between the fundamental response input signal level and the third-order intercept point along the noise floor, measured with a 3kHz bandwidth. For practical reasons, this measurement is sometimes made not at the actual noise floor – which is sometimes hard to ascertain – but rather at 3dB above the noise floor.

A certain measurement procedure is used that produces similar results. Two equal strength signals are input to the receiver at the same time. The frequency difference has traditionally been 20kHz for HF and 30 to 50kHz for VHF receivers. Modern band crowding may indicate a need for a specification at 5kHz separation on HF.

The amplitudes of these signals are raised until the third-order distortion products are raised to the noise floor level. For 20kHz spacing, using the two-signal approach, anything over 90dB is an excellent receiver, while anything over 80dB is at least decent.

The difference between the single-signal and two-signal (dynamic) performance is not merely an academic exercise. Besides the fact that the same receiver can show as much as 40dB difference between the two measures – favouring the single-signal measurement – the most severe effects of poor dynamic range show up most in the dynamic performance.

Fig. 4. Plot of a receiver's output signal versus its fundamental input signal. Note that the slope of the third-order line increases 3dB for every 1dB increase in the response to the fundamental signal.



Blocking

The blocking specification refers to the ability of the receiver to withstand very strong off-tune signals that are at least 20kHz away from the desired signal, although some use 100kHz separation. When very strong signals appear at the input terminals of a receiver, they may desensitise the receiver, i.e. reduce the apparent strength of desired signals over what they would be if the interfering signal were not present.

Figure 5 shows the blocking behaviour. When a strong signal is present, it takes up more of the receiver's resources than normal. As a result, there is not enough of the output power budget to accommodate the weaker desired signals. But if the strong undesired signal is turned off, then the weaker signals receive a full measure of the unit's power budget.

The usual way to measure blocking behaviour is to input two signals, a desired signal at 60dBμV and another signal 20 or 100kHz away at a much stronger level. The strong signal is increased to the point where blocking desensitisation causes a 3dB drop in the output level of the desired signal.

A good receiver will show ≥90dBμV, with many being considerably better. An interesting note about modern receivers is that the blocking performance is so good, that it's often necessary to specify the input level difference (dB) that causes a 1dB drop, rather than 3dB drop, of the desired signal's amplitude.

The phenomenon of blocking leads us to an effect that is often seen as paradoxical on first blush. Many receivers are equipped with front-end attenuators. These allow fixed attenuation values of 6dB, 12dB or 20dB – or some subset thereof – to be inserted into the signal path ahead of the active stages.

When a strong signal that is capable of causing desensitisation is present, adding attenuation often increases the level of the desired signals in the output, even though overall gain is reduced. This occurs because the overall signal that the receiver front-end is asked to handle is below the threshold where desensitisation occurs.

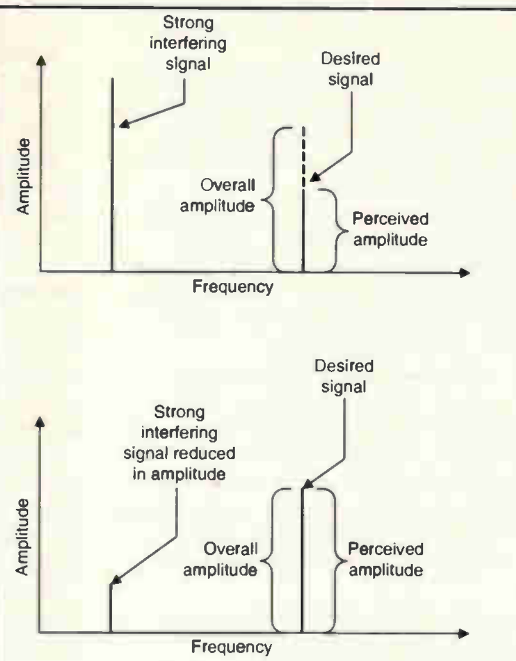


Fig. 5. Blocking – when very strong signals appear at the input terminals of a receiver, they may desensitise the receiver, i.e. reduce the apparent strength of desired signals over what they would be if the interfering signal were not present.

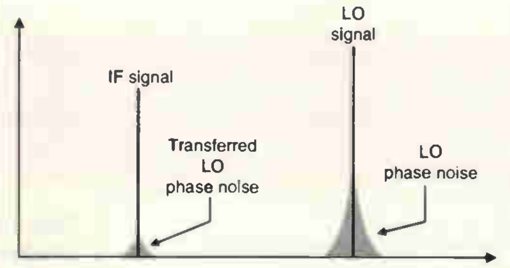


Fig. 6. In a superheterodyne receiver, the local oscillator beats with the desired signal to produce an intermediate frequency, IF, equal to either the sum LO+RF or difference LO–RF. If a strong unwanted signal is present, then it might mix with the noise sidebands of the LO, to reproduce the noise spectrum at the IF frequency.

Cross modulation

Cross modulation is an effect in which amplitude modulation (AM) from a strong undesired signal is transferred to a weaker desired signal. In HF receivers, testing is usually done with a 20kHz spacing between the desired and undesired signals, a 3kHz IF bandwidth on the receiver, and the desired signal set to 1000μV EMF (–53dBm). The undesired signal 20Hz away is amplitude modulated to the 30 percent level. This undesired AM signal is increased in strength until an unwanted AM output 20dB below the desired signal is produced.

A cross modulation specification ≥100dB would be considered decent performance. This figure is often not given for modern HF receivers, but if the receiver has a good third-order intercept point, then it is likely to also have good cross-modulation performance.

Cross modulation is also said to occur naturally, especially in transpolar and North Atlantic radio paths, where the effects of the aurora are strong.

According to one legend, there was something called the 'Radio Luxembourg effect' discovered in the 1930s. Modulation from a very strong broadcaster (BBC) appeared on the Radio Luxembourg signal received in North America. This effect was said to be an ionospheric cross modulation phenomenon. It apparently occurs when the strong station is within 175 miles of the great circle path between the desired station and the receiver site.

Reciprocal mixing

Reciprocal mixing occurs when noise sidebands from the local oscillator (LO) signal in a superheterodyne receiver mix with a strong undesired signal close to the desired signal.

Every oscillator signal produces noise, and that noise tends to amplitude modulate the oscillator's output signal. It will thus form sidebands either side of the LO signal. The production of phase noise in all LOs is well known, but in more recent designs the digitally produced synthesised LOs are prone to additional noise elements. The noise is usually measured in –dBc, i.e. decibels below carrier, or, in this case, dB below the LO output level.

In a superheterodyne receiver, the LO beats with the desired signal to produce an intermediate frequency, IF, equal to either the sum *LO+RF* or difference *LO–RF*. If a strong unwanted signal is present, then it might mix with the noise sidebands of the LO, to reproduce the noise spectrum at the IF frequency, Fig. 6.

