

**20% discount** on Basic Stamp evaluators

# ELECTRONICS WORLD

Austria Asch. 66.00  
Denmark DKr. 67.00  
Germany DM 18.00  
Greece Dra. 1100.00  
Holland Dfl. 11.75  
Italy L. 8800.00  
Malta Lm. 1.55  
IR £3.30  
Singapore S\$7.50  
Spain Pts. 850  
USA \$5.95

INCORPORATING WIRELESS WORLD

September 1997 £2.35

A REED BUSINESS PUBLICATION  
SOR DISTRIBUTION

## Self on the audio power interface

**Switched  
capacitor psus**

**Microammeter**

**Digital tv  
explained**

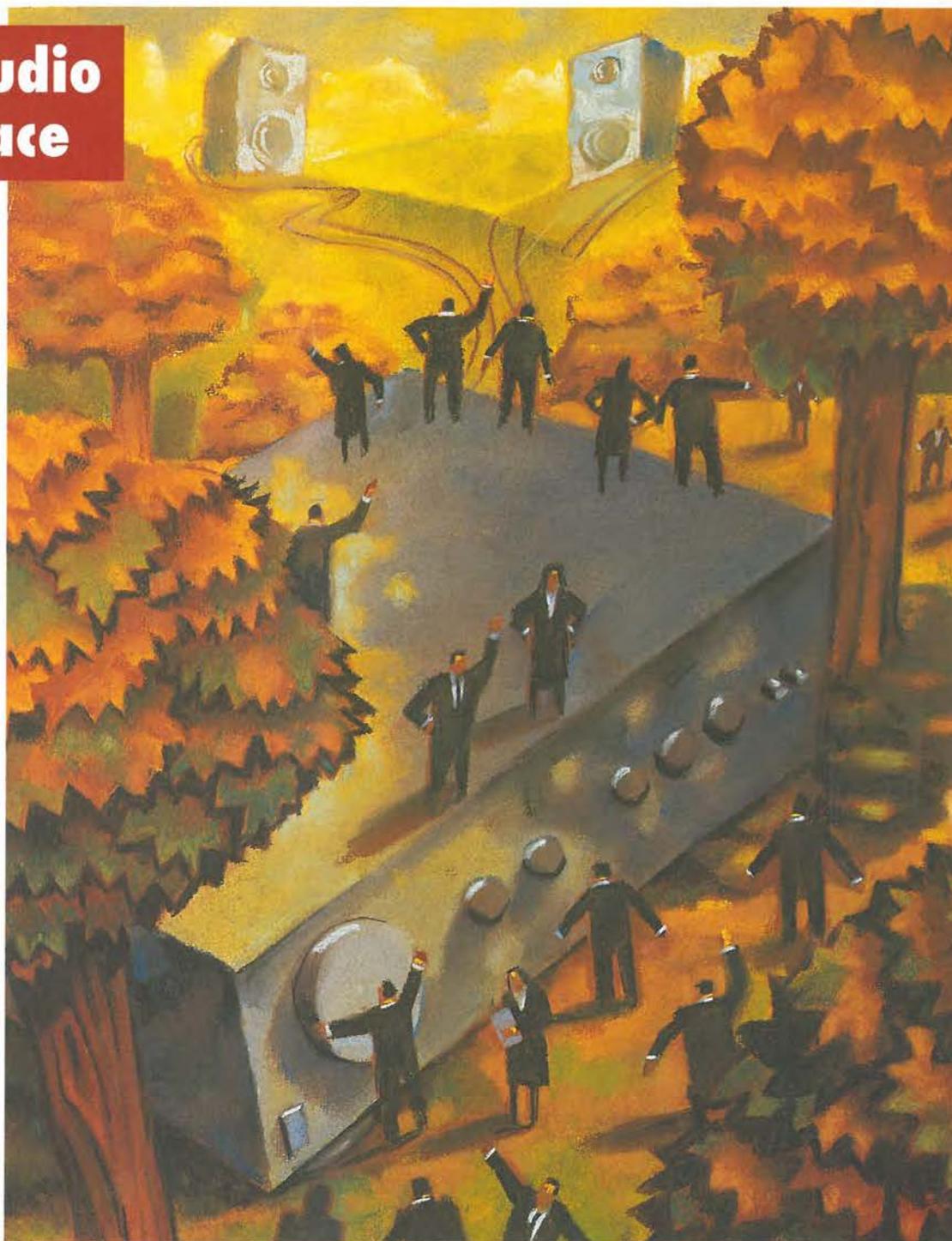
**MSF clock  
interface**

**Yagi by genes**

**Air-cored coil  
designer**

**10 circuit ideas**

**Internet for  
designers**



**£600 for a circuit idea?**



9 770959 833035

# NOW, THE BATTLE IS REALLY OVER

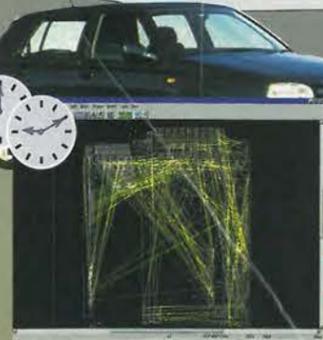
After ten years and with more than 20,000 users ULTimate Technology now offers exactly the performance and design capacity you need. Upgrades to larger versions are possible based on the price difference. Call us to determine which ULTiboard fits your requirements.

**START**

**ULTIBOARD 10 YEARS**

20,000 USERS

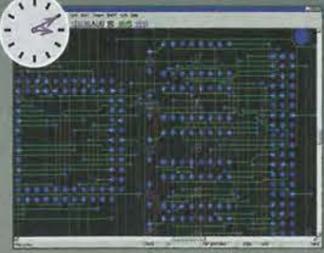
**CHALLENGER** The affordable route



The schematic is ready, the board outline established and all components are imported. The components with a fixed location are placed interactively. (10 min.)



The placement of the components is done with the real-time help of the Force Vectors indicating the preferred location. Detailed placement is performed with the help of the rats-nest. (90 min.)



ULTiboard features editing with real-time DRG. Reroute-While-Move allows shoving of busses (including vias) without losing connections. ULTiboard GXR finishes the design. (270 min.)

The core of each package is the ULTiboard PCB Design system, renowned for its short learning curve, Real-Time Design Rule Check (preventing errors) and the powerful interactive functionality. The low cost Challenger (£775 for 1400 pins design capacity) adds the gridded auto-router ULTiboard GXR (1/20" & 1/40"; suited for designs with thru-hole components). This best-seller is much in favour with interactive designers.

## SPECIAL OFFER

Each ULTiboard package with >1400 pins design capacity will be supplied with a FREE ULTicap Schematic Design System until September 30th. Call us for the reduced price!

## UPDATE POLICY

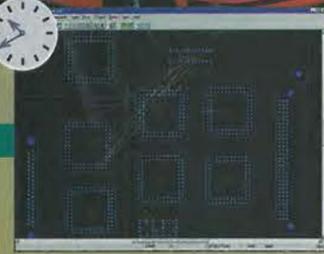
During this summer those who order the above (and also existing users with a valid update subscription) will receive a free upgrade with the SpiceAge Mixed Mode Simulator, integrated with the release of ULTicap Windows 95 and ULTibase, the latest components database, with which up to 14 relevant specs per component, as well as design-in data about equivalents, can be stored.

The Wizard adds advanced Auto-Placement to the Designer, which gives a tremendous boost to efficiency, and a powerful interactive Autorouter, which means the designer remains in charge! Top class performance from £2590.

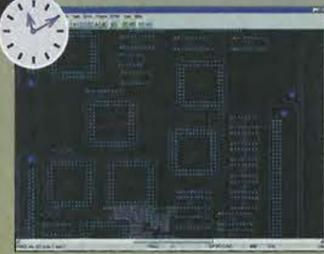
All prices are excl. VAT.

## DESIGNER The FAST lane

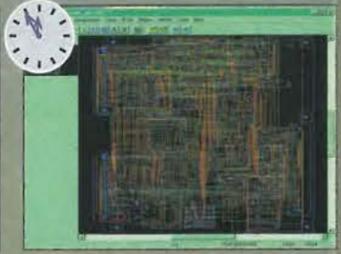
The ULTiboard designer offers besides all Challenger functions the high-end SPECCTRA SP4 Shape Based Auto-Router, very suitable for complex and/or SMD Designs. With its unequalled price/performance ratio it is the darling of engineering managers: from £1395.



AutoPlace rapidly and conveniently places the remaining components with algorithms that approach the interactive method of expert designers. On-line changes are possible. (5 min.)



Power and Ground are routed semi-automatically (under the management of the designer). The (EMC) critical connections are also layed interactively. (15 min.)

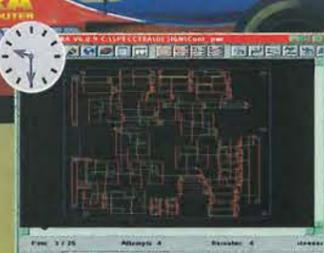


Now the SPECCTRA Autorouter is employed to finish the routing of the design at high speed and with high-grade quality. All design rules are fully respected. (45 min.)

## WIZARD The EXPRESS way



AutoPlace rapidly and conveniently places the remaining components with algorithms that approach the interactive method of expert designers. On-line changes are possible. (5 min.)



Power and Ground are routed semi-automatically (under the management of the designer). The (EMC) critical connections are also layed interactively. (15 min.)

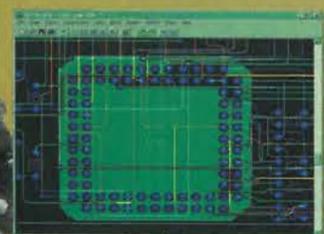


Now the SPECCTRA Autorouter is employed to finish the routing of the design at high speed and with high-grade quality. All design rules are fully respected. (45 min.)

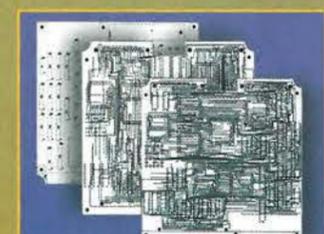


**FINISH**

CIRCLE NO. 101 ON REPLY CARD



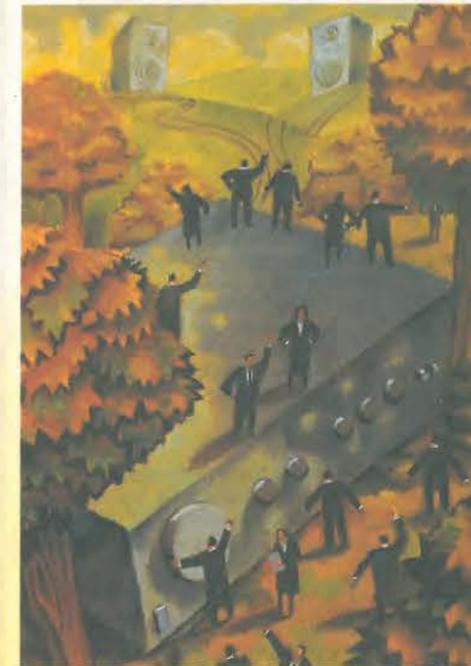
All adjustments are done quickly and efficiently with the interactive autorouter. All the corners of the traces are chamfered and polygons are placed. (10 min.)



Following the connectivity- and design rule checks, the output on matrix or laser printers, pen or photo plotters can be run. Back-Annotation automatically updates the schematic. (25 min.)

**ULTIMATE TECHNOLOGY** (UK) Ltd  
 E-mail: sales@ultiboard.com  
 Internet: http://www.ultiboard.com  
 UK/Ireland Sales-Office:  
 Unit 1, Lodges Barn  
 Coxbury Lane,  
 St. Briavels, Lydney,  
 Glos. GL 15 6QJ  
 tel. : (+44) 1594 - 810100  
 fax : (+44) 1594 - 810200

# Contents



Cover - Jamel Akib

**752 MULTILAYER AIR-CORED COILS**  
 Wheeler's equations are fine if you want to equate inductance from coil dimensions, but the designer's task is usually the reverse.

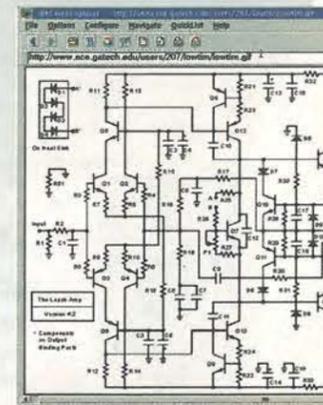
**754 SWITCHED CAPACITOR POWER SUPPLIES**  
 Ian Hegglin looks at the possibilities for efficient power converters without inductors.

**771 MEASURING MICROAMPS**  
 Robert Pearson's ammeter has ranges down to 20µA and only 0.1Ω shunt resistance.

**780 SKIN EFFECT**  
 Nick Wheeler outlines how rf signals tend to travel along a wire's surface.

**782 PWM AMPLIFIER**  
 Richard Lines' simple design is useful for low-frequency control, driving to 5A at 25V.

**Special offer**  
 20% reader discount on microcontroller evaluation kits - see page 751.



Findings from the Internet include a high-performance power amplifier - page 725.



Big bang. Explosions have been used at Los Alamos to generate massive magnetic pulses - see page 715.

## Regulars

**717 THE AUDIO POWER INTERFACE**  
 So you thought you knew all about damping factor and the like? Doug Self explores what really happens at the audio power amplifier's output.

**725 HANDS ON INTERNET**  
 Cyril's monthly findings include non Spice tools for electronics engineers.

**730 CAMCORDER DUBBER**  
 Ian Hickman has a cure for camcorder tapes with unwanted soundtracks.

**733 SOUND FROM ALL ANGLES**  
 Loudspeaker guru Martin Colloms explains the benefits and pitfalls of home cinema.

**739 GENETICALLY DESIGNED YAGI**  
 Richard Formato looks at a progressive method of antenna design and includes a three-element example for 50MHz.

**743 DIGITAL TV BROADCASTING**  
 Pat Hawker describes the technology behind the UK's planned digital tv services.

**748 CHANGING TIMES**  
 Ed Buckley's PIC-based interface turns raw MSF data in PC-ready RS232 time data.

**707 COMMENT**  
 History: who needs it?

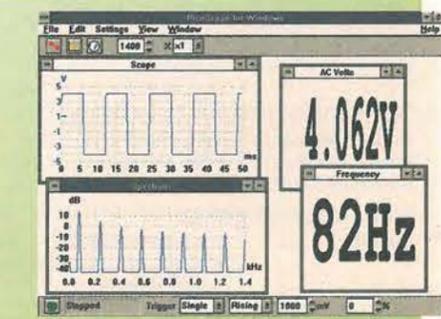
**708 NEWS**  
 GPS for sale? 60ns otp memory, UK research spending, Record audio cds, SiGe technology.

**713 RESEARCH NOTES**  
 Micromachines and chips integrated, DNA logic, chemical analysis.

**762 CIRCUIT IDEAS NEW REWARDS**

- Serial eeprom programmer
- 10pF to 10µF meter
- Calculator chip coprocessor
- High-power inductor
- New square roter
- High-order filters
- Current-dependent rectifier

Your circuit idea could win you a 50MHz virtual instrument plus £100, see page 762.



**775 NEW PRODUCTS**  
 Passive, active and computing products, classified for convenience.

**786 LETTERS**  
 Charging alkaline cells, Noise in EMC, Crossover distortion, Loudspeakers.

**OCTOBER ISSUE ON SALE 4 SEPTEMBER**

# Q. Why Simulate?

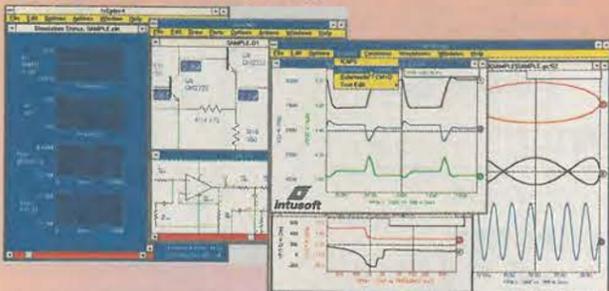
**A. Because It Really Works...**

...when you have the right software tools. With Intusoft's ICAP/4, The Virtual Circuit Design Lab, you can simulate the toughest System, IC, and Board-level designs.

**NEW ICAP/4Rx lower cost, high capability. ICAP/4Windows Ver 8.1, now shipping**

## → Ease of Use for The Beginner, Power For The Professional

With ICAP/4Windows you can sweep ANY circuit variable from the schematic and instantly view the results. Seamless schematic-simulator integration makes it easy to see the effects of design changes.



## → Unmatched SPICE Power

Interactive Native Mixed Mode SPICE 3F and XSPICE based simulator with unlimited circuit size

Simulate all types of designs: Power, ASIC, RF, Analog, Digital, Electro-Mechanical

Advanced Features: AHDL Modelling, Latest BSIM3 MOS model, Simulation Alarms, Scripting Language

State-of-the-Art Convergence Algorithms

Powerful Behavioural Modelling Enhancements

New.. Interface Your Simulation with Test Hardware

## → Bigger SPICE libraries than ANY other vendor

10000+ models with more model types than any other vendor! Special RF and Power Libraries!

## → Integration With OrCAD® Capture™ or Protel® Schematic3™

We are the first to bring you real integration with other schematic packages using OLE2 techniques. You can run IsSpice directly from other schematics and cross-probe the results. All simulation functions are available from dialogues and little or no typing is required.

## → Software That Meets Your Needs

Network Version (No Protection Key Required)  
Annual Maintenance Contracts are available  
Windows, 95, NT, DOS, Macintosh, Power Mac

## → Some Upgrade paths:

ICAP/4Rx → ICAP/4Windows → Test Designer  
→ ICAP for OrCAD  
→ ICAP for Protel

**Simply The Best SPICE At An Unbeatable Price!**

**New!**  
Magnetics Designer  
for transformer &  
inductor design  
**Even Newer!**  
Test Designer for fault  
analysis & design  
testability

**Download Your FREE SPICE Simulation Kit, App Notes, and FREE Model Libraries!**

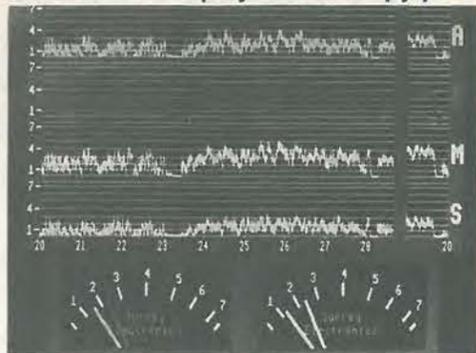
WebSite: <http://www.softsim.com>  
email: [info@softsim.com](mailto:info@softsim.com)

Technology Sources, 2 Signet Court, Swanns Road,  
CAMBRIDGE CB5 8LA, UK also trading as:  
Phone: 01223-516469  
Fax: 01223-729916

**SoftSim**

## CHART AUDIO LEVELS

In-vision colour display or hard copy printout



PPM10 In-Vision PPM and Chart Recorder generates a display emulating the well known coaxial TWIN movements for monitoring stereo audio levels and mono compatibility. Also: STEREO TWIN METER BOX comprising PPM9 board, featuring inherent stability with law under microprocessor control. A free standing mains powered box frequently used for final stereo monitoring when working to broadcast standards. Manufactured under licence from the BBC.

★ Advanced Active Aerial 4kHz-30MHz ★ Stabilizer frequency shift units for howl reduction ★ 10 Outlet Distribution Amplifier ★ Stereo Variable Emphasis Limiter ★ PPM9, PPM5 hybrid and PPM8 IEC/DIN -50/+6dB drives and movements ★ Broadcast Stereo Coders ★ Broadcast Monitor Receiver 150kHz-30MHz ★

**SURREY ELECTRONICS LTD**  
The Forge, Lucks Green, Cranleigh  
Surrey GU6 7BG  
Telephone: 01483 275997 Fax: 276477

## New Special Offers

New mini waterproof TV camera 40x40x13mm requires 10 to 20 volts at 120mA with composite video output (to feed into a video or a TV with a SCART plug) it has a high resolution of 450 TV lines Vertical and 350 TV lines horizontal, electronic auto iris for nearby dark (1 LUX) to bright sunlight operation and a pinhole lens with a 92 degree field of view, it focuses down to a few CM. It is fitted with a 3 wire lead (15 in grid and video out).....	£93.57 + VAT = £109.95 or 10+ £89.52 + VAT = £104.95	Used 8748 Microcontroller.....	£3.50
High quality stepping motor kits (all including stepping motors) 'Comstar' independent control of 2 stepping motors by PC (Via the parallel port) with 2 motors and software.....	Kit £67.00 Ready built £99.00	SL952 LHF Limiting amplifier LC 16 surface mounting package with data sheet.....	£1.95
Software support and 4 digital inputs kit.....	£27.00	DC-DC converter Reliability model V12P5 12v in 5v 200ma out 30v input to output Isolation with data.....	£4.95 each or pack of 10 £39.50
Power interface 4A kit.....	£36.00	Hour counter used 7 digit 240v AC 50Hz.....	£1.45
Power interface 8A kit.....	£46.00	QWERTY keyboard 58 key good quality switches new.....	£6.00
Stepper kit 4 (manual control) includes 200 step stepping motor and control circuit.....	£23.00	Airpax A82903-C large stepping motor 14v 7.5' step 270hm 68mm dia body 6.3mm shaft.....	£8.95
Hand held transistor analyser it tells you which lead is the base, the collector and emitter and if it is NPN or PNP or faulty.....	£35.45	Polystyrene capacitors box type 22.5mm lead pitch 0.9uf 250vdc.....	18p each
spare 6v battery.....	£1.20	1uf 250vdc.....	20p each
LEDs 3mm or 5mm red or green.....	7p each yellow 11p	15p.....	10p.....
each cable ties 1p each £5.95 per 1000, £49.50 per 10,000		1uf 50v bipolar electrolytic axial leads.....	15p each
Rechargeable Batteries		0.22uf 250v polyester axial leads.....	15p each
AA (HP7) 500mAh.....	£0.99	Polypropylene 1uf 400vdc (Wima MKP10).....	7.5p 100+
AA 700mAh.....	£1.75	27.5mm pitch 32x29x17mm case.....	75p each
C2AH with solder.....	£2.20	Philips 123 series solid aluminium axial leads.....	60p 100+
tags.....	£3.60	22uf 40v.....	40p each
D5AH with solder.....	£4.95	Philips 108 series long life 22uf 63v axial.....	25p 100+
tags.....	£4.95	Multilayer AVX ceramic capacitors all 5mm pitch 100v 100pf, 150pf, 220pf, 10,000pf (10n).....	15p 100+
1/2AA with solder.....	£2.50	500pf compression trimmer.....	3.5p.....
tags.....	£1.55	40 uf 370vac motor start capacitor (dielectric type containing no pcb).....	60p
AAA (HP16).....	£1.75	PPS 8.4V 110mAh.....	£5.95 or £49.50 for 10
180mAh.....	£1.75	Sub C with solder.....	£7.50 per 100
Standard charger charges 4 AA cells in 5 hours or 4Cs or 4Ds in 12-14 hours + 1xPP3 (1, 2 or 4 cells) may be charged at a time.....	£5.95	MX180 Digital multimeter 17 ranges 1000vdc 750vac 2Mohm 200mA transistor Hfe 9v and 1.5v battery.....	£19.00 for 6
High power charger as above but charges the Cs and Ds in 5 hours. AAs, Cs and Ds must be charged in 2s or 4s.....	£10.95	AMD 27256-3 Eproms.....	£2.00 each
Nickel Metal Hydride AA cells high capacity with no memory. If charged at 100ma and discharged at 250ma or less 1100mAh capacity (lower capacity for high discharge rates).....	£3.75	DIP switch 3PCD 12 pin (ERG SDC-3-023).....	20p each
Special offers, please check for availability.		LM557A TO3 case variable regulator.....	£7.50 per 100
Stock of 4 42x18mm Nicad batteries 17x16.5mm dia with red & black leads 4.8v.....	£5.95	Verbatim R300NH Streamer tape commonly used on nc machines and printing presses etc. it looks like a normal cassette with a slot cut out of the top.....	£4.95 ea.
5 button cell 6V 280mAh battery with wires (Varta 5x250K).....	£2.45	LM555 timer ic 16p.....	8 pin DIL socket 6p
Shaded pole motor 240Vac 5mm x 20mm shaft 80x60x35mm excluding the shaft £4.95 each.....		BS250 P channel mosfet.....	£0.45
115v AC 80v DC motor 4x22mm shaft 50mm dia x 60 long body (excluding the shaft) it has a replaceable thermal fuse and brushes.....	£4.95 each (£3.95 100+)	BC559 transistor.....	£3.95 per 100
7 segment common anode led display 12mm.....	£0.45	LM557A TO3 case variable regulator.....	£7.50 per 100
LM557A TO3 case variable regulator.....	£1.44 100+	74LS05 hex inverter.....	£10.00 per 100
GaAs FET low leakage current S8873.....	£12.95 10+		
	£7.95 100+		
	£0.45		
	£3.95 per 100		
	£20.00 per 100		
	£10.00 per 100		

All products advertised are new and unused unless otherwise stated. Wide range of CMOS TTL 74HC 74F Linear Transistors kits, Rechargeable batteries, capacitors, tools etc always in stock. Please add £1.95 towards p&p. VAT included in all prices.

**JPG Electronics, 276-278 Chatsworth Road, Chesterfield S40 2BH**  
Access/Visa Orders (01246) 211202 Fax: 550959  
callers welcome 9.30am to 5.30pm Monday to Saturday

CIRCLE NO. 107 ON REPLY CARD

ELECTRONICS WORLD September 1997

# History: who needs it?

BT is justifiably proud of its sensitive attitude towards ecological issues, sponsorship of the arts and its community programmes. All the more remarkable then that the company's regard for its own heritage is zero. For by the time you read these words, its highly regarded museum in London, The Story of Telecommunications, will have closed.

In a year that marks the 150th anniversary of the birth of Alexander Graham Bell, this seems a strange kind of celebration.

The collection will remain, but will no longer be open to visitors, and the same applies to the resource centre used by many researchers. BT says the closure is made pending a decision on its heritage policy – a subject of internal debate for the past 12 years without decision. Consultants have come, consultants have gone and still BT has no firm line on how to handle its history.

In reality, the closure is a simple matter of cash. Not a single department within BT is prepared individually to fund the cost of running what could – and should – be a showpiece facility. Hence the museum has been forced to shut its doors, simply to save five clerical salaries amounting to around £100,000 a year – or more graphically, 16 minutes of BT's annual profit.

For this trifling amount, BT is prepared to close down a facility that attracts 21 000 visitors annually – many of these youngsters on educational trips – and disperse to the four winds the public goodwill and accumulated knowledge and expertise of its staff.

It seems Philistine, but this is the same company which, notwithstanding the valiant efforts of the Computer Conservation Society in reconstructing Colossus at the wartime codebreaking headquarters at Bletchley Park, is intent on selling the site for development rather than dedicate it as a national museum of information technology. BT needs to make friends – not enemies – yet the company appears oblivious to the way it is alienating public opinion.

Earlier this year, the GEC company was forced to back down on its planned auction sale of historic Marconi artefacts, when the weight of informed opinion made this policy untenable.

BT's own heritage of what is effectively the national collection of communications is far larger in extent, and embraces an even wider rapport with everyday life, yet it is to be locked up and withdrawn from public gaze. Can this really be termed a responsible action for a major public company?

Had BT offered to donate its collection to the Science Museum, this would have been another matter. It argued that a national museum of communications should be established on an

**Electronics World** is published monthly. By post, current issue £2.35, back issues (if available) £2.50. Orders, payments and general correspondence to **L333, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.** Tlx: 892984 REED BP G. Cheques should be made payable to Reed Business Information Ltd. **Newstrade:** Distributed by Marketforce (UK) Ltd, 247 Tottenham Court Road London W1P 0AU 0171 261-5108.

**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 £32 UK 2 years £43.00 3 years £75.00. Surface mail 1 year £37.00 2 years £60.00 3 years £86.00 Air mail Europe/Eu 1 year £46.00 2 years £73.00 ROW 1 year £56.00 2 years £89.00



**...the museum has been forced to shut its doors, simply to save 16 minutes worth of BT's annual profit.**

independent basis – with the offer of some funding – this would be greeted with sympathy and understanding.

But the abrupt closure of an established facility purely to satisfy the accountants smacks of putting shareholders' gain before public responsibility.

There is now growing support for creating a National Museum of Information Technology, embracing communications, electronics and computing, with the Bletchley Park campus as the favoured site. Setting past indecision aside, now is the time to build on this momentum and create something for the new millennium. Otherwise our future generations will have to be content with photographs and fading memories.

As the descendant of the nineteenth-century telegraph companies, the old GPO telephones department and more, BT has a clear responsibility to the country to provide a facility for conserving its heritage. This task can be shared with other operators and manufacturers in this booming industry – and the time to start is now.

Ironically, it is one of Britain's newest and smallest telecomms operators which is showing the way. This year ScottishTelecom opened its World of Telecommunications museum in Edinburgh. It is ironic that BT's closure of its London museum has made this new venture the country's premier telecomms visitor centre.

Andrew Emmerson

## EDITOR

Martin Eccles  
0181 652 3128

## CONSULTANTS

Jonathan Campbell  
Philip Darrington  
Frank Ogden

## EDITORIAL ADMINISTRATION

Jackie Lowe  
0181-652 3614

## E-MAIL ORDERS

jackie.lowe@rbi.co.uk

## DESIGN

Alan Kerr

## ADVERTISEMENT MANAGER

Richard Napier  
0181-652 3620

## DISPLAY SALES EXECUTIVE

Joannah Cox  
0181-652 3620

## ADVERTISING PRODUCTION

0181-652 3620

## PUBLISHER

Mick Elliott

## EDITORIAL FAX

0181-652 8111

## CLASSIFIED FAX

0181-652 8938

## NEWSTRADE ENQUIRIES

0171 261 7704

## ISSN 0959-8332

## SUBSCRIPTION HOTLINE

01622 778000

## SUBSCRIPTION QUERIES

rpb.subscriptions@rbi.co.uk  
Tel 01444 445566  
FAX 01444 445447

For a full listing of  
RBI magazines:  
<http://www.reedbusiness.com>

**REED BUSINESS INFORMATION**

# UP DATE

## GPS is on the market

GEC-Plessey Semiconductors (GPS) is up for sale. GEC managing director, George Simpson, told a stockbrokers' analysts' meeting recently that he was looking to dispose of the UK's last fully integrated microelectronics manufacturer.

It is assumed that GPS and GEC were implementing the disposal before Simpson told analysts. However, GEC refused to make any official comment on the situation other than to say: "We have not announced any disposals."

In a written statement, GPS managing director Tom Urwin said: "GPS is now actively seeking a suitable partner." GPS appears to look on the move as an opportunity

to find an owner which will invest in it appropriately. Under GEC's ownership, investment constraints prevented GPS from maintaining leading edge production process technology.

Obvious candidates for ownership of GPS are Rockwell

Semiconductor of the US and Siemens of Germany. "GEC-Plessey has some attractive positions - they have a very good bipolar capability," Dr Dwight Decker, president of Rockwell, said last autumn. "What we're looking for is mixed signal technology with a broad application range. There are good reasons why we'd like to be geographically distributed."

Rockwell talked to GEC last year

about buying GPS.

Siemens Semiconductor owned briefly a share of GPS following the GEC-Siemens takeover bid for Plessey. Jurgen Knorr, president of Siemens Semiconductor said at the time: "We wanted GPS; we were interested in it years before."

If those two fail to buy GPS, then there is a possibility that one of Korean Big Three - which want to diversify out of dynamic ram - could buy GPS for its logic and system asic capabilities.

GPS is ninth in the world for gate array logic and has an unrivalled capability for putting systems-on-a-chip - expected to be the hottest growth area in the semiconductor business for the next decade.

## OTP memory has 60ns access

Philips Semiconductors has introduced a fast 60ns one-time-programmable, or otp, memory process for its microcontroller products. One-time-programmable memory made by this process is now included in Philips XA 16-bit and 80C51 8-bit microcontrollers.

Developed for Philips Semiconductors by Philips Research Labs, the new OTP is claimed to incorporate three innovations.

The first is that it takes only two additional mask steps compared with its standard 0.5µm c-mos process.

Secondly, it avoids the use of mask-intensive high voltage (13V) transistors to switch the programming voltage. Instead, it exploits the fact that the transistors only need to survive long enough to program the memory matrix once

and uses low voltage transistors that need no extra masks.

Including a conductivity-improving titanium salicide layer between the metallisation and control gate is the third development.

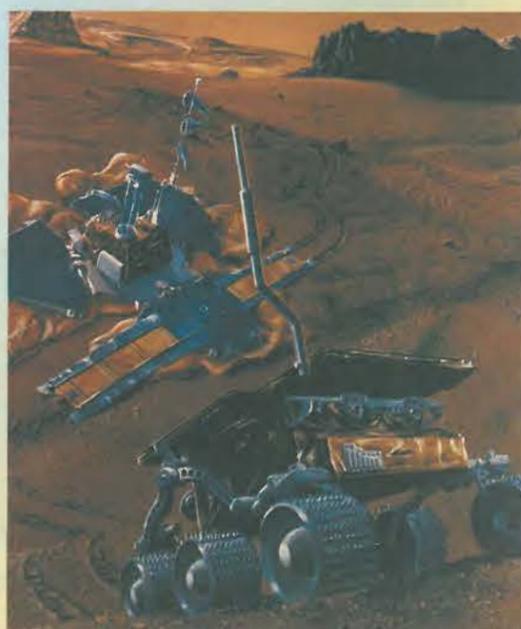
Philips has extended the control gate sideways so that it forms a top hat over the floating gate. This shields the control gate from contact with the salicide.

Each memory cell measures 7µm<sup>2</sup> and can operate between 1.8 and 3.3V. Blocks of up to 4MByte can be created at a time.

The company claims with the conventional vertical stack of equally sized floating gate-insulator-control gate, any salicide deposited on top of the stack also gets on to the stack sides and shorts out the two gates.