In the usual test scenario, the reciprocal mixing is defined as the level of the unwanted signal (dB) at 20kHz required to produce noise sidebands 20dB down from the desired IF signal in a specified bandwidth. This bandwidth is usually 3kHz on HF receivers. Figures of –90dBc or better are considered good.

The importance of the reciprocal mixing specification is that it can seriously deteriorate the observed selectivity of the receiver, yet is not detected in the normal static measurements made of selectivity. It is a 'dynamic selectivity' problem. When the LO noise sidebands appear in the IF, the distant frequency attenuation – more than 20Hz off-centre of a 3kHz bandwidth filter – can deteriorate 20 to 40dB.

The reciprocal mixing performance of receivers can be improved by eliminating the noise from the oscillator signal. Although this sounds simple, in practice it is often quite difficult.

A tactic that works well is to add high-Q filtering between the LO output and the mixer input. The narrow bandwidth of the high-Q filter prevents excessive noise sidebands from getting to the mixer. Although this sounds like quite the easy solution, as they say 'the devil is in the details.'

IF notch rejection

If two signals fall within the pass-band of a receiver they will both compete to be heard. They will also heterodyne together in the detector stage, producing an audio tone equal to their carrier frequency difference.

For example, suppose you have an AM receiver with a 5kHz bandwidth and a 455kHz IF. If two signals appear on the band such that one appears at an IF of 456kHz and the other is at 454kHz, then both are within the receiver pass band and both will be heard in the output. However, the

2kHz difference in their carrier frequency will produce a 2kHz heterodyne audio tone difference signal in the output of the AM detector.

In some receivers, there's a tunable, high-Q notch filter in the IF amplifier circuit. This tunable filter can be turned on then adjusted to attenuate the unwanted interfering signal, reducing the irritating heterodyne. Attenuation figures for good receivers vary from –35 to –65dB, or so – the more negative the better.

There are some trade-offs in notch filter design. First, the notch-filter Q is more easily achieved at low IF frequencies – such as 50kHz to 500kHz – than at high IF frequencies like 9MHz. Also, the higher the Q, the better the attenuation of the undesired squeal, but the touchier it is to tune. Some happy middle ground between the irritating squeal and the touchy tune is mandated here.

Some receivers use audio filters rather than IF filters to help reduce the heterodyne squeal. In the AM broadcast band, channel spacing is typically 8 to 10kHz, depending on the part of the world. The transmitted audio bandwidths – hence the sidebands – are 5kHz.

Designers of AM broadcast-band receivers usually insert an *RC* low-pass filter with a –3dB point just above 4 or 5kHz right after the detector in order to suppress the audio heterodyne. This filter is called a 'tweet filter' in the slang of the electronic service/repair trade.

Another audio approach is to sharply limit the pass band of the audio amplifiers. For AM broadcast-band reception, a 5kHz pass band is sufficient. This means that the frequencies higher can be rolled off at a fast rate in order to produce only a small response an octave higher (10kHz).

In shortwave receivers, this option is weaker because the station channels are typically 5kHz, and many don't bother to honour the official channels anyway. And on the amateur-radio bands frequency selection is a perpetually changing ad-hocracy, at best.

Although the shortwave bands typically only need 3kHz bandwidth for communications, and 5kHz for broadcast, the tweet filter and audio roll-off might not be sufficient. In receivers that lack an effective IF notch filter, an audio notch filter can be provided.

Internal spurii

All receivers produce a number of internal spurious signals that sometimes interfere with the operation. Both old and modern receivers have spurious signals from assorted high-order mixer products, from power supply harmonics, parasitic oscillations, and a host of other sources.

Newer receivers with either synthesised local oscillators and digital frequency read-outs – or both – produce noise and spurious signals in abundance. Note that low-power digital chips with slower rise times – CMOS, NMOS, etc – are generally much cleaner than higher-power, fast rise-time chips like TTL devices.

With appropriate filtering and shielding, it is possible to hold the 'spurs' down to –100dB relative to the main maximum signal output, or within about 3dB or the noise floor, whichever is lower. ■

SMALL SELECTION ONLY LISTED - EXPORT TRADE AND QUANTITY DISCOUNTS - RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK

Ring for Latest Reduced Prices on this advert

HP8444A Tracking Generator • 5-1300Mc/s - £450.
HP8444A OPT 059 Tracking Gen • 5-1500Mc/s - £650.
HP35601A Spectrum Anz Interface - £300.
HP4953A Protocol Anz - 3400.
HP8970A Noise Figure Meter + 346B Noise Head - £3k.
HP8755A+B+C Scalar Network Anz PI - £250 + MF 180C - Heads 11664 Extra - £150 each.
HP3709B Constellation ANZ £1,000.
FARNELL TVS70MKII PU 0-70V 10 amps - £150.
MARCONI 6500 Network Scaler Anz - £500. Heads available to 40GHz many types in stock.
Mixers are available forANZs to 60GHz.
Marconi TF2374 Zero Loss Probe - £200.
Racal/Dana 1250-1261 Universal Switch Controller + 200Mc/s PI Cards and other types.
Racal/Dana 9303 True RMS Levelmeter + Head - £450.
TEKA6902A also A6902B Isolator - £300-£400.
TEK CT-5 High Current Transformer Probe - £250.
HP Frequency comb generator type 8406 - £400.
HP Sweep Oscillators type 8690 A+B + plug-ins from 20Mc/s to 18GHz also 18-40GHz.
HP Network Analyser type 8407A + 8412A + 8601A - 100Kc/s - 110Mc/s - £500 - £1000.
HP 8410-A-B-C Network Analyser 110Mc/s to 12 GHz or 18 GHz - plus most other units and displays used in this [illegible] - 8411a-8412-8413-8414-8418-8740-8741-8742-[illegible] 8650. From £1k.
Racal/Dana 9301A-9302 RF millivoltm[illegible] stock £250-£400.
Racal/Dana Modulation Meter Ty[illegible] 1.5GHz - £150/£250 - 900[illegible]
Marconi Microwav[illegible] mainframe [illegible] 6650PI - 18-26.5 [illegible] 5-40GHz-£750 [illegible] £600. MF [illegible]
Gould [illegible] manual - £150.
B[illegible] Variable [illegible] EF3 0.1Hz-100Kc/s [illegible] other makes in stock.
Racal/Dana [illegible] RMS voltmeter - £250.
HP [illegible] storage normalizer - £400 with lead + S.A. [illegible]
Marconi mod meters type TF2304 - £250 - TF2305 [illegible]
Racal/Dana counters-99904-9905-9906-9915-[illegible] 9921-50Mc/s-3GHz - £100 - £400 - all fitted [illegible] FX standards.
HP180TR. HP181T, HP182T mainfra[illegible]
HP432A-435A or B-43[illegible] power meter [illegible] powerheads to 60GHz - £150 - £175 [illegible] heads available.
HP3586A or C selecti[illegible] 500.
HP86222A+B Sweep PI [illegible] + ATT £1000-£1250.
HP86290A+B Sweep PI [illegible] GHz - £1000 - £1250.
HP8620C Mainframe - £250. IEEE £350.
HP8165A Programmable signal source - 1MHz - 50Mc/s - £1k.
HP3455/3456A Digital voltmeter - £400.
HP5370A Universal time interval counter - £1k.
HP5335A Universal counter - 200Mc/s-£1000.
TEKTRONIX 577 Curve tracer + adaptors - £[illegible]
TEKTRONIX 1502/1503 TDR cable test [illegible]
HP8699B Sweep PI YIG oscillator .0[illegible] MF-£250. Both £500.
Dummy Loads & Power att up to 2.5 [illegible] up to 18GHz - microwave parts new and ex equ[illegible] - relays - attenuators - switches - waveguides - Yigs - SMA - APC7 plugs - adaptors etc. qty. in stock.
B&K Items in stock - ask for list.
Power Supplies Heavy duty + bench in stock - Farnell - HP - Weir - Thurlby - Racal etc. Ask for list. Large quantity in stock, all types to 400 amp - 100Kv.
HP8405A Vector voltmeter - late colour - £400.
HP8508A Vector voltmeter - £2500.