## EASIER ROUTE TO ELECTRONICS WORLD SUBSCRIPTIONS

You can now obtain or renew a subscription by e-mailing [rbp.subscriptions@rbi.co.uk](mailto:rbp.subscriptions@rbi.co.uk)  
Our Hotline number 01622 778000 remains the same, as do the normal enquiry lines, 01444 445566 voice, Fax 01444 445447.



Independence Day... Nasa's Jet Propulsion Laboratories' (JPL) latest probe, the Mars Pathfinder, is set to land on the planet on 4 July. It comprises the Lander which will oversee the various experiments and communicate the results back to Earth, and the Rover vehicle which will explore the planet surface, taking pictures as it goes. To cut the project's cost, the Mars Pathfinder has made use of commercial-off-the-shelf components including VMEbus cards and Wind River's VxWorks real time operating system (RTOS). The RTOS is used to control the probe's flight and planet descent - triggering the airbags before it hits the planet's surface - and the Rover vehicle.

## UK research spending worsens

The proportion of UK electronics companies' sales turnover spent on research and development fell last year, according to the DTI's *UK R&D Scoreboard 1997*.

Although r&d expenditure went up two per cent to £1.204bn, as a percentage of sales it fell by 0.1 per cent to just 3.1 per cent of sales turnover. This fall was not as great as that in the previous year, however, when it fell from 4.2 to 3.2 per cent.

"Too many of our companies appear to lag behind the competition," said science, energy and industry minister John Battle, commenting on the scoreboard. "Evidently those companies may be under-investing in absolute amounts and in terms of research and development intensity [percentage of sales spent on r&d] when compared with their top international competitors. This could have serious implications for the long term."

1996				1995			
Rank	Company	R&D spend	% of sales	Rank	Company	R&D spend	% of sales
1	GEC	£432m	6.9	1	GEC	£412m	7.1
2	Siemens	£133.6m	8.9	2	ICL	£149.6m	4.8
3	IBM	£112m	2.2	3	Siemens	£132.6m	10.3
4	ICL	£101.3m	3.5	4	IBM	£100.7m	2.2
5	Racal Elec	£70.8m	6.7	5	Racal Elec.	£64.7m	6.8
6	Motorola	£36.7m	1.2	6	Motorola	£36.7m	1.2
7	HP	£31.9m	1.7	7	BICC	£31m	0.7
8	BICC	£30m	0.7	8	HP	£29.8m	1.7
9	Bowthorpe	£23.5m	4.5	9	Rank Xerox	£21m	0.5
10	Rank Xerox	£20m	0.6	10	Cray Elec.	£20.3m	7.7

GEC maintained its position at number one spending £432m, increasing its expenditure by five per cent on the previous year. Siemens unseated ICL, whose research and development expenditure dropped 32 per cent, and moved to number two with a spend of £133.6m. IBM, ICL and Racal came third, fourth and fifth respectively.

Despite wanting more investment, Battle called for greater focus on the management of r&d. "Of course, devoting simply more money to r&d is not the only answer to ensuring the long term competitiveness of UK companies," said Battle. "Investment needs to be managed carefully so that it leads to successful development of new ideas."

## CDs allow audio recording

Philips Electronics says it will introduce one of the first audio cd recorders by the year end. The cd recorder is based on Philips' recordable cd technology and uses cd recordable disks that allow only one recording or cd rewritable disks that can be recorded and erased several times.

The cd recorder will be introduced in Europe first and then into markets worldwide. It is expected to cost

£450. However, the market for the recorder may be limited to just two or three years especially once recordable DVD systems become available in 1999.

Recordable DVD will be able to record audio and video sources and could also be used as a computer peripheral, recording computer data.

The recorder will implement copy protection agreements such as the Serial Copy Management System.

## Actel £1000 fpga design tools is now free on a Web page

Actel has made a version of its fpga design tools free for distribution over the Web, saving designers over £1000.

"Customers have asked for many years why they have to pay for this software," said Vaughan Price, European sales director. "We've taken the big step. This is something that has to be done."

Actel is the first company to make its design software for fpgas free, claimed Price. Altera is expected to follow suit, later this year.

The Designer Lite software includes all the features needed for fpga design. The only drawback is

the tool is limited to designs of 8000 gate or fewer.

"Below 8000 gates, people look at fpgas for first choice in logic integration. We want to remove all the obstacles," said Price. At these gate counts, designers will save up to \$2500 on the cost of tools. "But the real saving," he said, "is in the time and the convenience."

Included in the software is place and route, timing driven layout and analysis, and Verilog and Vital libraries. By the month end a VHDL synthesis tool will be added to the kit.

Designer Lite is available from [www.actel.com](http://www.actel.com).

## DVD - slow take off?

DVD players for television sets will penetrate less than two per cent of homes during the next five years, says a study from Strategy Analytics, an electronics and IT consultancy. The report claims that less than half a per cent of European homes will have DVD by the year 2000. Worldwide, DVD will only become accepted when recordable DVD becomes available, thereby replacing VHS video recorders. Annual sales are expected to reach 10m units by 2010.

## Europeans show interest in buying digital radio

Over a third of households in Europe are interested in buying digital radios. This is one of the results of a consumer study conducted by RSL/Ipsos for the World DAB Forum.

The survey was undertaken across six European countries with the participation of 5000 people. More than a third of those sampled who are also car drivers confirmed their interest in buying a DAB car radio due to its better reception.

A similar level of interest was shown for hi-fi sets and portable radios. pc-linked DAB services also appealed to special interest groups who use IT systems and pcs on a regular basis. The respondents were prepared to pay up to 50 per cent more for car radios and hi-fi receivers featuring DAB features, and twice as much for portables.

This was the largest ever consumer study of potential DAB penetration in Europe.

# SiGe device costs could be cut by new process

An Italian research group is attempting to reduce the cost of silicon-germanium devices by using ion implantation for their fabrication. SiGe heterojunction bipolar transistors, or hbt's, are faster than silicon-based ones, letting devices operate at 5GHz without resorting to GaAs technology.

The group, called IMETEM, comprises 15 people from the University of Catania. It resides at SGS-Thomson Microelectronics' wafer

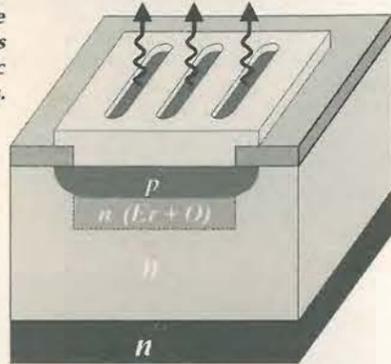
fab and research centre in Catania.

The group claims that existing techniques for producing SiGe structures, like molecular beam epitaxy (MBE) and chemical vapour deposition (CVD), although successful, are difficult to incorporate into current ULSI technology. This, it says, is delaying the adoption of SiGe commercially.

Its proposed approach for fabricating SiGe heterojunctions is a technique based on high dose germanium ion implantation into silicon. Ion implantation offers a high wafer throughput and can be confined to particular regions of the wafer.

Other IMETEM devices under development include an infra-red silicon led (see diagram). Silicon is not normally suitable for leds but, by including erbium-oxygen complexes in the material lattice near the PN junction, IMETEM has created an emitter that operates at 1.54µm, the fibre-optic communication wavelength. The group is also starting to look at silicon carbide-based semiconductors for high voltage use.

Silicon is not normally suitable for leds, but a new SiGe process from Italy could be used to produce leds for fibre-optic communications.



# New ideas for multi-media lans

US firms Microsoft, 3Com and videoconferencing specialist PictureTel are to collaborate to enable local area networks (LANs) to carry moving pictures and voice as well as data.

This, they believe, will "crack the technological barriers" which so far have prevented video communications to every office desktop.

To do this they have brought together PictureTel software - built around LiveManager 3.0, which is designed to handle continuous video and voice traffic without affecting other critical LAN traffic - with Microsoft's NetMeeting 2.0 software and 3Com's PACE high-performance LAN technology.

Meanwhile, Sony Broadcast & Professional UK has signed an ISDN reseller agreement with BT.

This is aimed at reducing the cost of purchasing systems by allowing Sony to sell a combined package of videoconferencing equipment and ISDN.

# New c-mos process promises 2.4GHz devices

Texas Instruments has detailed a 0.18µm c-mos process at a recent technology symposium in Japan. This is a follow on technology to its 0.21µm Timeline process announced last year.

With 25 picosecond delays and 2.4GHz analogue speeds, the company is targeting the 0.18µm process at wireless and optical communications. Radio and intermediate-frequency circuits, along with dsp baseband processing could be placed on the same device, claims Richard Kerslake, TI's Asic

marketing manager. The 2.4Gbit/s data rate is aimed at the new STM16 fibre optics communications standard.

"What would be really beautiful," said Kerslake, "would be to run this [STM16] straight into c-mos without using anything horrible like GaAs."

For the process, TI has switched to a shallow trench isolation. This, coupled with the reduced process dimensions doubles the available transistors.

While few, if any, designs will need 250m transistors, halving the die size for a given design could bring

significant cost reductions.

The as yet experimental process is to move to a production standard in the near future. Commercial use for the process is not expected for two years, but Kerslake expects design starts by the end of next year.

Most manufacturers - TI included - have yet to move to full production on 0.25µm geometries.

TI's own Timeline process, actually 0.21µm drawn, is only now ramping to production on microprocessors. Asics will follow shortly, said Kerslake.

# Traffic info for mobile phones

Trafficmaster, the traffic-guidance system firm, is to launch a service in the autumn which will provide mobile phone users with details of road hold-ups and delays.

The traffic firm would not disclose details of its proposed system.

However, it is expected that small in-car receivers will warn drivers of nearby traffic problems, prompting them to call a hotline for further details.

A spokesperson for Trafficmaster

said: "We have recently concluded a three-year deal with a mobile phone operator." However, she could not confirm the operator's identity.

Reports that the deal is with Cellnet were branded as hearsay by both companies. Dave Massey of Cellnet's corporate affairs said: "From our point of view this is speculation."

# Altera and Jam

Jam, a programming language for in-system programmable logic devices, has been unveiled by Altera.

The company claims JAM more than halves file sizes, while reducing the average device programming time by a factor of ten. Altera and its supporters are proposing the language goes to JEDEC for adoption as an industry standard.

Programmable logic manufacturers Cypress Semiconductor and Vantis, test equipment companies GenRad, JTAG and Teradyne, and device programmer manufacturers Data I/O and BP Microsystems all support the language.

# New: Windows software for TiePieSCOPE HS508 and TP508

This powerful windows software gives you new possibilities and intuitive control of the five integrated devices (Oscilloscope, Voltmeter, Transient recorder, Spectrum analyzer and Square wave generator) to perform all your advanced measurements

### Oscilloscope:

- Number of samples settable between 10 and 32760
- Up to 32K samples on screen
- Free settable pretrigger between 0 and 100%
- Easy time axis zoom: scaleable scrollbar slider
- Free settable sample frequency from 0.01Hz to 50MHz
- Graphical adjustment of vertical offset and gain
- WYSIWYG trigger level, - hysteresis and slope-adjustment with one control
- Place the mouse over a control, press the right button and adjust all properties of that control using the popup menu
- Cursor measurements
- Storing and recalling reference signals
- Math channel available
- Speedbutton toolbar
- Colour printing supported

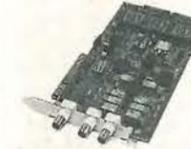
### Voltmeter:

- Up to six clear, fully configurable displays
- 10 math operations, like true RMS, mean, peak to peak, frequency etc.
- 16 display functions like Ch1+Ch2, Ch2-Ch1, Ch1\*Ch2, log(Ch/Ch2) etc.
- Data logging to disk and printer
- Speedbutton toolbar



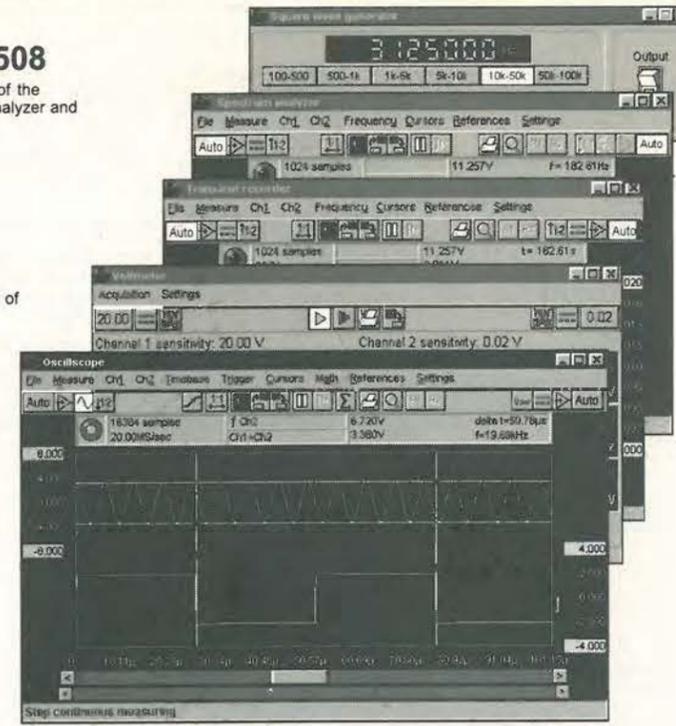
### TiePieSCOPE HS508

- interface parallel printer port
- resolution 8 bits
- input range 200mV - 80V full scale
- price £597.00 incl. software, manual and 2 probes (1:1/1:10 switchable)



### TP508

- interface PC-XT/AT ISA slot
- resolution 8 bits
- input range 20mV - 80V full scale
- price £630.00 incl. software, manual and 2 probes (1:1/1:10 switchable)



Minimum system requirements: Windows 3.1 or higher, 386 processor, 4MB RAM, 4MB free disk space

Prices are excluding VAT

TiePie engineering (NL)  
P.O. Box 290  
8600 WL SNEEK  
The Netherlands  
Tel.: +31 515 415 416

E-mail: tiepie@tiepie.nl  
Site: http://www.tiepie.nl



TiePie engineering (UK)  
28, Stephenson Road, Industrial Estate,  
St. Ives, Cambs, PE17 4WJ,  
United Kingdom  
Tel: +44 1480 460028 Fax: +44 1480 460340

CIRCLE NO. 108 ON REPLY CARD

**Takeda Riken Spectrum Analyser Type: TR4122B c/w Digital Memory Unit PRICE: £2000**

**Adret 740A Signal Generator 0.1-1120MHz PRICE: £15000**

**HP8660C + HP86632B + HP86603A Synthesized Signal Generator 1-2600MHz PRICE: £2300**

**Rohde & Schwartz Polyskop SWOB 5 + Accessories PRICE: £1800**

Adret 740A UHF Generator 0.1-560MHz £750	A & D AD3522 FFT Analyser + Results Printer £300	Adret 2230A Frequency Synthesizer 1MHz £50	HP 34800 Digital Voltmeter + 3484A Multi Function Meter £225
Anritsu MS420A Network Spectrum Analyser 10Hz-30MHz £1,750	Adret 5104 Driving Synthesizer 90-120MHz £125	Adret 461A Amplifier £50	HP 461A Amplifier £50
B & K 8235 500W 300dB Coaxial Attenuator £2,800	Boonton 8240 Modulation Meter £300	Adret 4303B Signal Generator £75	HP 5008A Signal Analyzer £50
Bird 3255 500W 300dB Coaxial Attenuator £2,800	Farnell 53500 Signal Generator £375	Advance TC17 Timer Counter £115	HP 5008A Signal Analyzer £50
Dushman CE24 Frequency Selective Level Meter £400	Farnell RB1030/35 Electronic Load 1KW 30A 35V £120	Alken SH2400P 20-100MHz £75	HP 5150A Thermal Printer £40
Datron 1061 Autocal £900	Farnell 83020 Power Supply Stabilised £130	APLAB LK200 Regulated Power Supply 0-30V 0-2A £25	HP 5245A Plug In Unit + HP5245L Counter £30
Datron 1061 Autocal £900	Farnell 050 Synthesized Signal Generator £390	Brookdeal TCU250 Regulated Power Supply 0-50V 2A £110	HP 5246L Electronic Counter £30
Farnell MF10090 Power Supply £600	Farnell 15707 MK2 Stabilized Power Supply £250	Brookdeal 411 Phase Sensitive Detector £25	HP 5302A 50MHz Universal Collator £40
Farnell MF10090 Power Supply £600	Farnell P5520 Pulse Signal Generator 10-520MHz £400	Brookdeal 1238 DC Calibrator £25	HP 5304A Timer Counter £30
Farnell PSU Type: MP30 Auto Ranging £250	Farnell FT52 Recorder Test Set £400	Brookdeal 8412 Phase Sensitive Detector £25	HP 5304A Asci-Parallel Converter £30
Fluke 45 Data Display Multimeter AC Calibrator £2,400	Fluke 8520A Digital Multi Meter £200	Brookdeal Ortholock/SC/9505 2 Phase Locking Analyser £75	HP 5901A HP71B Isolated D/A/PSU Programmable £40
Fluke 5200A Programmable AC Calibrator £2,400	Fluke 8600A Digital Multi Meter £150	Brookdeal 2422 Reference Unit £25	HP 6111A DC Power Supply 0-20V 0-1A £75
Fluke 540B Thermal Transfer Standard c/w Voltage Plug-1 £400	Giga 0R1101A 12-18GHz Microwave Signal Generator £200	Brookdeal 8425 Scan Delay Generator £25	HP 6130C Digitally Controlled Voltage Sources £60
HP 11683A Range Calibrator £250	Giga GU1328A 2-8GHz Microwave Signal Generator £200	Coscor 333A Test Set £40	HP 8403A Modulator £50
HP 16310 Logic Analyser £550	Harris RF/2305 Receiver/Exciter £200	Drohn-Hilt 5300A Function Generator £75	HP 8418A/101 Auxiliary Display Holder £50
HP 1725A 275MHz Delay Sweep £350	Hitchai V5508 50MHz Oscilloscope £150	ICOPICO 004 Digital Ohmmeter £75	HP 8717B Transistor Bias Supply £30
HP 3312A Function Generator 0-13MHz £1,800	HP 181A Main Frame c/w 1840A + 1825A £125	Dana 4200 Digital Multi Meter £20	HP 8405A Frequency Combined Generator £75
HP 3355A Synthesizer Level Generator 81MHz £2,000	HP 11713A Attenuator Switch Driver £300	Datron 1030 RMS Volt Meter £25	HP 6130C Digitally Controlled Voltage Sources £60
HP 3336B + A Synthesizer Level Generator £2,000	HP 1741A 100MHz Oscilloscope £200	Datron 1050 DC Volt Meter £20	HP 8403A Modulator £50
HP 3455A Digital Voltmeter £350	HP 1742A 100MHz Oscilloscope £275	Datron 1030 RMS Volt Meter £25	HP 8418A/101 Auxiliary Display Holder £50
HP 3455A Digital Voltmeter £350	HP 3400A RMS Volt Meter £120	Farnell AC/DC Millivolt Meter TM2 £20	HP 8717B Transistor Bias Supply £30
HP 35650 System Main Frame £2,000	HP 3570A Network Analyser 50Hz-13MHz £150	Farnell F51 Function Generator £300	HP 8405A Frequency Combined Generator £75
HP 3580A Spectrum Analyser 5Hz-50Hz £600-800	HP 3770B Telephone Line Analyser £200	Farnell DM131 Digital Multimeter £30	HP 6130C Digitally Controlled Voltage Sources £60
HP 3581C Selective Volt Meter 15Hz-50kHz £350	HP 433A Distribution Analyser £300	Farnell LFI 10MHz 1MHz Sine/Square Oscillator £65	HP 6460T1 100MHz Digital Frequency Meter £25
HP 3582A Spectrum Analyser 0.001Hz-25.599kHz £1,500	HP 435A Power Meter £175	Farnell LFM2 Sine/Square Oscillator £65	HP 6460T1 100MHz Digital Frequency Meter £25
HP 5411D Digital Oscilloscope 500MHz £2,700	HP 488A Microwave Amplifier 1-2GHz £250	Farnell SC9B Signal Generator Interface £150	HP 6460T1 100MHz Digital Frequency Meter £25
HP 54200A Digital Oscilloscope £1,500	HP 5005A Signature Multimeter £150	Feedback EW904 Electronic Watt Meter £200	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 54501A 100 MHz Digital Oscilloscope £1,500	HP 5315A Universal Counter £200	Fluke 780A Universal Counter/Timer £150	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 6002A DC 0.50V 0.15A 200W £400	HP 5328A Universal Counter £150	Fluke 8600A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 6261B DC 0.20V 0-50A £450	HP 8005B Pulse Generator 0.3Hz-10MHz £150	Fluke 780A Universal Counter/Timer £150	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8502A Transmission Reflection Test Set 500kHz-1.3GHz £3,500	HP 8015A Pulse Generator 1Hz-50MHz £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8502A 500kHz-1.3GHz Network Analyser £3,000	HP 8016A Wave Generator £175	Fluke 780A Universal Counter/Timer £150	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8554B RF Section 0-1200MHz £700	HP 8412B Phase Magnitude Display £175	Fluke 8015A Pulse Generator 1Hz-50MHz £175	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8602B Signal Generator £1,100	HP 8414A Polar Display £175	Fluke 8016A Wave Generator £175	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8647A 250kHz-1000MHz Signal Generator £2,500	HP 8418 Polar Display £175	Fluke 8016A Wave Generator £175	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8648 5.4-12.5GHz Signal Generator £2,000	HP 8443A Tracking Generator/Counter £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8740A Transmission Test Unit £350	HP 8444A Automatic Prescaler £350	Fluke 780A Universal Counter/Timer £150	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8741A Reflection Test Unit 0.1-2GHz £350	HP 8405A Vector Voltmeter £250	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8742A Reflection Test Unit 2-12.4GHz £2,000	HP 8552B RF Section 0-100MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8754A Network Analyser 4-1300MHz £2,000	HP 8553L RF Spectrum Analyser 0-110MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8910A Modulation Analyser 150kHz-1300MHz £2,500	HP 8558A LF Spectrum Analyser £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 8938B Audio Analyser £3,200	HP 8601A RF Section 0.1-110MHz £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 9325B Frequency Function & Waveform Synthesizer £3,000	HP 8750A Storage Normalizer £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
HP 86200 + HP86222B Sweep Generator 0.01-2.4GHz £1,500	HP 891C Microwave Amplifier 2-4GHz £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Iwatsu SAS/8130 Waveform Analyser £400	HP 8413A Phase Gain Indicator Unit £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Iwatsu DM5/6430 Digital Memory Oscilloscope £1,100	HP 8414A Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Iwatsu DM5/6430 Digital Memory Oscilloscope £1,100	HP 8418 Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
JRC NJ2/900JN Cellular Tester £500	HP 8443A Tracking Generator/Counter £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Kikusui PL2100W 100W Electronic Load £450	HP 8444A Automatic Prescaler £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Kikusui TD5850 W/S1 Auto Tester £1,800	HP 8405A Vector Voltmeter £250	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Leader Loc/7005 Oscilloscope Calibrator £500	HP 8552B RF Section 0-100MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
Leory 9100 Arbitrary Function Generator £500	HP 8553L RF Spectrum Analyser 0-110MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8558A LF Spectrum Analyser £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8601A RF Section 0.1-110MHz £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8750A Storage Normalizer £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 891C Microwave Amplifier 2-4GHz £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8413A Phase Gain Indicator Unit £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8414A Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8418 Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8443A Tracking Generator/Counter £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8444A Automatic Prescaler £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8405A Vector Voltmeter £250	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8552B RF Section 0-100MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8553L RF Spectrum Analyser 0-110MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8558A LF Spectrum Analyser £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8601A RF Section 0.1-110MHz £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8750A Storage Normalizer £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 891C Microwave Amplifier 2-4GHz £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8413A Phase Gain Indicator Unit £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8414A Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8418 Polar Display £175	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8443A Tracking Generator/Counter £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8444A Automatic Prescaler £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8405A Vector Voltmeter £250	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8552B RF Section 0-100MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8553L RF Spectrum Analyser 0-110MHz £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8558A LF Spectrum Analyser £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8601A RF Section 0.1-110MHz £350	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8750A Storage Normalizer £200	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 891C Microwave Amplifier 2-4GHz £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8413A Phase Gain Indicator Unit £500	Fluke 8000A Digital Multimeter £50	HP 1000F MK11 10Hz-32MHz P.O. Frequency Counter £70
	HP 8414		

**DIFFERENTIAL THERMOSTAT KIT** Perfect for heat recovery, solar systems, boiler efficiency etc. Two sensors will operate a relay when a temp difference (adjustable) is detected. All components and pcb. £29 ref LOT93

**SOLAR WATER HEATING PLANS £6 REF SOLP**  
**PC POWER SUPPLIES**  
**PACK OF 8 FOR £9.95**

That's right! 8 power supplies for £9.95! These are all fan cooled (usually 12v) our choice of specs etc, and are sold as seen. But worth it for the fans alone! ref XX17

**MAINS POWER SAVER** UK made plug in unit, fitted in seconds, can reduce your energy consumption by 15%. Works with fridges, soldering irons, conventional bulbs etc. Max 2A rating. £9 each ref LOT71, pack of 10 £69 ref LOT72

**DC TO DC CONVERTERS**  
 DRM59 input 10-40vdc output 5v 8A E15 DRM128 input 17-40vdc output 12v 8A E18 DRM158 input 20-40vdc output 15v 8A E18

DRM248 input 29-40vdc output 24v 8A E12 DRS123 input 17-40vdc output 12v 3A E10 DRS153 input 20-40vdc output 15v 3A E20 DRS243 input 29-40vdc output 24v 3A E8

**HITACHI LM225X LCD SCREENS** 270x150mm, standard 12 way connector, 640x200 dots, tac spec sheet, £15 each ref LM2

**HOME DECK CLEARANCE** These units must be cleared! Leads, a infra red remote qwerty keyboard and receiver, a standard UHF modulator, a standard 1200/75 BT approved modem and loads of chips, capacitors, diodes, resistors etc all for just £10 ref BAR33.

**PORTABLE X RAY MACHINE PLANS** Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies can be used for experimental purposes. Not a toy or for minors! £6/set. Ref FXP1.

**TELEKINETIC ENHANCER PLANS** Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing psychic phenomenon. £4/set Ref F/TKE1.

**ELECTRONIC HYPNOSIS PLANS & DATA** This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set. Ref F/EH2.

**GRAVITY GENERATOR PLANS** This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means - cause it to levitate. £10/set Ref F/GRA1.

**WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS** Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects. 'Plasma in a jar', St Elmo's fire, Corona, excellent science project or conversation piece. £5/set Ref F/BTC1/LG5.

**COPPER VAPOUR LASER PLANS** Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commission of NEGEV in Israel. £10/set Ref F/CVL1.

**VOICE SCRAMBLER PLANS** Miniature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/V59.

**PULSED TV JOKER PLANS** Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED. £8/set Ref F/TJS.

**BODYHEAT TELESCOPE PLANS** Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.

**BURNING, CUTTING CO2 LASER PLANS** Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LCT.

**DYNAMO FLASHLIGHT** Interesting concept, no batteries needed just squeeze the trigger for instant light apparently even works under water in an emergency although we haven't tried it yet! £6.99 ref SC152

**ULTRASONIC BLASTER PLANS** Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquids. Many cleaning uses for PC boards, jewelry, coins, small parts etc. £6/set Ref F/ULB1.



Water pump motors, mains powered, 165x75mm, 5mm shaft. £6 ea ref MM10.  
 Pack of 3 for £12 ref MM11.

**ANTI DOG FORCE FIELD PLANS** Highly effective circuit produces time variable pulses of acoustical energy that dogs cannot tolerate £6/set Ref F/DDG2

**LASER BOUNCE LISTENER SYSTEM PLANS** Allows you to hear sounds from a premises without gaining access. £12/set Ref F/LLIST1

**PHASOR BLAST WAVE PISTOL SERIES PLANS** Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PS4

**INFINITY TRANSMITTER PLANS** Telephone line grabber/room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/TELEGRAB.

**BUG DETECTOR PLANS** Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/BD1.

**ELECTROMAGNETIC GUN PLANS** Projects a metal object a considerable distance - requires adult supervision £5 ref F/EML2.

**ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND!** £5/set Ref F/EMA1.

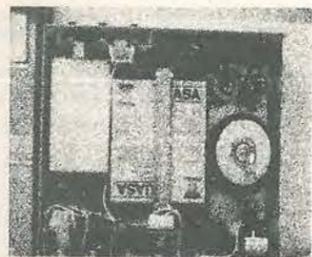
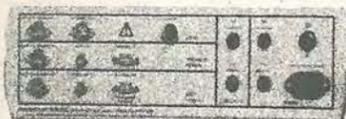
**PARABOLIC DISH MICROPHONE PLANS** Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5

**2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000VDC OUTPUT GENERATOR PLANS** Operates on 9-12vdc, many possible experiments. £10 Ref F/HVM7/TCL4.

**MEGA LED DISPLAYS** PCB fitted with 5 seven segment displays each measuring 55 x 38mm. £5 ref LEDs5.

**MOD TRANSMITTING VALVES SJ180E £80 ref LOT112**

**SWITCHED MODE PSU'S** 244 watt, +5 32A, +12 6A, -5 0.2A, -12 0.2A. There is also an optional 3.3v 25A rail available. 120/240v // P. Cased, 175x90x145mm. IEC inlet Suitable for PC use (6 d/drive connectors 1 m/board). £15 ref LOT135



**VIDEO PROCESSOR UNITS? 76v 10AH BATT/24V 8A TX** Not too sure what the function of these units is but they certainly make good strippers! Measures 390x320x120mm, on the front are controls for scan speed, scan delay, scan mode, loads of connections on the rear. Inside 2x 6v 10AH sealed lead acid batts, pcb's and a 8A? 24v toroidal transformer (mains in), sold as seen, may have one or two broken knobs etc due to poor storage. £15.99 ref VP2

**MINI FM TRANSMITTER KIT** Very high gain preamp, supplied complete with FET electret microphone. Designed to cover 88-108 Mhz but easily changed to cover 63-130 Mhz. Works with a common 9v (PP3) battery. 0.2W RF. £9 Ref 1001.

**3-30V POWER SUPPLY KIT** Variable, stabilized power supply for lab use. Short circuit protected, suitable for professional or amateur use 24v 3A transformer is needed to complete the kit. £14 Ref 1007.

**1 WATT FM TRANSMITTER KIT** Supplied with piezo electric mic. 8-30vdc. At 25-30v you will get nearly 2 watts! £15 ref 1009.

**FM/AM SCANNER KIT** Well not quite, you have to turn the knob your self but you will hear things on this radio that you would not hear on an ordinary radio (even TV). Covers 50-160mhz on both AM and FM. Built in 5 watt amplifier, inc speaker. £18 ref 1013.

**3 CHANNEL SOUND TO LIGHT KIT** Wireless system, mains operated, separate sensitivity adjustment for each channel, 1,200 w

**BULL ELECTRICAL**

250 PORTLAND ROAD, HOVE, SUSSEX.  
 BN3 5QT. (ESTABLISHED 50 YEARS).

MAIL ORDER TERMS: CASH, PO OR CHEQUE  
 WITH ORDER PLUS £3.50 P&P PLUS VAT.

24 HOUR SERVICE £4.50 PLUS VAT.  
 OVERSEAS ORDERS AT COST PLUS £3.50  
 (ACCESS, VISA, SWITCH, AMERICAN EXPRESS)

phone orders : 01273 203500

FAX 01273 323077

E-mail bull@pavilion.co.uk

CIRCLE NO. 110 ON REPLY CARD

power handling, microphone included. £17 Ref 1014.

**Install a coin box telephone at home for less than £5**

By using our phone box, you get everything you need to convert any standard telephone into a coinbox telephone. You simply open the box, plug your telephone into a connector inside and then plug the coinbox lead into your telephone socket, it's that simple! There are one or two catches however.

**Catch one** is that the lock and hinges may be damaged/broken, this doesn't really matter because you could replace the hinges easily and change the lock or you could refit the front panel onto a box of your own choosing.

**Catch two** is that the three coin slots accept £1, 50p and 10p's this is fine except that the 10p slot is for the older 10p piece so you would need to glue a small piece of plastic across the bottom of the slot on the inside to reduce the hole size. Full programming instructions are included with every coinbox Bargain price £4.99 ref CBT1

**4 WATT FM TRANSMITTER KIT** Small but powerful FM transmitter, 3RF stages, microphone and audio preamp included. £24 Ref 1028.

**STROBE LIGHT KIT** Adjustable from 1-60 hz (a lot faster than conventional strobes), Mains operated. £17 Ref 1037.

**COMBINATION LOCK KIT** 9 key, programmable, complete with keypad, will switch 2A mains. 9v dc operation. £13 ref 1114.

**PHONE BUG DETECTOR KIT** This device will warn you if somebody is eavesdropping on your line. £9 ref 1130.

**ROBOT VOICE KIT** Interesting circuit that distorts your voice! adjustable, answer the phone with a different voice! 12vdc £9 ref 1131

**TELEPHONE BUG KIT** Small bug powered by the phone line, starts transmitting as soon as the phone is picked up! £12 Ref 1135.

**12V FLOURESCENT LAMP DRIVER KIT** Light up 4 foot tubes from your car battery! 9v 2a transformer also required. £8 ref 1089.

**VOX SWITCH KIT** Sound activated switch ideal for making bugging tape recorders etc, adjustable sensitivity. £10 ref 1073.

**SOUND EFFECTS GENERATOR KIT** Produces sounds ranging from bird chips to sirens. Complete with speaker, add sound effects to your projects for just £9 ref 1045.

**15 WATT FM TRANSMITTER (BUILT)** 4 stage high power, preamp required 12-18vdc, can use ground plane, yagi or open dipole. £89 ref 1021.

**HUMIDITY METER KIT** Builds into a precision LCD humidity meter, 9 ic design, pcb, lod display and all components included. £29

**PC TIMER KIT** Four channel output controlled by your PC, will switch high current mains with relays (supplied). Software supplied so you can program the channels to do what you want whenever you want. Minimum system configuration is 286, VGA, 4.1, 640k, serial port, hard drive with min 100k free. £24.99

**NICKEL PLATING KIT** Professional electroplating kit that will transform rusting parts into showpieces in 3 hours! Will plate onto steel, iron, bronze, gunmetal, copper, welded, silver soldered or brazed joints. Kit includes enough to plate 1,000 sq inches. You will also need a 12v supply, a container and 2 12v light bulbs. £45 ref NIK39.