LIGHT AND OPTICAL EQUIPMENT
Anritsu ML93A & Optical Lead Power M[illegible]
Anritsu ML93B & Optical Lead Power [illegible]
Power Sensors for above MA9[illegible] MA98[illegible]
Battery Pack MZ95A.
Anritsu MW97A Pulse E[illegible] tester
PI available - MH914C 1.3 - [illegible] 1.3 - MH913B 0.85 - MH925A 1.3 - MH929A 1.5[illegible] A 1.3GI - MH914C 1.3SM - £500 + one P.I.
Anritsu MW98A Time Domain Reflector.
PI available - MH914C 1.3 - MH915B 1.3 - MH913B 0.85 - MH925A 1.3 - MH929A 1.55 - MH925A 1.3GI - MH914C 1.3SM - £500 + one P.I.
Anritsu MZ100A E/O Converter.
+ MG912B (LD 1.35) Light Source + MG92B (LD 0.85) Light Source £350.
Anritsu MZ118A O/E Converter.
+MH922A 0.8 O/E unit + MH923 A1.3 O/E unit £350.
Anritsu ML96B Power Meter & Charger £450.

Anritsu MN95B Variable Att. 1300 £100.
Photo Dyne 1950 XR Continuous Att. 1300 - 1500 £100.
Photo Dyne 1800 FA. Att £100.
Cossor-Raytheon 108L Optical Cable Fault Locator 0-1000M 0-10kM £200.
TEK P6701 Optical Converter 700 MC/S-850 £250.
TEK OF150 Fibre Optic TDR – £750.
HP81512A Head 150MC/S 950-1700 £250.
HP84801A Fibre Power Sensor 600-1200 £250.
HP8158B ATT OPT 002+011 1300-1550 £300.
HP81519A RX DC-400MC/S 550-950 £250.
STC OFR10 Reflectometer – £250.
STC OFSK15 Machine jointing + eye ma[illegible] – £2[illegible]

MISCELLANEOUS ITEMS
HP 4261 LCR meter – £650.
HP 4274 FX LCR meter – £[illegible]
HP 3488 Switch Control [illegible] 00.
HP 75000 VXI [illegible] E1326B-DVM-quantity.
HP 83220A [illegible] 990MC/S convertor for use wit[illegible] 22A – £[illegible] 00.
HP 1630 [illegible] 1650 Logic ANZ's in stock.
HP 8754A Network ANZ 4-1300MC/S - [illegible] cables - £[illegible] 00.
HP 8754A Network ANZ H2[illegible] 4-[illegible] MC/S [illegible] 602A + Cables [illegible] 00.
HP 8350A Sweeper [illegible] PI 2-8.4GHz [illegible] PI 5.9-12.4[illegible] 3 – £3[illegible]
HP MICROWAVE TWT AMPLIFIER [illegible] 1-2G[illegible]
[illegible] 00.
HP PREAMPLIFIER 8447A 0.1-[illegible] dual – £300.
HP PREAMPLIFIER 8447D 0.01-1.3GHz – £400.
HP POWER AMPLIFIER 8447E 0.01-1.3GHz – £400.
HP PRE + POWER AMPLIFIER 8447F 0.01-1.3GHz – £[illegible]
HP 35[illegible] Gain Phase Meter 1Hz-13MC/S OPT[illegible] Dual – £4[illegible]
MARCONI [illegible] Modulation Meter-50kHz-2.2GHz – £[illegible]
MARCONI 2610 True RMS Meter – £450.
MARCONI [illegible] 93B AF Power Meter [illegible] mad filter – £250-[illegible]
MARCONI 6950-6960B Power Meter + Heads – £400-£[illegible]
MARCONI SIGNAL SOURCE-6055-6056-6057-6[illegible] FX Range [illegible] – £250-£[illegible]
RACAL 1792 COMMUNICATION RX – £[illegible] late model with backlighting and [illegible]
RACAL 1772 COMMUNICATION RX – £400-£[illegible]
TEK MODULE MAINFRAMES – TM[illegible]-502-503-504-506-[illegible] 3-5006.
TEK PI 5010-M1[illegible] log M[illegible] – £250. FG Pr[illegible] 20MC/S Function Gen – £40[illegible] S1 Prog Scanner [illegible] DM Prog DMM – £[illegible] 00
TEK 7000 OSCILLOSCOPE MAINFRAMES – 7603-7[illegible] 7[illegible] 7904A-7104 – £1[illegible] 000.
TEK 7000 PI's – 7A11-7A12-7A13-7A18-7A19-7A22-7A24-7A2[illegible] 7A42-7B1[illegible] 7B85-7B92A-7D15-7D20.
TEK 7000 – 7S11-7S12-7S14-7M11-S1-S2-S3A-S4-S5-S6-S51-S5[illegible]
HP POWER SUPPLIES – 6621A-6623A-6[illegible] 652A. [illegible] Also [illegible] 00 types £POA.
WE KEEP IN STOCK HP and other makes of RF frequency doublers which when [illegible] to the RF output socket of a S/Generator doubles the output frequency EG.50-1300MC/S to 50-2600MC/S price from £250 - £450 each.