**Miniature adjustable timers, 4 pole c/o output 3A 240v, HY1230S, 12vDC adjustable from 0-30 secs. £4.99**

**HY1260M, 12vDC adjustable from 0-60 mins. £4.99**

**HY2405S, 240v adjustable from 0-5 secs. £4.99**

**HY24060M, 240v adjustable from 0-60 mins. £6.99**

**BUGGING TAPE RECORDER** Small voice activated recorder, uses micro cassette complete with headphones. £28.99 ref MAR29P1.

**POWER SUPPLY** fully cased with mains and o/p leads 17v DC 900mA output. Bargain price £5.99 ref MAG6P9

**COMPOSITE VIDEO KIT.** Converts composite video into separate H sync, V sync, and video. 12v DC. £12.00 REF: MAG8P2.

**VENUS FLYTRAP KIT** Grow your own carnivorous plant with this simple kit £3 ref EF34.

**6"x12" AMORPHOUS SOLAR PANEL** 12v 155x310mm 130mA. Bargain price just £5.99 ea REF MAG6P12.

**FIBRE OPTIC CABLE BUMPER PACK** 10 metres for £4.99 ref MAGSP13 ideal for experimenters! 30 m for £12.99 ref MAG13P1

**ELECTRONIC ACCUPUNCTURE KIT** Builds into an electronic version instead of needles! good to experiment with. £9 ref 7P30

**SHOCKING COIL KIT** Build this little battery operated device into all sorts of things, also gets worms out of the ground! £9 ref 7P36.

**HIGH POWER CATAPULTS** Hinged arm brace for stability, tempered steel yoke, super strength latex power bands. Departure speed of ammunition is in excess of 200 miles per hour! Range of over 200 metres! £8.99 ref R/9.

**COMPAQ POWER SUPPLIES WITH 12V DC FANS** Ex equipment psu's, some ok some not but worth it for the fan alone! probably about 300 watt PC unit with IEC input. £3.50 each ref CQ1

**9-0-9V 4A TRANSFORMERS,** chassis mount. £7 ref LOT19A.

**FRESNEL PERSPEX SCREENS** 11"x11"x316" as used in overhead projectors etc. New. £19 ref FRESN

**MEGA LED DISPLAYS** Build your self a clock or something with these mega 7 seg displays 55mm high, 38mm wide. 5 on a pcb for just £4.99 ref LOT16 or a bumper pack of 50 displays for just £29 ref LOT17.

**SOLID STATE RELAYS**  
 CMP-DC-200P 3-32vdc operation, 0-200vdc 1A £2.50  
 SMT20000/3 3-24vdc operation, 28-280vac 3A £4.50

**FREE COLOUR CATALOGUE WITH EVERY ORDER**

**WE BUY SURPLUS STOCK FOR CASH**  
 SURPLUS STOCK LINE 0802 660335

**RESEARCH NOTES**

Jonathan Campbell

**"Second silicon revolution" gets commercial fillip**

Traditionally, the focus of the microelectronics industry has been to pack more transistors onto a chip, leading to more powerful computers. But micromachine technology developed by Sandia National Laboratories and being commercialised by Analog Devices could change that strategy by working to integrate electronics with small machines into usable devices.

Such chips will have the ability to sense where they are and what is going on around them, with an early application likely to be in automobile air bag sensors.

A three-axis accelerometer that can detect changes in velocity along three planes of motion has already been built using Sandia technology and designs developed by the University of California at Berkeley's Sensor and Actuator Lab.

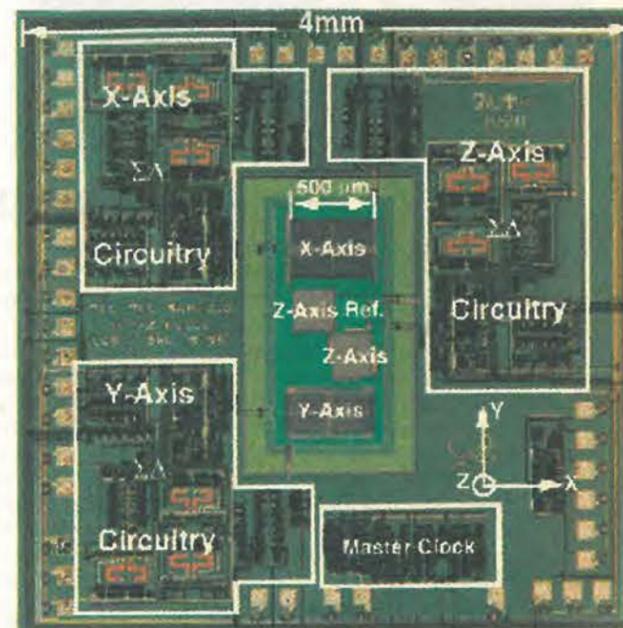
Analog Devices, an industry leader in the manufacture of air bag micromachine sensors, is taking the technology to make integrated micro machines - a tiny, smart machine that combines microcircuits, sensors, and actuators on a single computer chip. In the air bag sensor, Analog uses micro machines to signal when a vehicle is undergoing sufficiently

rapid and sustained deceleration for the air bag to deploy. Sandia is already a world leader in this field and the work is expected to help stimulate production of a new generation of very small consumer and military devices, such as anti-tamper, anti-skid, and active-vibration-control systems.

Sandia estimates the specific market for micromachine-based inertial sensors worldwide is estimated to be \$3.8 billion, and talks in terms of these new devices heralding a "second silicon revolution."

Researchers at the University of California at Berkeley's Sensor and Actuator Lab, credited with making some of the earliest known micro machines, also will be involved in designing new, smarter products.

One advantage of the technology is that batches of silicon micro machines can be fabricated through manufacturing techniques already widely used to make integrated circuits. So micro machines are far cheaper than the complicated multi-metal constructions originally necessary to signal an air bag to inflate. Rather than being made individually, micro machines can be fabricated quickly and cheaply by



the thousands.

Also, because the machines have so little weight, they are less likely to be damaged by sudden deceleration, because force is proportional to mass - which, in this case, is almost non-existent.

Micromachines integrated into a chip promise the next silicon revolution

**DNA computers - made on the workbench**

Manufacture of biological logic gates has brought forward the possibility of building DNA computers able to process in just a few hours complex information that would take today's conventional computers hundreds of years to solve.

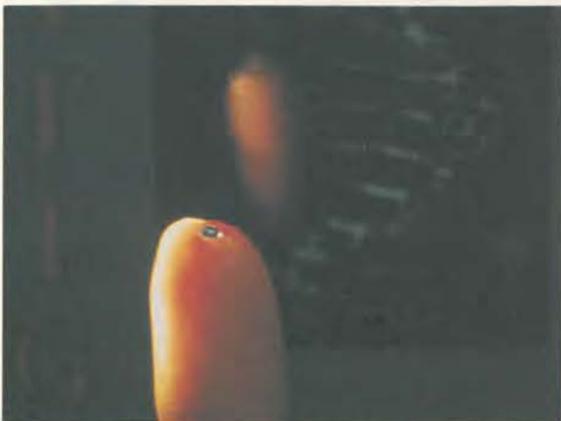
One of the most surprising aspects of this recent breakthrough at University of Rochester is that the DNA logic gates were made using only the most common-place biological laboratory techniques, such as DNA ligation and gel electrophoresis

Conventional logic gates convert the endless series of binary data coursing through the machine into a series of signals that the computer uses to perform its operations. They process electronic signals from transistors, converting two input signals into one output signal in a way that allows a computer to perform complex operations.

Up to now, the only logic gates used for computing have been electronic structures that detect signals coming from transistors.

But the logic gates, developed by Animesh Ray and Mitsu Ogihara at Rochester, rely not on electrical signals to perform logical operations, but rather on DNA codes.

The Rochester gates - actually tiny DNA processing centres - detect specific fragments of the genetic blueprint as input, then splice together the fragments to form a single output. For instance, a genetic And gate links two DNA inputs by chemically binding them so they are locked in an end-to-end orientation, much as two



Scientists at the University of Rochester have built logic gates that rely not on electrical signals but rather on DNA codes to perform operations. Picture shows a sample of DNA against a computer monitor displaying a model of the DNA helix.

Legos might be fastened end-to-end by a third Lego stuck on top.

An enzyme called DNA ligase seals the gap between the ends of the two input strands, yielding a single new strand.

Using regular gel electrophoresis, the length of this new strand can be precisely measured, providing the DNA computer's answer or output to the two input strands.

Ogihara recently showed mathematically that a computer consisting of a series of DNA-filled test tubes can work more efficiently than a digital computer in analysing the information cascading in from a tangled web of logic gates. This includes the type of calculations now done every day, as well as more

complex arrangements.

Ray and Ogihara are among a growing group of scientists who believe that DNA could serve as a very compact, efficient, and accurate form of memory in computers – just as it does in the cells of the human body. The potential benefits of a DNA computer are astounding: 500g of DNA has the capacity to store more information than all the electronic computers ever built, and the computing power of a teardrop-sized DNA computer using the new DNA logic gates could dwarf that of the world's most powerful supercomputer, which even now is the size of a house.

Contact: Animesh Ray, University of Rochester, Tel: 00 1 716 275 8986.

## Honey I shrunk the lab!

Silicon laboratories, where the functionality of specialised chemical analysis instruments has been shrunk down to fit on a computer chip, have come closer to reality following an announcement from a researcher at Purdue University.

Technology has been patented by Purdue, and PerSeptive Biosystems of Boston, that will allow scientists to pack hundreds of laboratories – each fully capable of carrying out complex chemical analyses – on a single silicon chip, reducing the cost and boosting the efficiency of many chemical and medical analyses.

The laboratory chips should be available in three to five years, according to Fred Regnier, professor of chemistry at Purdue and co-founder and chief technical officer of PerSeptive Biosystems. The aim is to allow physicians and medical professionals to perform chemical analyses using the chips that currently are done at specialised laboratories.

For instance, in standard chromatography, a solution to be separated is poured through a tube or column packed with various particles that are coated with a chemical compound. The different components of the solution are attracted to the particles with different affinity. As the mixture flows through the column, it separates into a series of zones, each containing a pure substance.

The miniature laboratories employ the same principle. The difference is in their size and the way they are made. Channels and microscopic 'particles' are created, this time using photolithography and chemical etching – the same technologies that are used to build semiconductors. The entire laboratory – with chemical reaction vessels the size of a speck of dust and chromatography columns the size of a human hair – is cut from a single piece of silicon, similar to the creation of a sculpture. Liquids are moved on the chip by voltage

applied at the ends of the channels.

What makes this device different to similar devices under development is that Regnier has found a way to create tiny, rectangular particles within the channels. These monolith structures, etched into the column as a single unit, serve the same purpose as the packing materials used in conventional chromatography columns, and they allow the miniature laboratory to perform more complex procedures.

Despite their diminutive size, the laboratories on a chip can obtain accurate measurements using only a fraction of a drop of liquid. Instead of working with microlitres of liquid, the chips need only picolitres. Yet measurements can still be made to within a few percent accuracy.

The mini-laboratories also differ from standard chromatographs in that they contain no moving parts. So they are much simpler devices and are much less expensive to build than conventional laboratory equipment. A standard liquid pumping system and column, for example, may cost £10000, but a chip can be fabricated for £300, and up 100 mini-laboratories can be lined up on a single chip.

The ability to fabricate specialised instruments at low cost and to connect large numbers of them together could have a major impact on areas of science such as clinical analysis and drug discovery. The new technology may be particularly useful in pharmaceutical laboratories where scientists analyse thousands of natural and synthetic compounds in search of new drug candidates.

Other applications could include clinical settings such as a doctor's office, where the miniature laboratory could be used by medical professionals to perform diagnostic procedures. For simple diagnostic procedures, laboratories could be designed to work in a fashion similar to pregnancy test kits.

Contact: Fred Regnier, Purdue University, West Lafayette, Indiana. Tel: 00 1 765 494-3878; e-mail, fregnier@purdue.edu



Purdue researcher Fred Regnier (right) and colleague stand next to a liquid chromatograph while examining a silicon wafer that contains a scaled-down version of the device. The mini-laboratory is capable of carrying out many of the same types of chemical separations as the full-sized instrument. (Purdue News Service Photo by David Umberger)

## Process adds to coating development

A new coating process that enables novel compounds to be formed and also solves some of temperature problems currently inherent in coating chips has been developed at the University of Buffalo.

By using such extremely high temperatures and then quenching the heat, the new technique solves one of the trickier problems in computer-chip fabrication: how to coat them while avoiding high temperatures that can cause computer chip samples to fail. This has been a serious drawback for fabricators of expensive chips for research-grade supercomputers, such as the Cray.

The new hybrid technique marries the advantages of the two conventional fabrication methods – laser ablation and molecular beam epitaxy – while overcoming their disadvantages. Just as importantly, the method, called laser assisted molecular beam deposition, OR Lambd, can also manufacture new coatings for electronic devices in the same stage.

"Instead of simply sputtering a target material from point A to point B, we're chemically modifying it at

the same time," says James Garvey, professor of chemistry and principal investigator.

The key to Buffalo's fabrication method is that it causes chemical reactions that would be impossible to generate otherwise, and it does it all in one step.

Like laser ablation and molecular beam epitaxy, Lambd uses extremely high heat to remove particles of a target material from one surface and transport it to another, creating a thin film.

What makes Lambd different is that those molecules then collide with a pulse of gas, the identity of which is determined by the type of chemical product desired. The technique also seems to remove from the fabrication process certain toxic precursors that otherwise are necessary in generating thin films.

For example, electronic wafers often must be coated with titanium nitride to act as a diffusion barrier – a process that requires a very toxic precursor, requiring extensive safety and disposal equipment.

With the new technique, nitrogen gas is simply blown over a rod of



Laser assisted molecular beam deposition, or Lambd, could open up new chip coating opportunities

titanium, depositing titanium nitride directly on the substrate. The process results in a thin film of protective titanium nitrate without the use of toxic precursors.

So far, several unique materials have been formed using Lambd, such as hybrid organic/inorganic films where an organic material with good optical characteristics has been encapsulated in silica glass. These new materials could have valuable photonics applications for new computer devices.

## Explosion packs punch into magnetic pulse

In a remote corner of Los Alamos National Laboratory, scientists from around the world spent weeks setting up an apparatus designed to measure what happens to certain compounds under extremely high magnetic fields – then they blew it to bits.

The Dirac experimental campaign is an international collaboration begun in 1996 to investigate the atomic structure and chemistry of materials by subjecting them to an exceedingly strong magnetic pulse driven by an explosive charge. Scientists are probing how materials conduct electricity in extreme conditions. The magnetic forces created briefly in the experiment by the explosion make it possible to investigate aspects of the structure of condensed matter that are otherwise impossible to study.

To attain the intense magnetic fields required, the research team placed sample materials inside an electromagnet, with the samples cooled to a few degrees above absolute zero. The magnet was

surrounded with about 18kg of explosives, arranged to produce a perfectly uniform implosion.

In the millionths of a second before the equipment turned to dust, sensors captured measurements of how the sample's electrical resistance changed as the magnetic field was squeezed and concentrated by the blast.

Magnetic field strength is measured in teslas.

Sustained fields in research magnets are generally around 60 tesla – one tesla is about 20000 times stronger than Earth's field. The Dirac experiments have achieved momentary pulsed fields reaching 850 tesla. Insights from these experiments may help in the design of superconductors and better semiconductors.

But for the scientists, the pay-off is the glimpse at secrets that are normally hidden from observation. ■

Contact: Los Alamos National Laboratory, New Mexico, USA.



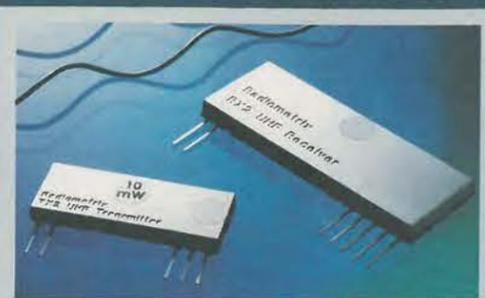
Explosions have been used at Los Alamos to generate massive magnetic pulses.