SPECTRUM ANALYZERS
HP [illegible] Hz-50kHz – £750.
HP 3582A Dual 0.2Hz-25.5kHz – £1,[illegible]
HP 3585A [illegible] Hz-40MC/S – £[illegible]
HP 3588A 10Hz-150MC/S – £[illegible] 50[illegible]
HP 8568A 100Hz-1.5GHz – £[illegible] 00
HP 8568B 100Hz-1.5GHz – £[illegible] 00
HP 8590B [illegible] C/S-1.8GHz – £4,500.
HP 8566B [illegible] 22GHz) – £3,500.
HP 3561A Signal Analyzer 15Hz-50k[illegible] 00.
TEK492 [illegible] Hz-21GHz OPT 2 – £2,500.
TEK492P 50kHz-21GHz OPT 1-2-3 – £3,[illegible]
TEK 492AP 50kHz-21GHz OPT 1-2-3 – £[illegible] 00.
TEK492BP 50kHz-21GHz – £3,000-£4,000.
TEK495 100kHz-1.8GHz – £2,000.
HP 8557A 0.01MC/S-350MC/S – £500 + MF180T or 180C – £150 – 182T – £500.
HP 8558B 0.01-1500MC/S – £750 – MF180T or 180C – £150 – 182T – £500.
HP 8559A 0.01-21GHz – £1,000 – MF180T or 180C – £150 – 182T – £500.
HP 8901A AM FM Modulation ANZ Meter – £800.
HP 8901B AM FM Modulation ANZ Meter – £1,750.
HP 8903A Audio Analyzer – £1,000.
HP 8903B Audio Analyzer – £1,500.

MARCONI 2370 SPECTRUM ANALYZERS – HIGH QUALITY – DIGITAL STORAGE – 30Hz-110MC/S Large qty to clear as received from Gov – all sales is from [illegible] complete or add £100 for basic testing and adjustment – callers preferred – pick your own from [illegible] – discount on qtys of five.
A EARLY MODEL GREY – horizontal alloy cooling fins – £[illegible]
B LATE MODEL GREY – vertical alloy cooling fins – £300.
C LATE MODEL BROWN – as above (few only) – £500.

OSCILLOSCOPES
TEK 465-465B 100MC/S + 2 probes – £250-£300.
TEK 466 100MC/S storage + 2 probes – £200.
TEK 475-475A 200MC/S-250MC/S + 2 probes – £300-£350.
TEK 2213-2213A-2215-2215A-2224-2225-2235-2236-2245-60-100MC/S – £250-£400.
TEK 2445 4ch 150MC/S + 2 probes – £450.
TEK 2445A 4ch 150MC/S + 2 probes – £600.
TEK 244[illegible] 4ch 1[illegible] probes – £750.
TEK [illegible] 00MC/S + 2 probes – £500.
TEK [illegible] C/S + 2 probes – £550.
TEK 245[illegible] 4ch [illegible] MC/S – £1,150.
TEK 2465A 4ch-350MC/S – £1,550.
TEK D.S.O. 2430A -150MC/S + 2 probes – £1,750.
TEK D.S.O. 2440 -300MC/S + 2 probes – £2,000.
TEK TAS 475-485 -100MC/S-20MC/S-4 ch + 2 probes – £900-£1.1K.
HP1740A – 100MC/S + 2 probes – £250.
HP1741A – 100MC/S storage + 2 probes – £200.
HP1722A – 1722A - 1725A – [illegible] MC/S + 2 probes – £300-£[illegible]
HP1744A – 100MC/S storage large screen – £250.
HP1745A – 17[illegible] 100MC/S large screen – £350.
HP54100A – [illegible] GHz [illegible] – £500.
HP54[illegible] 0A – [illegible] ing – £500.
HP54[illegible] A – [illegible] 0MC/S digitizing – £500.
HP54[illegible] D – [illegible] digitizing – £1,000.

MICROWAVE COUNTERS – ALL LED READOUT
EIP 351D Autohet 20Hz-18GHz – £750.
EIP 371 Micro Source Locking – 20Hz-18GHz – £[illegible] 0.
EIP 451 Micro Pulse Counter – 300MC/S-18GHz – £[illegible]
EIP 545 Microwave Frequency Counter 10Hz-18GHz – £[illegible]
EIP 548A Microwave Frequency Counter 10Hz-26.5GHz – £[illegible]
EIP [illegible] Microwave Source Lock [illegible] GHz – £1.2K.
EIP 588 Microwave Pulse Counter [illegible] MC/S-26.5GHz – £1.4K.
SD 6054B Micro Counter 20Hz-24GHz – SMA Socket – £800.
SD 6054[illegible] Micro Counter 20Hz-18GHz – N Socket – £700.
SD 6054D Micro Counter 800MC/S-18GHz – £600.
SD 6246A Micro Counter 20Hz-26GHz – £1.2K.
SD 6244A Micro Counter 20Hz-4.5GHz – £400.
HP5352B Micro Counter OPT 010-005-46GHz – new in box – £[illegible]
HP5340A Micro Counter 10Hz-18GHz – Nixey – £500.
HP5342A Micro Counter [illegible] z-18-24GHz – £800-£1K – OPTS 001-0[illegible] 03-0[illegible] 011 available.
HP534[illegible] A + 534[illegible] Source Synchronizer – £1.5K.
HP534[illegible] MC/S 11 Digit LED Readout – £400.
HP5353A + 5354A Plugin – 4GHz – £700.
HP5345A + 5355A Plugin with 5356A 18GHz Head – £1K.
HP5385A 1GHz 5386A-5386A 3GHz Counter – £1K-£2K.
Racal/Dana Counter 1991-160MC/S – £200.
Racal/Dana Counter 1992-1.3GHz – £600.
Racal/Dana Counter 9921-3GHz – £350.

SIGNAL GENERATORS
HP8640A – AM-FM 0.5-512-1024MC/S – £200-£400.
HP8640B – Phase locked – AM-FM-0.5-512-1024MC/S – £500-£1.2K. Opts 1-2-3 available.
HP8654A – B AM-FM 10MC/S-520MC/S – £300.
HP8656A SYN AM-FM 0.1-990MC/S – £900.
HP8656B SYN AM-FM 0.1-990MC/S – £1.5K.
HP8657A SYN AM-FM 0.1-1040MC/S – £2K.
HP8660C SYN AM-FM-PM-0.01-1300MC/S-2600MC/S – £2K.
HP8660D SYN AM-FM-PM-0.01-1300MC/S-2600MC/S – £3K.
HP8673D SYN AM-FM-PM-0.01-26.5 GHz – £12K.
HP3312A Function Generator AM-FM 13MC/S-Dual – £300.
HP3314A Function Generator AM-FM-VCO-20MC/S – £600.
HP3325A SYN Function Generator 21MC/S – £800.
HP3326A SYN 2CH Function Generator 13MC/S-IEEE – £1.4K.
HP3336A-B-C SYN Func/Level Gen 21MC/S – £400-£300-£500.
Racal/Dana 9081 SYN S/G AM-FM-PH-5-520MC/S – £300.
Racal/Dana 9082 SYN S/G AM-FM-PH-1.5-520MC/S – £400.
Racal/Dana 9084 SYN S/G AM-FM-PH-.001-104MC/S – £300.