# LOW-COST AND MINIATURE TRANSMITTER/RECEIVER PAIR

## LICENCE EXEMPT UHF MODULES DESIGNED FOR EMC COMPLIANCE

# RADIO PACKET CONTROLLERS INCORPORATING BiM TRANSCEIVER

## BI-DIRECTIONAL RADIO DATALINKS



- All TX2 and RX2 modules feature:
- Miniature, PCB-mountable UHF transmitter/receiver pair
  - Cable-free data link up to 75m 'in building' and 200m over open ground
  - Operation at 433.92MHz (Europe) & 418MHz (UK)
  - Full EMC screening and internal filtering
  - Ideal for portable, battery-powered applications



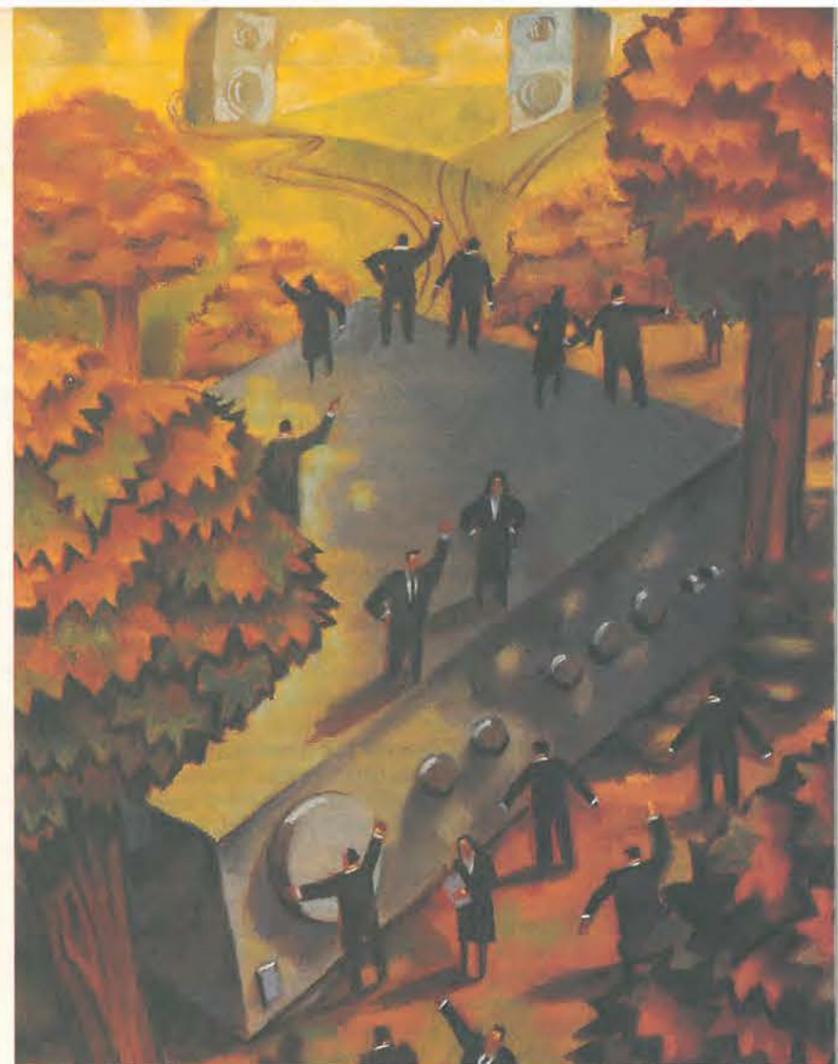
- All RPC and BiM modules feature:
- Half-duplex data transmission up to 40Kbit/s
  - Reliable "in-building" operating range of 30m
  - Outdoor operation over distances of 120m
  - Duty cycle power saving
  - Direct interface to 5V CMOS logic
  - Operation at 433.92MHz (Europe) & 418MHz (UK)

Full data available on <http://www.radiometrix.co.uk>

**RADIOMETRIX Ltd**

Hartcran House, Gibbs Couch, Carpenters Park, Watford, Herts, WD1 5EZ, England.  
Tel: +44 (0)181 428 1220 • Fax: +44 (0)181 428 1221  
email: radiometrix@dial.pipex.com

CIRCLE NO. 111 ON REPLY CARD



The interface between an audio power amplifier and its loudspeakers is important, but not for the reasons you might think, reveals Doug Self.

# The audio power interface

A good deal has been written in recent years about speaker cables. Much of this has been raving nonsense – perpetrated by those drawn to audio as it appears to be a subject in which one can profess expertise without the trouble of actually learning anything. Some approaches are well-intentioned but misguided, such as worrying about how cables perform at 1GHz. This article attempts something most unusual – it looks at what cables actually do in their real situation.

Figure 1 shows the most important elements in the amplifier-cable-speaker system. Their basic interactions must be understood before worrying about possible second-order effects at radio frequencies.

**Putting a damper on damping factor**

One of the most misunderstood features of this system is the effect of amplifier output impedance on speaker dynamics. The parameter 'damping factor' purports to measure how much this output impedance degrades the electromagnetic damping of loudspeaker units. In fact 'damping factor' must

be the most misnamed parameter in existence, for an amplifier's ability to damp loudspeaker resonances is effectively NIL. This is so important and apparently so little understood that the next section deals with this first.

Damping factor is defined as the ratio of the load impedance  $R_{load}$  to the amplifier output resistance  $R_{out}$ .

$$\text{damping factor} = \frac{R_{load}}{R_{out}}$$

Steady-state amplifiers often have output resistance around 50 to 100mΩ so an 8Ω speaker means a damping factor of at best 160 times. This simple definition ignores the fact that amplifier output impedance usually varies considerably across the audio band, increasing with frequency as negative feedback factor falls; the output 'resistance' is actually more like an inductive reactance at high audio frequencies. The presence of an output inductor to give stability with capacitive loads increases this reactance.

A further condemnation of damping factor is that the bass

8 CAVANS WAY,  
BINLAY INDUSTRIAL ESTATE,  
COVENTRY CV3 2SF  
Tel: 01203 650702  
Fax: 01203 650773  
Mobile: 0860 400683

(Premises situated close to Eastern-by-pass in Coventry with easy access to M1, M6, M40, M42, M45 and M69)

**MISCELLANEOUS**

Adret 740A - 100kHz-1120MHz Synth. signal generator	£2000
Anritsu ME422B - DS-3 transmission analyser	£2000
Anritsu MG42A - Pulse pattern generator	£1500
Barr & Stroud - EF3 variable filter (0.1Hz-100kHz)	£150
Danbridge JP30A - 30KV insulation tester	£1500
Dravetz 808 - ADC/DAC Multifunction Analyser	£250
E.I.P.331 - 18GHz frequency counter	£350
Farnell AP70-30 P.S.V. - (0-70v, 0-30A) auto ranging	£750
Fluke 5100A - Calibrator	£2500
Fluke 5100B - Calibrator	£2500
Fluke 5101B - Calibrator	£4000
Fluke 5205A - Precision power amplifier	£1500
Fluke 7105A - Calibration system (As new)	£5000
Guideline 9152 - T12 Battery standard cell	£550
Heldan 1107 - 30-10V Programmable power supply (IEEE)	£400
Hewlett Packard 331A - Distortion analyser	£300
Hewlett Packard 338A - distortion measuring set	£1500
Hewlett Packard 432A - Power Meter (with 478A Sensor)	£275
Hewlett Packard 438A or B - Power Meter (with 3481A/3484A)	£750
Hewlett Packard 1830D - Logic Analyser (43 channels)	£850
Hewlett Packard 18600A - Fitted with 16510A/16515A/16530A/16531A	£4000
Logic analyser	£4000
Hewlett Packard 3352A - 21MHz synthesiser/function gen.	£1500
Hewlett Packard 3358A - Synthesised signal generator (10Hz-21MHz)	£1000
Hewlett Packard 3437A - System voltmeter	£350
Hewlett Packard 3438A - Digital multimeter	£200
Hewlett Packard 3465A - 6 1/2 digit multimeter (auto scale)	£750
Hewlett Packard 3468A - Digital voltmeter	£750
Hewlett Packard 3478A - Multimeter (5 1/2 digit) HPB	£550
Hewlett Packard 3488A - HP-IB switch/control unit (various plug-ins available)	£850
Hewlett Packard 3711A/3712A/3791B/3793B - Microwave link analyser Sensor	£2495
Hewlett Packard 3776A - PCM Terminal test set	£2000
Hewlett Packard 3779 A/C - Primary mux analyser	£500/£300
Hewlett Packard 4271B - LCR meter (digital)	£350
Hewlett Packard 4275A - Multi-frequency LCR meter	£3950
Hewlett Packard 4279A - 1MHz, C-V meter	£8500
Hewlett Packard 4320A - Milliohmeter (as new)	£2000
Hewlett Packard 4342A - O - Meter	£250
Hewlett Packard 4848A - Transmission impairment measuring set	£2000
Hewlett Packard 4853A - Protocol analyser	£1995
Hewlett Packard 4872A - Lan protocol analyser	£2000
Hewlett Packard 4882A - System P.S.U. 0-60V-10A	£150
Hewlett Packard 5322A - 100MHz universal frequency counter	£250
Hewlett Packard 5385A - Frequency counter (1GHz (HPB) with Opt's 001/003/004/005)	£395
Hewlett Packard 6181C - D.C. current source	£150
Hewlett Packard 6261B - Power supply 20V-50A	£480

**DISCOUNT FOR QUANTITIES**

Hewlett Packard 8011A - Pulse gen. 0.1Hz-20MHz	£500
Hewlett Packard 8152A - Optical average power meter	£1250
Hewlett Packard 8158B - Optical attenuator with opt's 002 & 001	£1100
Hewlett Packard 8165A - 50MHz programmable signal source	£1050
Hewlett Packard 8349B - Microvoltage broadband Amp (as new) 2-20MHz	£2250
Hewlett Packard 8360B - Sweep oscillator mainframe (plug-ins avail)	£2500

## TELNET

Hewlett Packard 8366A - Millimeter wave source 26.5GHz-40GHz	£4000
Hewlett Packard 8368A - Millimeter wave source 33GHz-50GHz	£4250
Hewlett Packard 8402A - Modulator	£500
Hewlett Packard 8405A - Vector voltmeter	£500
Hewlett Packard 8620C - Sweep oscillator mainframe	£400
Hewlett Packard 8683A - Microwave signal gen. (2.3-8.5GHz)	£2500
Hewlett Packard 8884A - 8.4GHz to 12.5GHz Sig Gen	£2500
Hewlett Packard 8760A - Storage normaliser	£375
Hewlett Packard 8891A - Modulation Analyser	£2500
Hewlett Packard 8903A - Audio analyser (20Hz-100kHz)	£1995
Hewlett Packard 8958A - Cellular radio interface	£3500
Hewlett Packard 11729B - Carrier noise test set	£2000
Krohn-Hite 5200 - Sweep function generator	£350
Marconi 893B - AF power meter	£225
Marconi 2018 - 30kHz-1040MHz synth signal generator	£1750
Marconi 2018A - 80kHz-1040MHz synthesised sig. gen	£1950
Marconi 2022A - 10kHz-1GHz - AM/FM signal generator	£2000
Marconi 2610 - True RMS voltmeter	£360
Marconi 2871 - data communications analyser	£1500
Marconi 2955 & 2958 - Radio Comms test set + tace adaptor	£3500
Philips PM 5167 - 10MHz function gen.	£400
Philips PM 5190 - LF synthesiser with GPIB	£300
Philips PM 5191 - Colour TV pattern generator	£350
Philips PM 5697 - Vectorscope	£550
Philips PM 6873 - 120MHz high resolution universal counter	£300
Philips PM 6870 - 120MHz high resolution timer/counter	£300
Philips PM 6882 - 1.5 GHz programmable high resolution timer/counter	£300
Racal Dana 1002 - 1300MHz frequency counter opts 48-495	£600
Racal Dana 9081 - Synthesised Sig Gen 520MHz	£300
Racal Dana 9084 - Synth. sig. gen. 104MHz	£450
Racal Dana 9301A - True RMS R.F. millivoltmeter	£300
Racal Dana 9308 - True RMS R.F. level meter	£650
Racal Dana 9821 - 3GHz frequency counter	£450
Rohde & Schwarz SMDU - 15Hz-525MHz (FM & AM) Sig-Gen	£500
Rohde & Schwarz SMFP2 - 1GHz radio comms test set + options	£2500
Rohde & Schwarz UR2 - RMS Voltmeter DC 10Hz to 25MHz	£500
Schaffner NSG 203A - Line voltage variation simulator	£395
Schaffner NSG 222A - Interference simulator	£395
Schaffner NSG 223 - Interference generator	£750
Schaffner NSG 431 - Electrostatic discharge, simulator	£1250
Schlumberger 4720 - 125MHz Freq. Counter	£750
Schlumberger 4831 - Radio Comms Test Set	£8000
Schlumberger 4832 - Radio Code Test Set	£300
Schlumberger 7060/7065/7075 - Multimeters from	£350
Systron Donner 1900B - Microwave Sweeper (12-18GHz)	£1150
Tektronix 577 - Curve Tracer	£850
Tektronix - Plug-ins - Many available such as PG508, PG504, SC504, SW503, S5502 etc.	£1750
Tektronix TMS600 & AFG5101 - Arbitrary Function Gen.	£1750
Tektronix 1240 - Logic Analyser	£750
Tektronix AJ4503 & TM501 + PG302 - current probe amplifier	£395
Tektronix AA5001 + TM5008 - Mainframe programmable distortion analyser	£1995
Tektronix PG505 + TG501 + SG503 TM503 - Oscilloscope calibrator	£1995
Time 9614 - Voltage calibrator	£750
Wavetek 171 - Synthesised function generator	£250
Wavetek 172B - Programmable sig. source (0.0001Hz-3MHz)	£450
Wavetek 184 - Sweep generator	£250
Wayne Kerr 8995 - Precision LCR meter	£850
Wayne Kerr 4225 - LCR bridge	£600
Wayne Kerr 6425 - Precision component analyser	£2750
Wilson 85265 - Programmable sweep gen. (3.6-6.5GHz)	£850
Beckman 9020 - 20MHz dual channel	£150
Cosor 3102 - 60MHz dual channel	£250
Gould 05245A/250/255/300/3000/3051/4000 - From	£125
Hammy 203/203-4/203-5/203-6 - From	£150
Hewlett Packard 180A/180C/181A/182G - From	£200
Hewlett Packard 1746A, 1741A, 174A, - 100MHz dual ch	from £350

## OSCILLOSCOPES

Hewlett Packard 54100D - 1GHz digitizing	£2995
Hewlett Packard 54601A - 100MHz digitizing 4 channel	£1750
Hitachi V152/V212/V222/V302B/V302F/V353F/V550B/V600F - From	£125
Hitachi VC285 - 100MHz digital storage (as new)	£2000
Intron 2020 - 120MHz digital storage (as new)	£850
Iwatsu 55 5710/55 5702 - From	£125
Meguro MSO 1270A - 100MHz digital storage (as new)	£350
Kikusui 5100 - 100MHz dual channel	£350
Kikusui COS 6100 - 100MHz 5 channel 12 trace	£475
National VP 5703A - 100MHz digital storage	£750
Nicolet 310 - LF DSO with twin disc drive	£350
Nicolet 3091 - Low freq D.S.O.	£300
Philips PM 3211/PM 3213/PM 3214/PM 3217/PM 3234/PM 3240/PM3243/PM3244/PM 3261/PM 3262/PM 3263/PM 3540 - From	£125
Philips PR2225A - 400MHz dual channel	£1750
Scopec 14D-15 - 15MHz dual channel	£100
Tektronix 2446A - 150MHz - 4 channel	£1800
Tektronix 465 - 50MHz dual channel	£350
Tektronix 2221 - 50MHz digital storage	£1500
Tektronix 1784 - 400MHz Waveform processing oscilloscope	£1500
Tektronix 464/468 - 100MHz storage	from £350
Tektronix 465/468B - 100MHz dual ch.	from £350
Tektronix 468 - 100MHz D.S.O.	£750
Tektronix 475/475A - 200MHz 50MHz dual channel	from £475
Tektronix 484 - 25MHz 2 channel + analogue storage	£250
Tektronix 484 - 150MHz 2 channel	£400
Tektronix 2213 - 60MHz dual ch.	£425
Tektronix 2215 - 60MHz dual ch.	£450
Tektronix 5402 - 50MHz 2 or 4 channel from	£450
Tektronix 2235 - 100MHz Dual channel	£300
Tektronix 2238 - 100MHz Dual Trace with Counter/Timer/Dmm	£395
Tektronix 2238 - 5100MHz dual ch. (portable)	£750
Tektronix 2235 - 5100MHz dual ch. (portable)	£250
Tektronix 7113, 7603, 7613, 7623, 7633, - 100MHz 4 ch.	from £250
Tektronix 7704 - 250MHz 4 ch.	from £500
Tektronix 7904 - 500MHz with storage	from £700
Tektronix 7934 - 500MHz with storage	from £1600
Teledquipment D13 - 50MHz dual channel	£200
Teledquipment DM83 - 20MHz 4 channel	£150
Trio CS - 1022 - 20MHz dual channel	£125

## SPECTRUM ANALYSERS

Advantest 4131 - 10kHz - 3.5GHz (IGPB)	£5000
Altech 757 - 10kHz-22GHz	£2750
Ando AC 6211 - Spec analyser 1.7GHz	£2995
Hewlett Packard 1411 + 8552B + 8555A - (10MHz-19GHz)	£1800
Hewlett Packard 1827 with 8559B - (10MHz-21GHz)	£3750
Hewlett Packard 1827 with 8559B - (10MHz-1500MHz)	£2750
Hewlett Packard 8562A - 50MHz dual channel	£250
Hewlett Packard 853A with 8559B - (0.01-21MHz)	£4250
Hewlett Packard 3562A - dynamic signal analyser, dual channel	£7500
Hewlett Packard 3580A - 5Hz-50kHz	£395
Hewlett Packard 3582A - 25kHz analyser, dual channel	£2500
Hewlett Packard 3586A - 20kHz-40MHz	£500
Hewlett Packard 3709B - Constellation Analyser with 15709A High Impedance Interface (as new)	£8750
Hewlett Packard 8505A - Network analyser (500kHz-1.3GHz)	£3950
Hewlett Packard 8505A - 0.01-220GHz	£2750
Hewlett Packard 8754A - Network analyser 1300MHz	£2750
Meguro MSA 4801 - 1-300MHz (as new)	£1500
Meguro MSA 4812 - 1-100MHz (as new)	£2000
Meguro 2276 - 115kHz spec analyser	£500
Takada R10N 4132 - 100MHz	£2750

SEND LARGE S.A.E. FOR LIST OF MANY MORE ITEMS AVAILABLE - ALL EQUIPMENT IS USED - WITH 30 DAYS GUARANTEE. PLEASE CHECK FOR AVAILABILITY BEFORE ORDERING - CARRIAGE & VAT TO BE ADDED TO ALL GOODS

CIRCLE NO. 112 ON REPLY CARD

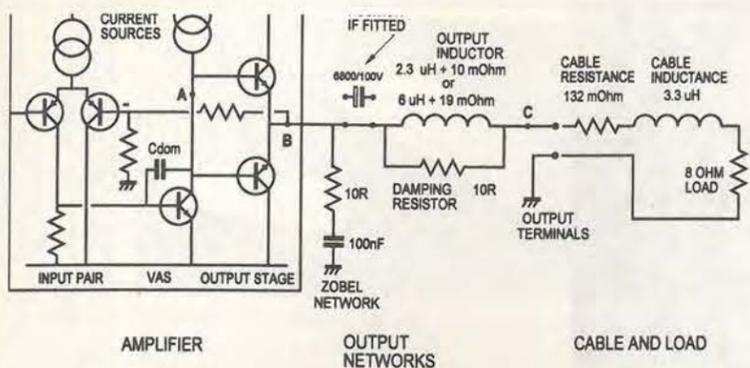


Fig. 1. Amplifier-cable-speaker system. Simplified amplifier with Zobel network and output inductor, 5m of cable with series resistance and inductance, and a resistive load. Values are typical.