SPECIAL OFFERS

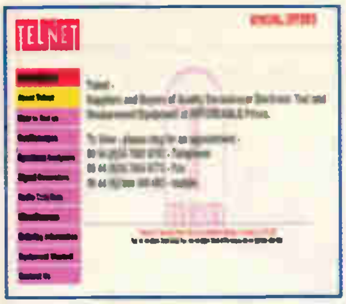
MARCONI 2019A SYNTHESIZED SIGNAL GENERATORS – 80KC/S-1040MC/S – AM-FM – £400 inc. instruction book – tested.
MARCONI 2022E SYNTHESIZED SIGNAL GENERATOR – 10KC/S-1.01GHz AM-FM – £500 inc. instruction book – tested.
R&S APN 62 LF Sig Gen 0.1Hz – 260 kHz c/w book – £250.

MARCONI 2383 S.ANZ 100Hz – 4.2 GHz. £2K
H.P. RF AMP 8349A 2-20 GHz microwave. £2K.
H.P. RF AMP 8347A 100 kHz - 3GHz £1,500.
H.P. 8922 radio communication test sets.
G – H – M. options various. £2,000 - £3,000 each.
H.P. 4193A VECTOR IMPEDANCE METER + probe kit. 400 kHz. To 110 ML/S. £3,500.

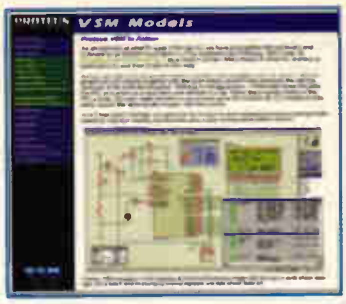
H.P. 83220A – E GMS UNITS for above. £1,000 - £1,500.
WAVETECK SCLUMBERGER 4031 RADIO COMMUNICATION TEST SET. Internal Spectrum ANZ. £1,800 - £2,000.
ANRITSU MS555A2 RADIO COMM ANZ. To 1000MC/S. No C.R. tube in this model. £450.
TEK 2445A – 4CH – 150MLS SCOPE + New X1 + X10- probe. Instruction book. £500 each.

ITEMS BOUGHT FROM HM GOVERNMENT BEING SURPLUS. PRICE IS EX WORKS. SAE FOR ENQUIRIES. PHONE FOR APPOINTMENT OR FOR DEMONSTRATION OF ANY ITEMS, AVAILABILITY OR PRICE CHANGE. VAT AND CARRIAGE EXTRA. ITEMS MARKED TESTED HAVE 30 DAY WARRANTY. WANTED: TEST EQUIPMENT-VALVES-PLUGS AND SOCKETS-SYNCROS-TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel: (01274) 684007. Fax: 651160



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 call
Pat Bunce
Tel 0208 643 6207

E-mail
p.bunce@cumulusmedia.co.uk

ACQUIVISION
http://www.acquivision.com

AcquiVision solutions, including XY-Plotting, Oscilloscopes (with FFT), Data Logging and Custom Software, have been getting the most from computers since 1994. Download software. Telephone (01903)830502.

AQUILA VISION
http://www.aquila-vision.co.uk

Aquila Vision specialises in supplying and supporting Embedded Microprocessor Development products from PICs to DSPs. We also stock robotics boards, Linux and general interest CD-ROM's.

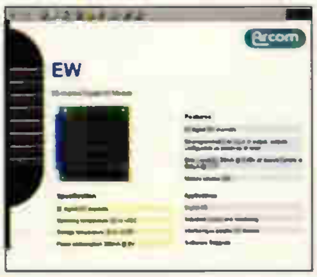
ALCATEL COMPONENTS
http://www.components
@alcatel.de

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.

ARCOM
http://www.arcomcontrols.com/ew

A leading international supplier of



communication and control technology to industry, Arcom provides leading edge solutions through a comprehensive range of market leading products.

A.R.S.
http://www.ars-surplus-stock.com

We buy electronic, electrical, computer and test equipment. Visit our website or e-mail us at info@ars-surplus-stock.com Telephone us on 01271 867285

ASHWELL ELECTRONICS
http://www.ashwell-hq.com

Ashwell provide technical support for Apex Microtechnology op-amps and DC/DC'S; Aeroflex; EMP filtered connectors; M S Kennedy; Mintech obsolescence; NSC Mil/Aero; Teledyne Relays and isocom mil/optocouplers.

BROADERCASTING COMMUNICATIONS SYSTEMS
www.broadercasting.co.uk

WINRADIO now brings you a complete choice in personnel computer controlled radio scanning and reception solutions ● Broadcast ● Media ● Monitoring ● Professional Amateur Radio communications

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.

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."

CONCEPT ELECTRONICS
http://www.conceptkey.co.uk

Concept Keyboards are specialists in the design and manufacture of customer specified membrane panels and keyboards, and electronic design. Concept's membrane manufacture is supported by a full electronic production facility to provide a complete turnkey keyboard and electronics service, fully accredited to ISO9001.

CONTROL SOLUTIONS
www.controlsolutions.co.uk

Data acquisition and control for beginners, hobbyists, and professionals. Perform mathematical and logical operations on data in real time. Email: info@controlsolutions.co.uk.

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.

DANIEL MCBREARTY

http://www.danmcb.demon.co.uk/eng.html

Experienced engineer based in London, specialist in audio and control systems. Available for design, project engineering or general consultancy. Background of high-quality work.

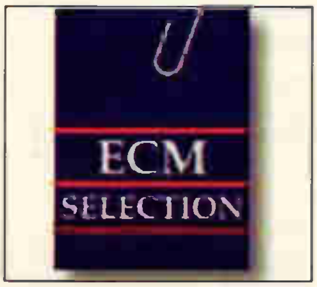
DESIGNER SYSTEMS CO.

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.

ECM SELECTION

http:// www.ecmsel.co.uk



For the pick of the UK's Top High-Tech Software and Hardware career opportunities - from fresh Grad/PhD to Senior Engineer/Manager – £22,000 - £70,000

EAGLE PCB DESIGN SOFTWARE

http://www.puresoft.co.uk

- Professional PCB design made easy!
- Fully functional freeware download.
- Schematics, Layout & Autorouting.
- Free tech support

EDWIN PCB DESIGN SOFTWARE

http://www.swifteurotech.co.uk

Swift Eurotech supply the best-selling EDWin CAD/CAE system for PCB design, including schematics, simulation and PCB design. Discounts up to 60% for non-commercial users.