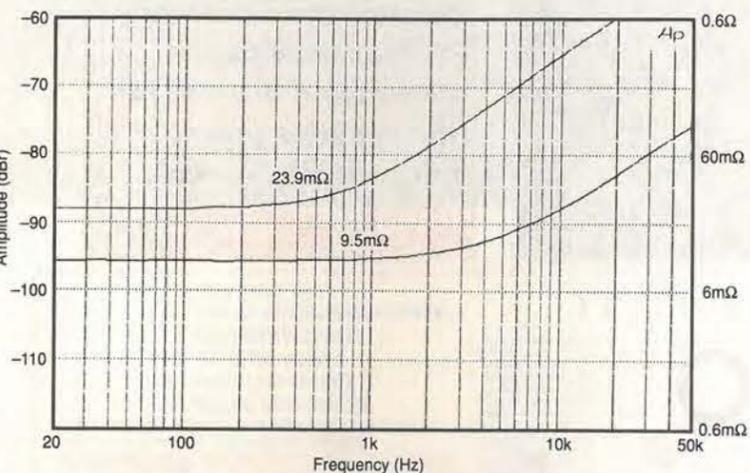


Fig. 2. Output impedance of a 'blameless' amplifier, with and without 6uH output inductor. Adding the inductor, upper trace, increases both the flat low-frequency output impedance, due to its series resistance, and the rising high-frequency impedance.

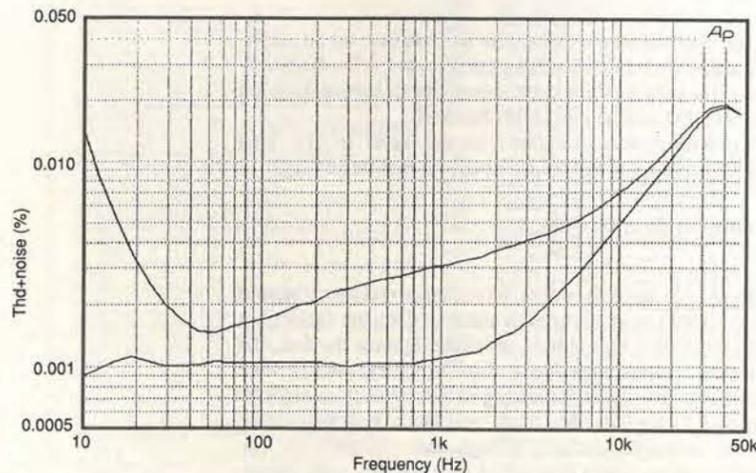


Fig. 3. Distortion with and without a standard 6800uF/100V electrolytic at 40W into 8Ω. There is extra distortion across the audio band, as well as a sharp rise at hf.

resonance is the one frequency where a real loudspeaker can be pretty much guaranteed to have an impedance nothing like 8Ω. With a sealed box, peak resonance impedance is often 30Ω or more.

In the face of these potential complications, it is a mercy that damping factor as such has very little effect on loudspeaker behaviour. A factor of 160 times, as derived above, promises a truly radical effect on cone response – implying that resonances and such have been reduced by 160 times as the amplifier output takes an iron grip on cone movement. Nothing could be further from the truth.

The electrical damping of a loudspeaker unit depends on the total series resistance in the voice-coil circuit. This is the sum of speaker coil resistance, resistance in the crossover, speaker cabling, and, last of all, amplifier output impedance. Values for these will be typically 7Ω, 1Ω, 0.2Ω and 0.05Ω, so the amplifier only contributes 0.6% of the total, and its effect on speaker dynamics must be negligible.

Does amplifier output impedance matter?

Setting guidelines for crossover inductors, Neville Thiele states that a winding resistance of 5% of the voice-coil resistance was low enough to have no significant effect on drive unit dynamics.<sup>1,2</sup>

If it was possible to make an amplifier change the speaker low-frequency resonance, this would be a really poor idea; the bass resonance is an integral part of the speaker design, and tampering with its frequency and Q is unlikely to improve anything.

The irrelevance of 'damping factor' was practically investigated and fully confirmed by James Moir as far back as 1950<sup>3</sup>, though this has not prevented periodic resurgences of controversy, nor stopped writers from claiming that inadequate loudspeaker cables have a direct effect on bass transient response, with 'bad' cables usually alleged to yield 'flabby' or 'woolly' bass. In contrast, Martin Colloms deals very sensibly with damping factor in reference 4.

So 'damping factor' is almost an arbitrary ratio, with little physical reality. Nonetheless, one reason to strive for a high figure – which after all, can do no harm – is the numbers game of impressing potential customers with specifications figures. It is as certain as anything can be that the subjective difference between two amplifiers, one with a damping factor of 100, and the other boasting 2000, is undetectable by human perception. Nonetheless, the two specifications look very different in the brochure, so minimising output impedance to maximise the damping factor may be of commercial importance. See the end of this article for more details.

Although amplifier output impedance is of little interest in terms of speaker dynamics, it is still worth minimising. Too high an output resistance causes power losses into low-value loads. These look more significant than they are when expressed in watts.

A potentially more serious problem is that non-zero output resistance causes output voltage to vary as speaker impedance varies with frequency, introducing unwanted response irregularities.

Despite this demonstration of its irrelevance, the rest of this article continues to refer to damping factor, to show how an apparently impressive figure shrivels away as more parts of the system are taken into account.

Amplifier output impedance

Audio amplifiers, with a few very special exceptions,<sup>5</sup> approximate to perfect voltage sources and aspire to zero output impedance across the audio band. The amplifier output is

essentially unaffected by loading, so that the frequency-variable impedance of loudspeakers does not give an equally variable frequency response.

While a true zero impedance is impossible with simple negative feedback, a very close approximation is possible if even modest feedback factors are used. A judicious mixture of voltage and current feedback can make the output impedance zero, or even negative – in other words, heavier loading makes the output voltage increase. This is clever, but usually pointless, as you will see. Solid-state amplifiers are quite happy with lots of feedback, but it is usually impractical in valve designs.

The highest output impedances are found in valve equipment, where global feedback inclusive of the output transformer is low or non-existent; impedances around 0.5Ω are usual. Some idiosyncratic semiconductor designs also have high output resistances<sup>6</sup> with 0.6Ω; far too high.

Figure 1 shows a simplified amplifier plus output networks – Zobel network and output inductor – and simple representations of the speaker cable and load. The output impedance of a real solid-state amplifier is very low indeed if it has a reasonable amount of global negative feedback.

Using a 'blameless' Class-B amplifier with a complementary feedback pair output stage<sup>7</sup> the negative feedback factor at 20kHz is 29dB as usual, increasing at 6dB/octave as frequency falls. Figure 2 shows the resulting output impedance of this 'blameless' design in its 'naked' state, ie measured at point B before the output inductor, by injecting a 10mA signal current into the output via a 600Ω resistance.

At low frequencies, the output impedance is approximately 9mΩ, corresponding to an 8Ω damping factor of 890. To put this into perspective, one metre of 32/0.2 equipment cable, ie. 32 strands of 0.2mm diameter, has a resistance of 16.9mΩ. It is thus quite possible for the internal cabling resistance in an amplifier to equal or exceed the output impedance of the amplifier itself at low frequencies.

Output impedance rises at 6dB/octave above 3kHz, as global negative feedback reduces, reaching 36mΩ at 20kHz. The 3kHz break frequency does not correspond with the amplifier dominant pole frequency, which is much lower, at around 10Hz.

More to output impedance than meets the eye

The closed-loop output impedance of an amplifier is determined by its open-loop output impedance and the negative feedback factor. The former is not simply the output impedance of the output stage, because it is driven from the voltage amplifier stage, giving a significant and frequency-variable source impedance at point A, Fig. 1.

For the standard emitter follower and complementary feedback pair stages I have considered before, driven from a zero-impedance source, the raw output impedance is in the region of 150 to 180mΩ for both, if the emitter resistors  $R_e$  are my usual 0.1Ω. Increasing  $R_e$  to 0.22Ω increases the output impedance to 230 to 280mΩ, demonstrating that these resistors form the greater part of the output impedance.

Taking the average open-loop output impedance as 200mΩ, and the negative feedback factor at 20kHz as 29dB, or 28 times, you would expect the closed-loop output impedance to be 200/28, ie 7mΩ. Since it is actually about 33mΩ at this frequency, there is clearly more going on than simple theory suggests.

In a real amplifier the output stage is not driven from a zero impedance, but a high one that falls proportionally with frequency; for my 'blameless' Class-B design it falls from 3kΩ at 1kHz to about 220Ω at 20kHz<sup>8</sup>. A 220Ω source impedance gives an open-loop output impedance of about 1Ω, which

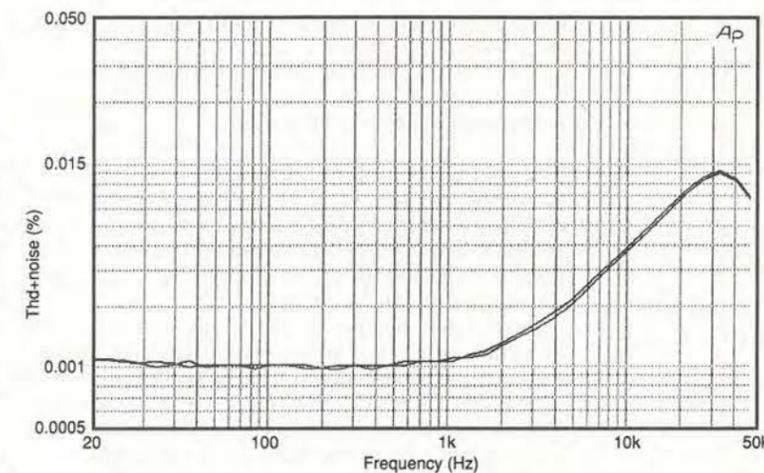


Fig. 4. With and without a very large output capacitor, the BHC Aerovox 100000uF/40V driving 40W into 8Ω. Capacitor distortion is eliminated.

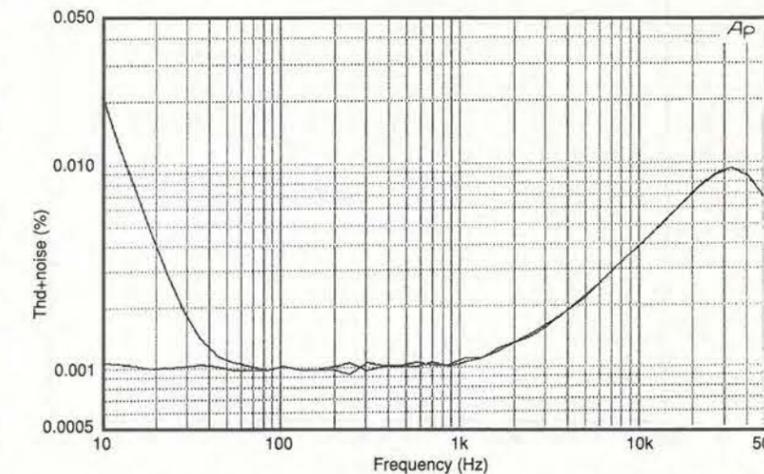


Fig. 5. Distortion with and without an 'audiophile' Cerafine 4700uF/63V capacitor. Midband distortion is eliminated but the low-frequency rise is much the same as with the standard electrolytic.

divided by 28 gives 35mΩ – very close to the measured value.

Fortunately, all these measured closed-loop values are so low compared with other impedances in the amplifier-cable-speaker system that they can be ignored. There seems little point in deeper investigation at this stage.

In practice, my 'blameless' design has an output inductor of 6uH. This is at the high end of the permissible range of inductance, the aim being absolutely ensured stability into capacitive loads.

My version has 20 turns of 1.5mm diameter copper wire, with a dc resistance of 19mΩ. This is a heavyweight component, designed to minimise resistive losses into a 4Ω load, but even so its extra resistance pushes the flat part of the impedance curve up to 24mΩ, so inductor resistance dominates the low-frequency output impedance as measured at the amplifier terminals, point C.

Damping factor is abruptly reduced from 890 to 330. If low output impedance is a priority, the coil wire must be as thick as cost/quality trade-offs allow. Naturally the coil inductance makes the rising portion of the impedance curve higher. The

output impedance now rises from 700Hz, still at 6dB/octave, and reaches 0.6Ω at 20kHz.

Since it is clear that the output networks of an amplifier have important effects on its output impedance, their role and component values are worth a look.

**The role of the output capacitor**

AC-coupled amplifiers have the advantage that there are no dc-offset problems, yet they remain unfashionable. The output capacitor used to be condemned for reducing the low-frequency damping factor, but as explained above, this is actually the least of our worries.

Large output electrolytics have significant equivalent series resistance, or esr, and some series inductance. For typical amplifier-output sizes esr will be of the order of 100mΩ; this is probably why ac-coupled amplifiers rarely had output inductors, as it is enough resistance to provide isolation from capacitive loading, as discussed later.

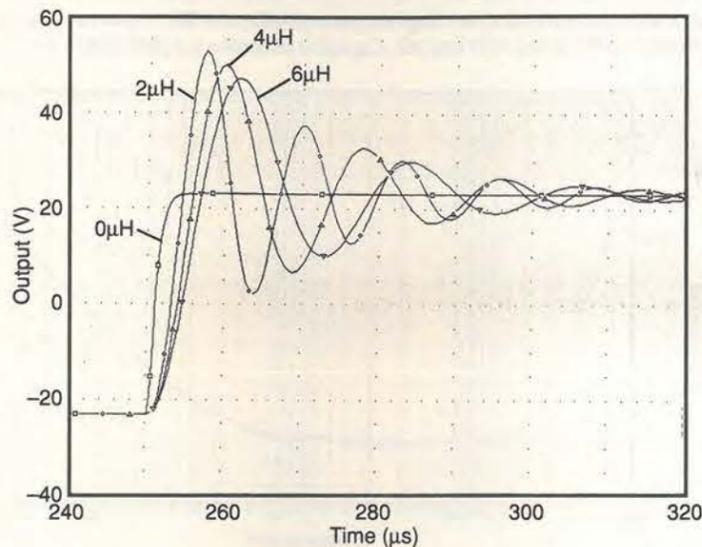


Fig. 6. The output inductor value has little effect on ringing amplitude.

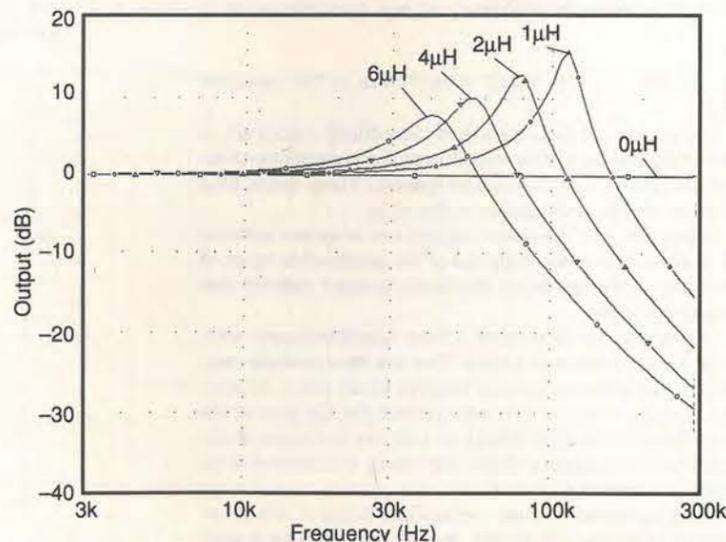


Fig. 7. Effect of output inductor value on frequency response. Higher values cause more invasion of the audio band.