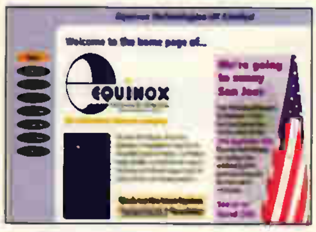
EDAForce

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.

ELECTRONICS AND COMPUTING PRINCIPLES

http://www.eptsoft.com

Studying electronics or computing or just want to keep up-to-date in an easy and enjoyable way, then this fully interactive software is for you.

FARADAY TECHNOLOGY LTD

http://www.faradaytech.co.uk

Over 17 years experience in the design and manufacture of high quality passive filters and delay lines. Used in Broadcast, Telecommunications, Medical, Multimedia, and computer industries. Currently exporting worldwide

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.

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

FLASH DESIGNS LTD

http://www.flash.co.uk

Flash supply low cost AVR ISP programmers (£39), MINI-ICE starter kits (from £69), Portable Easy-ICE emulators (from £199), ICE Adapters & 'C' compilers for any ATMEL AVR, MCS51, Dallas, Hitachi H8 microcontroller. Download FLASH NEWS now, Watch out for Special Offers'. ARE YOU developing code in a Flash?

GOOT PRODUCTS

http://www.kieagoot.co.uk

Kiea Trading Company is the sole agent of Goot products, We specialise in supplying the soldering and desoldering product range manfactured by Goot Japan for the UK market. Goot uses advanced production technology to manufacture high quality soldering iron products for industrial, professional and general purpose use.

HSPS LTD

http://dspace.dial.pipex.com/hsps/

FILTER DESIGNER - Advanced analog and digital filter design software for the PC. - Standard and Professional versions.- Free download of Evaluation version.

HTB ELEKTRONIK

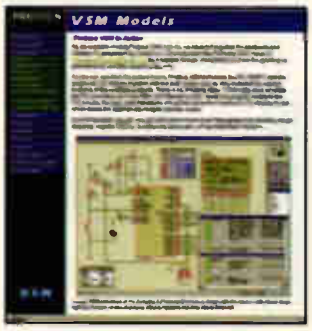
http://www.htb-elektronik.com

We are selling second-hand test & measurement equipment and accessories for over 10 years,from all leading manufactures.

LABCENTER

http://www.labcenter.co.uk

Download evaluation versions of our unique Proteus VSM mixed mode SPICE and CPU simulator, and also the full range of Proteus PCB Design products. Register the Proteus Lite shareware versions online for as little as £20.



LOW POWER RADIO SOLUTIONS

http://www.lprs.co.uk

LPRS markets low power radio transmitters, receivers and transceiver modules manufactured by ourselves, Radiometrix, Circuit Designs, RDT and Micrel. Applications for telemetry, video and remote control.

LEVY/LATHAM GLOBAL

http://www.levylatham.com

U.S. Military Surplus meters, plug-ins, test sets, oscilloscopes, power supplies, signal generators, spectrum analyzers and radio components from Tektronix, Hewlett Packard, Sony, Phillps and more!

MATRIX MULTIMEDIA LTD

www.matrixmultimedia.co.uk

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

NORCALL

http://www.norcall.co.uk

Suppliers and repairers of MOBILE RADIO EQUIPMENT
SALES
HIRE
REPAIR
Huge stocks of used radios and spares Pye Philips Simoco Icom Kenwood Standard Cleartone Maxon Yaesu Key Midland.
WE CAN PROGRAM ANYTHING
24hr Service

OMEGA RESEARCH LTD

http://www.omega-research .co.uk

'SMD prototyping adapters. Unique, flexible, low cost adapters to allow bench working with SM devices. Range suits most devices down to 0.5mm pitch.'

PCA:PHILIP COLLINS & ASSOCIATES PTY. LTD

http://www.pca.cc

PCA manufactures Radphone 2000DX remote control systems for shortwave broadcasters and government agencies wanting worldwide control of communications receivers and transceivers from any tone phone.

POLY-FLEX CIRCUITS LTD

http://www.polyflex.com

Design, manufacture and population of printed polyester flexible circuits, including Flip Chip on Flex providing practical, low cost, reliable solutions for today's small lightweight products.

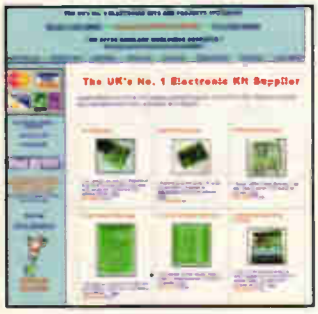
QUILLER ELECTRONICS

http://www.quiller.com

100+ pages of detailed technical information on Schrack Relays, MEC Switches, Hirose Connections.

QUASAR ELECTRONICS

www.quasarelectronics.com



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

RADIOMETRIX

http://www.radiometrix.co.uk

Radiometrix specialises in the design and manufacture of VHF & UHF, RF data modules. We offer a broad range of PCB mounted miniature transmit, receive and transceiver modules for OEM use.

RADIO-TECH LIMITED

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

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

RALFE ELECTRONICS

professional test & measurement

www.ralfe-electronics.co.uk

RD RESEARCH

http://www.looking.co.uk/spice

Analogue and digital SPICE modelling software. Full details available on this site. Available on a 30 day evaluation basis.

RS COMPONENTS LTD

http://rswww.com

The award winning on-line service from RS

- 110,000+ products available
- Technical data library
- Stock availability check
- Integrated on-line purchasing
- Order by 8pm - with you tomorrow.

SESCOM, INC.

http://www.sescom.com

SESCOM, INC. is a 30-year manufacturer of audio "problem solvers" and transformers. We also offer easily-fabricated aluminum enclosures for small production runs and prototypes.

SOFTCOPY

http://www.softcopy.co.uk

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

STAFFORDSHIRE WIRELESS COMPANY

http://www.staffs-wireless.com

Wireless, communication, test equipment, bought and sold for very competitive prices visit our web site or telephone John on 01889 569928 or 0973 296461.

SUPRA AUDIO CABLES

http://www.jenving.se

Jenving Technology AB is the manufacturer of Supra Audio Cables. OEM productions are also accepted.

TEST EQUIPMENT SOLUTIONS

http://www.TestEquipmentHQ.com

Quality second user test equipment with full warranty and support. All types of equipment from all leading manufacturers including general purpose, communications and industrial test.

TELONIC

http://www.telonic.uk.com

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

TELNET

http://www.telnet.uk.com

Top quality second-user Test and Measurement Equipment
eMail telnetkm@msn.com

TEMWELL CORPORATION

http://www.temwell.com.tw

Manufacturer & Exporter of Heelical BPF Filter, 30 Watts BPF Power Filter and Handset/Base Station Duplexers

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.

THERMOSPEED

http://www.thermospeed.co.uk

Temperature and pressure, control and instrumentation. Full on-line purchasing.
* Overnight ex-stock delivery
* Create your own hotlist
* Download datasheets
* Full technical support

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.

TRIDENT MICROSYSTEMS LTD

http://www.trident-uk.co.uk

Visit the Trident website for details and datasheets on their entire LCD and printer product range. Download data and subscribe for our regularly updated newsletter.

TOWER HILL TECHNICAL SERVICES

http://www.towerhillaerials.com

Everything you need for DIY Satellite & TV aerial installation. The one stop shop for TV, FM, Satellite, Amateur Radio PMR Aerials, Distribution Equipment, Cable & Accessories"

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

VANN DRAPER ELECTRONICS LTD

http://www.vanndraper.co.uk

Test equipment from Grundig, Kenwood, Hitachi, Fluke, Avo, Glassman, Advance in a comprehensive site including oscilloscopes, multimeters, power supplies, generators, counters, soldering, digital tv etc.

VUTRAX PCB DESIGN SOFTWARE

http://www.vutrax.co.uk

VUTRAX electronic schematic and pcb design system for Windows 95, 98 NE, NT and 200. Limited Capacity FREE version downloads available, all upgradeable to various customised levels.

UK ELECTRICAL DIRECT

http://www.uked.com

For a comprehensive on-line directory, buyers guide and resource locator for the UK Electrical Industry look at this site. Many of the companies listed have links to their own web sites, making this a one-stop shop for a huge amount of information.

UK MAILING LIST GROUP

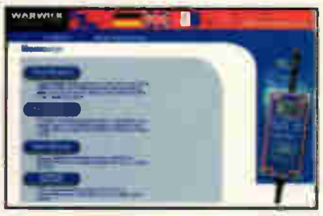
http://www.egroups.com/list/uktvrepair

Following on from the newsgroup discussion last month there is a UK Email group for TV technicians where you can send an Email to everyone in the group. There's just over 30 people in the group at present. For more details and how to register look at the egroup home page. Just a general comment though - you do have to be careful who you give your Email address to so that you can avoid "spamming" - that is getting lots of unwanted Email about dubious Russian site (amongst others).

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.



WOOD & DOUGLAS

http://www.woodanddouglas.co.uk

Wood & Douglas Ltd is the leading independent British designer and manufacturer of quality radio products for International telemetry, data,voice & video wireless communications.

REPAIRWORLD

http://www.repairworld.com

Repairworld is a sophisticated US based fault report database which is updated bi-weekly. It operates on a subscription basis and describes itself as an "affordable solution for all technicians". You can see some samples of the material for free, monitors, VCR, DVD and Camcorders being of particular relevance to UK users. The site also provides a "chat room".

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 call

Pat Bunce Tel 0208 643 6207

E-mail p.bunce@cumulusmedia.co.uk

T & M EQUIPMENT

AGILENT TECHNOLOGIES (Hewlett Packard)

8714ES/100 3GHz network analyser. Option 100 (fault location) (List over £18000) £12,500

8653ES network analyser with 006 and 010 (6GHz + time-domain options) (list £32k) £20000

All above supplied with new Agilent calibration and one year warranty.

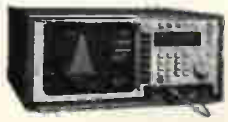
• ralfe electronics • *exclusively professional T&M ©*

• Unit 1 Olds Close •
• Olds Approach •
• Watford • Herts WD1 8RU •
• England •

TEL (+44) 01923-721396
FAX (+44) 01923-721402

EST 45 YRS

AGILENT TECHNOLOGIES



1145A active probe 2-channel (list £725)	£350
3336A level generator	£1000
214B pulse generator	£1500
10715A digital interferometer	£1000
346A noise source	£850
8018A serial data generator	£750
8175A digital signal generator (order pods separately)	£2000
83440C lightwave detector 20GHz 1300/1550nm	£2000
85033D 3.5mm calibration kit 30kHz to 6GHz (list £2381)	£1500
85032B N-type calibration kit (list £1578)	£850
85053B 3.5mm verification kit	£2000
85056D 2.4mm economy calibration kit (list £4904)	£2500
8591E spectrum analyser 1.8GHz options /021/101/105	£4500
85132F 7mm to 3.5mm flexible test port cable set (list £2682)	£1750
85133F 2.4mm flexible test port cable set (list £4249)	£2500
89441A 2.65GHz vector signal analyser, many options listing at>50k 2 in Stock	£call
8657A synthesized signal generator 0.1 - 1040MHz	£2000
8657B synthesized signal generator 0.1 - 2080MHz	£4000
8903B/10/51 audio analyser	£2000
8903E audio analyser	£1250
8922 E, F, G and H gsm test sets, each	£500
8904A function generator	£1000
E1413C a/d converter (VXI based) (list £4932)	£1500
E1415A algorithmic closed loop controller (VXI based) (list £5221)	£2000
E1610A VXI card 34Mb/s line interface for BSTS	£2500
E1697A VXI card 155Mb/s optical line interface	£5000
E5200A broadband service analyser, options /02/051/122/122/138/138/139/139	£5000
J2171A ethernet interface module	£1500
J3458A fast ethernet lanprobe option 201 OR 202 and ANS	£2000
J3911A multiport token-ring Lanprobe	£2000
J3914A E1 WanProbe	£2000
J3921A E3 ATM probe	£6500
J3935A Telegra D analyser /201/202 options (list £13250)	£6500
J3972A 3c STM-1 performance enhanced ATM probe	£6500
R85026A 26.5 - 40GHz waveguide detector	£650

Certificate No. 95/013

ISO9002 ACCREDITED STOCKIST MEASUREMENT & TEST EQUIPMENT

SPECIAL PURCHASE – AGILENT TECHNOLOGIES (HEWLETT PACKARD) 8560A 2.9GHz SYNTHESIZED SPECTRUM ANALYSERS

Model 8560A

50Hz-2.9GHz, synthesized tuning.
10Hz resolution bandwidth
See our web-site for full detailed specifications.

Just £5500 each (including bonus option /002 – inbuilt tracking generator).

All equipment sold calibration-checked by independent laboratories and carries un-conditional refund and 90-day guarantees.

TEST EQUIPMENT WANTED.

TOP PRICES PAID FOR PROFESSIONAL HIGH-END UNITS

AGILENT TECHNOLOGY SPECIALISTS.

FOR COMPLETE STOCK LISTING PLEASE CHECK OUR WEBSITE

www.ralfe-electronics.co.uk

CIRCLE NO.131 ON REPLY CARD

TiePieScope HS801 PORTABLE MOST

ABRITARY WAVEFORM GENERATOR-
STORAGE OSCILLOSCOPE-
SPECTRUM ANALYZER-
MULTIMETER-
TRANSIENT RECORDER-

Reliability

- The HS801: the first 100 Mega samples per second measuring instrument that consists of a MOST (Multimeter, Oscilloscope, Spectrum analyzer and Transient recorder) and an AWG (abritary waveform generator). This new MOST portable and compact measuring instrument can solve almost every measurement problem. With the integrated AWG you can generate every signal you want.

- The versatile software has a user-defined toolbar with which over 50 instrument settings quick and easy can be accessed. An intelligent auto setup allows the inexperienced user to perform measurements immediately. Through the use of a setting file, the user has the possibility to save an instrument setup and recall it at a later moment. The setup time of the instrument is hereby reduced to a minimum.

- When a quick indication of the input signal is required, a simple click on the auto setup button will immediately give a good overview of the signal. The auto setup function ensures a proper setup of the time base, the trigger levels and the input sensitivities.

- The sophisticated cursor read outs have 21 possible read outs. Besides the usual read outs, like voltage and time, also quantities like rise time and frequency are displayed.

- Measured signals and instrument settings can be saved on disk.This enables the creation of a library of measured signals. Text balloons can be added to a signal, for special comments. The (colour) print outs can be supplied with three common text lines (e.g. company info) en three lines with measurement specific information.

- The HS801 has an 8 bit resolution and a maximum sampling speed of 100 MHz. The input range is 0.1 volt full scale to 80 volt full scale. The record length is 32K/64K samples. The AWG has a 10 bit resolution and a sample speed of 25 MHz.The HS801 is connected to the parallel printer port of a computer.

- The minimum system requirement is a PC with a 486 processor and 8 Mbyte RAM available. The software runs in Windows 3.xx / 95 / 98 or Windows NT and DOS 3.3 or higher.

- TiePie engineering (UK), 28 Stephenson Road, Industrial Estate, St. Ives, Cambridgeshire, PE17 4WJ, UK
Tel: 01480-460028; Fax: 01480-460340

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

Web: http://www.tiepie.nl

CIRCLE NO. 132 ON REPLY CARD

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.

Service Link

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 Reed Business Information. Advertisements together with remittance should be sent to Electronics World Classified, Cumulus Business Media, Anne Boleyn House, 9-13 Ewell Road, Cheam, Surrey SM3 8DZ. **Tel: 020 8722 6028.** **Fax: 020 8770 2016**

ARTICLES WANTED

FOR SALE

LINEAGE

SERVICES

ADVERTISERS' INDEX

ELECTRONICS WORLD

INCORPORATING WIRELESS WORLD

READER INFORMATION SERVICE

For more information about any of the products or services in this issue of ELECTRONICS WORLD, simply ring the relevant enquiry number.

Enquiry numbers may be found at the bottom of each individual advertisement.

101	102	103	104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119	120	121	122
123	124	125	126	127	128	129	130	131	132	133
134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150					

						500	501	502	503	504
505	506	507	508	509	510	511	512	513	514	515
516	517	518	519	520	521	522	523	524	525	526
527	528	529	530	531	532	533	534	535	536	537
538	539	540	541	542	543	544	545	546	547	548
549	550	551	552	553	554	555	556	557	558	559
560	561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580	581
582	583	584	585	586	587	588	589	590	591	592
593	594	595	596	597	598	599	600			

Name

Job title

Company Address

Telephone NOVEMBER 2001

Only tick here if you do not wish to receive direct marketing promotions from other companies. ☐

Newsagent order form

Pass this order form to your newsagent to ensure you don't miss the next issue of *EW*.

To ....

(name of Newsagent)

Please reserve me the December issue of *Electronics World* and continue to order every month's issue until further notice

Name..

Address..

....

....

....

Thank you

Subscribe today!

Guarantee your own personal copy each month

Save on a 2 year subscription

ELECTRONICS WORLD

INCORPORATING WIRELESS WORLD

SEE OVER!

ELECTRONICS WORLD
Reader Information Service
Cumulus Business Media Limited
Perrymount Road
Haywards Heath
Sussex RH16 3DH

PLEASE AFFIX STAMP

ELECTRONICS WORLD

INCORPORATING WIRELESS WORLD

SUBSCRIPTION CARD

Please enter my subscription to ELECTRONICS WORLD. I enclose Cheque/Eurocheque to the value of £ ____________ made payable to **Reed Business Information**

Please charge my Mastercard/Visa/ Amex account ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

With £ ____________ Expiry Date ____________

Signature ____________

Name ____________

Job Title ____________

Address ____________

____

____________ Postcode ____________

Tel: ____________ Country ____________

SUBSCRIPTION RATES	
UK 1 year	£36
UK 2 years	£58
UK 3 years	£72
Student rate (proof required)	£21.30
Airmail	
Europe 1 year	£51
Europe 2 years	£82
Europe 3 years	£103
Rest of the world 1 year	£61
Rest of the world 2 years	£98
Rest of the world 3 years	£123
Surface mail 1 year	£41

Post to:
ELECTRONICS WORLD
P.O. Box 302
Haywards Heath,
West Sussex RH16 3DH UK.

CREDIT CARD HOTLINE
Tel: +44 01444 445566
Fax: +44 01444 445447

Please tick here if you do not wish to receive direct marketing-promotion from other companies ☐

049

ELECTRONICS WORLD

INCORPORATING WIRELESS WORLD

SUBSCRIPTION CARD

Please enter my subscription to ELECTRONICS WORLD. I enclose Cheque/Eurocheque to the value of £ ____________ made payable to **Reed Business Information**

Please charge my Mastercard/Visa/ Amex account ☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

With £ ____________ Expiry Date ____________

Signature ____________

Name ____________

Job Title ____________

Address ____________

____

____________ Postcode ____________

Tel: ____________ Country ____________

SUBSCRIPTION RATES	
UK 1 year	£36
UK 2 years	£58
UK 3 years	£72
Student rate (proof required)	£21.30
Airmail	
Europe 1 year	£51
Europe 2 years	£82
Europe 3 years	£103
Rest of the world 1 year	£61
Rest of the world 2 years	£98
Rest of the world 3 years	£123
Surface mail 1 year	£41

Post to:
ELECTRONICS WORLD
P.O. Box 302
Haywards Heath,
West Sussex RH16 3DH UK.

CREDIT CARD HOTLINE
Tel: +44 01444 445566
Fax: +44 01444 445447

Please tick here if you do not wish to receive direct marketing-promotion from other companies ☐

049