The series inductance is very low and probably irrelevant, being quoted by one manufacturer as "...a few tens of nanohenries". Capacitor esr alone is enough to reduce the damping factor to 80.

A more serious problem with amplifier output capacitors is the distortion they cause. Like other forms of capacitor distortion, this seems to be something people just don't like to talk about.

Output capacitor distortion is a serious problem; it is not confined to low frequencies, as is the case in small-signal circuitry. For a 6800μF/100V output capacitor driving 40W into 8Ω, there is 0.0025% mid-band third-harmonic distortion, as in Fig. 3. This is five times more than the amplifier generates in this frequency range.

The harmonic distortion rise at the low-frequency end is much steeper than for small-signal capacitor distortion, for reasons that are not yet clear. A load of 4Ω doubles the distortion at a given frequency.

I know only two cures for this problem. The head-down no-messing approach uses a huge output capacitor, far larger than required for a good low frequency response. A 100mF/40V *Aerovox* from BHC gave Fig. 4. Alternatively, an allegedly 'audiophile' capacitor gives some interesting results; a *Cerafine Supercap* of only moderate size, at 4700μF/63V, gave Fig. 5, where the midband distortion is gone, but the low-frequency rise remains.

What special audio properties this component is supposed to have is unknown; electrolytics are never advertised as 'low midband thd', but that seems to be true here. The case volume is about twice as great as conventional electrolytics of the same value, so the difference may be a thicker dielectric film than normally used for this voltage rating.

Either of these special capacitors is more expensive than the rest of the amplifier electronics put together. A dc-coupled amplifier with protective output relay looks like the more economical option.

**The Zobel network**

Almost all power amplifiers have a Zobel network in their arrangements for stability. This simple but enigmatic network comprises a resistor and capacitor in series from the amplifier output rail to ground, on the amplifier side of the output inductor.

The resistor is usually 10Ω, and the capacitor almost invariably 100nF. These convenient values and their constancy in differing amplifier designs suggests they are not critical, but not so; my experiments suggest that the traditional values really are optimal for stability.

The function of the Zobel network – also called a Boucherot cell – is rarely discussed, but it is sometimes said to prevent an excessively inductive reactance being presented to the amplifier output by a loudspeaker voice-coil. The implication here is that this could cause high-frequency instability.

It is intuitively easy to see why a capacitive load on an amplifier with a finite output resistance might cause global hf instability by introducing extra lagging phase-shift into the global negative feedback loop. But it is less clear why an inductive load should be a problem; if a capacitive load reduces stability margins, surely an inductive load would increase them.

Some experiments were clearly necessary. I removed the standard 10Ω+0.1μF Zobel from a 'blameless' Class-B amplifier with my usual negative feedback factor of 29dB at 20kHz. This amplifier had a complementary feedback pair output.

With an 8Ω resistive load, the thd performance and stabil-

ity were unchanged. However, a 0.47mH inductor in series with 8Ω, roughly simulating a loudspeaker unit, provoked what appeared to be local vhf instability in the output stage. There was definitely no Nyquist instability of the global negative feedback loop, and no evidence that an inductive load presented difficulties in the audio band.

Increasing the Zobel resistance from 10 to 22Ω gave some evidence of stability problems, and I had to conclude that the standard values are just about right. Note that the Zobel network is at much too high an impedance to have any shunting effect on the amplifier output impedance.

A few designs have a second Zobel network after the output inductor; the thinking behind this is obscure. Reference 9 shows that a second Zobel network can be useful – if it is assumed that cable capacitance is at least 50nF. Since 500pF is a more usual value, the relevance of this is unclear.

**The output inductor**

The function of an output inductor is to prevent instability when a capacitive load is connected. It does this by isolating the amplifier from the shunt capacitance without causing significant losses at audio frequencies.

Low-value resistors have been used instead, but their efficiency is questionable, and they seriously degrade damping factor. Direct connection is only safe for simple amplifiers with very low feedback factors.

The resistance of even thick inductor wire causes an apparently disastrous collapse in the damping factor from 890 to 330. As such, this is unimportant. The worst effect of resistance is probably unwanted response irregularities due to speaker impedance variations with frequency.

An output inductor must be air-cored to eliminate the possibility of distortion due to magnetic saturation. Ferrite vhf chokes give stability, but their linearity must be regarded as dubious. In the seventies, there was a fashion for using one of the big power-supply electrolytics as a coil-former; this is not a good idea. The magnetic characteristics of the capacitor are unknown, and its lifetime will be reduced by heat dissipated in the coil resistance.

Usually, the output inductor has a value of between 1 and 7μH, the upper limit being set by the need to avoid significant roll-off at 20kHz into a 4Ω load. Great caution is required when designing an amplifier for home construction, and so when I designed the Class-B 'blameless' amplifier,<sup>10</sup> the inductor value was set near the upper limit at 6μH to ensure stability. If 2Ω loads are contemplated this upper limit must be halved.

**What is the least inductance needed?**

Further investigations into the minimum inductance required for stability showed that a 'blameless' amplifier without its inductor is still fairly immune to capacitance-induced oscillation. This is possibly because the level of global feedback is fairly modest at 29dB at 20kHz.

The capacitances tried in parallel with 8Ω were 100nF, 470nF, 1μF, and 2μF, and a fast square wave was used to test for ringing. A 100nF capacitor caused close to continuous oscillation, but there was only well-damped ringing on the amplifier output A for 470nF, 1μF, and 2μF.

With the 6μH inductor replaced there was complete amplifier stability in all cases. The 6μH inductor was then cut in half, giving 2.3μH and 10.1mΩ dc resistance; this was also stable for all capacitor values, but has not been tested with real speakers.

An alternative method of stabilisation is a series resistor instead of an inductor. Even with 100nF, a 0.1Ω wire-wound output resistor completely removed ringing on the amplifier

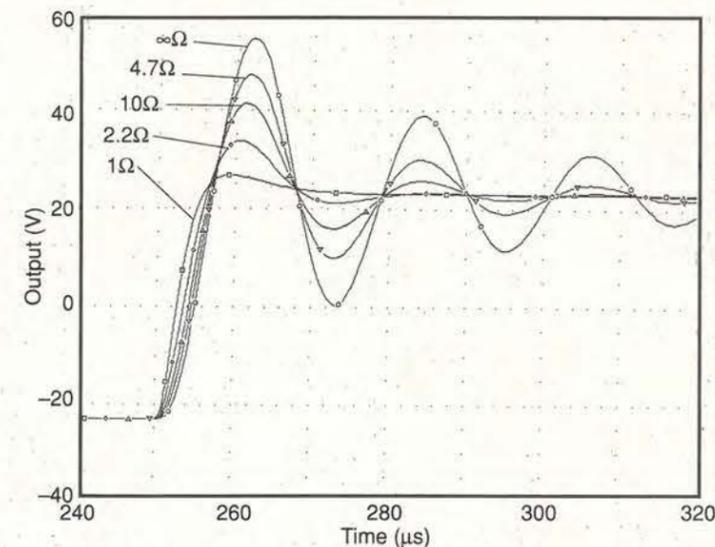


Fig. 8. Damping resistor value has a powerful effect on ringing; 2.2Ω reduces it greatly, and 1Ω prevents it completely.

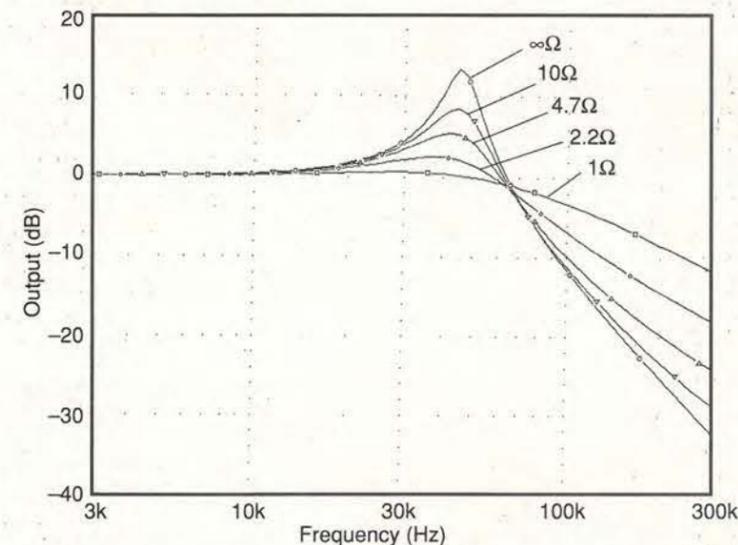


Fig. 9. The effect of damping resistor value on frequency response. Lower values damp the LC resonance better.

output. This is cheaper, but obviously less efficient than an inductor, as 100mΩ of extra resistance has been introduced instead of 10mΩ for our new 2.3μH inductor.

With 0.1Ω, the damping factor cannot exceed 80. A more important objection is that the 4Ω output power appears to be significantly reduced. An amplifier capable of driving 200W into 4Ω is reduced to a 190W unit. This doesn't look so good in the specifications – even though the reduction in perceived loudness is negligible.

The output inductor is only actually wanted for its isolating qualities, but it has at least two other effects. It adds to the cable inductance and the combination causes a high-frequency roll-off when driving an 8Ω load. Secondly, it introduces major confusion into testing with capacitive loads, as described next.

**Effects of load characteristics**

Amplifier transient response is usually tested with a square-wave. The output is loaded with 8Ω and 2μF in parallel to roughly simulate an electrostatic loudspeaker, as this is often

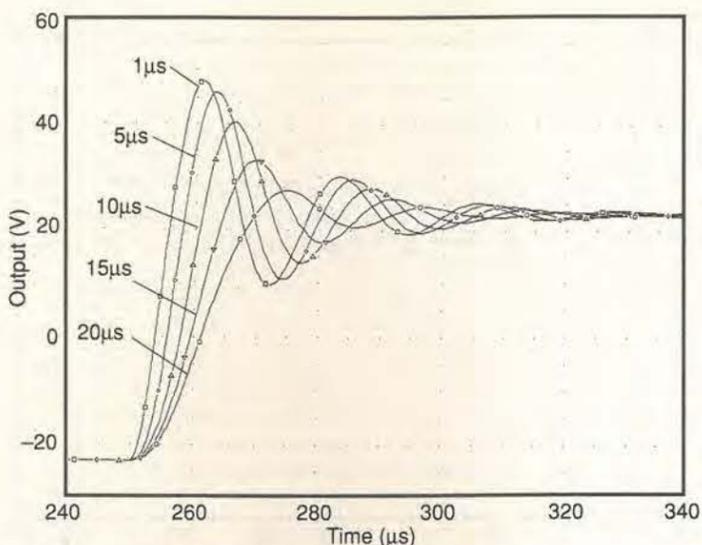


Fig. 10. Test-signal rise time has more effect on ringing than any other parameter. Varied here from 1 to 20µs.

regarded as the most demanding condition. When there is an inductor in the amplifier output, and significant capacitance in the load, they resonate together. This produces a peak in the frequency response at hf, together with overshoot and ringing on fast edges. It is usual to put a low-value damping resistor across the inductor; this reduces the Q of the output LC combination on capacitive loading, and thus reduces overshoot and ringing.

The damped ringing that is seen during these capacitive loading tests is visible at point C but absent at A and B. It is due to the output inductor resonating with the test load capacitance, and has nothing whatever to do with amplifier stability; this test does not really examine amplifier response at all. The ringing is usually around 40kHz or so, and this is much too slow to be blamed on any normally compensated amplifier.

If a power amplifier is provoked by shorting out the output inductor and applying a capacitive load, the oscillation is normally around 100-500kHz, which is destructive of output transistors if it persists. It is nothing like the neat ringing seen in typical capacitive load tests. In the power amplifier itself there is no such thing as 'nicely-damped' ringing; damped oscillation at 500kHz means you are one shaved inch from disaster.

A 'blameless' amplifier is rather resistant to capacitance-induced oscillation. Paralleled with 100 nF directly across the output, a resistance of 8Ω induced damped ringing at 420kHz, while 470nF gave ringing at 300kHz, and 2µF at 125kHz.

The 8Ω/2µF test reveals nothing about amplifier transient response, but it is embedded in tradition, and it is too optimistic to expect its doubtful nature to be universally recognised. Several factors affect output ringing, and can be manipulated to tidy up overshoot and avoid deterring potential customers:

**Output inductance.** Increasing the inductance with all other components held constant reduces the overshoot, Fig. 6, and the amount of response peaking, but the peak moves downward in frequency so the rising response begins to invade the audio band, Fig. 7.

**The damping resistor across the output coil.** Reducing it to below 10Ω lowers the Q of the output LC circuit, reducing overshoot and ringing. It may be wire-wound without self-inductance problems.

Adding a 10Ω damping resistor reduces overshoot from 58% to 48%, and greatly reduces ringing, Fig. 8. Response peaking is reduced, with only a slight effect on its frequency, Fig. 9. The damping resistor can be reduced to well below 10Ω, if stability remains dependable. This can cut transient overshoot further to 20%, and eliminate ringing altogether.

**Load capacitance.** Increasing this with the shunt load resistor held at 8Ω gives more overshoot and lower frequency ringing that decays more slowly. Response peaking is both sharper and lower in frequency, which is not a good combination. However, the capacitance is part of the standard test load and outside the designer's control, so it is not considered further.

**Rise time.** It is a commonplace that in audio technology, the real truth is quite different from the conventional wisdom. In fact, by far the most important factor affecting overshoot and ringing is the rise-time of the applied square wave. Figure 10 demonstrates how the overshoot given by the circuit of Fig. 1 is 51% for a 1µs rise-time, but only 12% for a 20µs rise-time.

The 'transient response' apparently being measured depends critically on the details of the test gear and amplifier slew-rate, and can be cynically manipulated to give the result you want.

**Minimising output impedance.** Leaving aside specmanship, it is worthwhile minimising output impedance, not because it optimises speaker dynamics, but because it minimises frequency response variations due to varying speaker impedance.

The naked amplifier output impedance will be less than the inductor resistance. To minimise the latter, first determine how low the output inductance can be for stability with capacitive loads. Lower inductance means fewer turns and less wire. However, the inductance of the usual single-layer coil varies with the square of the number of turns. Halving inductance only reduces turns, and hence series resistance, by root-two.

It will also be desirable to minimise the resistance of the amplifier internal wiring, and carefully consider any extra resistance introduced by output relays and loudspeaker switching.

References

- Dickason, V, 'The Loudspeaker Design Cookbook,' 5th edn, 1995, p. 122. Distributed by Old Colony Sound Lab. (Thiele on crossover inductor DC resistance).
- Thiele, N, personal communication, April 1997.
- Moir, J, 'Transients and Loudspeaker Damping' *Wireless World*, May 1950, p166.
- Colloms, M, 'Loudspeaker and Headphone Handbook,' ed John Borwick. Focal Press (Butterworth-Heinemann) Pub 1994. ISBN 0-240-51371-1, p. 230.
- Mills, A, 'Distortion Reduction in Moving-Coil Hawksford Loudspeaker Systems Using Current-Drive Technology,' *JAES* March 1989, p. 129.
- Olsher, D, 'Times One RFS400 Power Amplifier Review,' *Stereophile*, Aug 1995, p. 187. (0.6Ω output resistance).
- Self, D, 'Distortion In Power Amplifiers,' Part 7, *Electronics World* Feb 1994, p. 137. (Blameless Class-B amplifier)
- Self, D, 'Audio Power Amplifier Design Handbook,' Newnes 1996, p. 127, ISBN 0-7506-2788-3.
- Brown, I, 'Between Amplifier and Speaker' *Electronics World*, Feb 1995, p. 114.
- Self, D, as ref. 7 but p. 139.

Surplus always wanted for cash!

THE ORIGINAL SURPLUS WONDERLAND! THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

**LOW COST PC's - SPECIAL BUY 'AT 286'**  
40Mb HD + 3Mb Ram  
LIMITED QUANTITY only of these 12MHz HI GRADE 286 systems Made in the USA to an industrial specification, the system was designed for total reliability. The compact case houses the motherboard, PSU and EGA video card with single 5 1/4" 1.2 Mb floppy disk drive & integral 40Mb hard disk drive to the front. Real time clock with battery backup is provided as standard. Supplied in good used condition complete with enhanced keyboard, 640k + 2Mb RAM, DOS 4.01 and 90 DAY Full Guarantee. Ready to Run!  
Order as HIGRADE 286 **ONLY £129.00 (E)**

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

**LOW COST 486DX-33 SYSTEM**  
Limited quantity of this 2nd user, superb small size desktop unit. Fully featured with standard simm connectors 30 & 72 pin. Supplied with keyboard, 4 Mb of RAM, SVGA monitor output, 256k cache and integral 120 Mb IDE drive with single 1.44 Mb 3 1/2" floppy disk drive. Fully tested and guaranteed. Fully expandable  
Only **£399.00 (E)**  
Many other options available - call for details.

**FLOPPY DISK DRIVES 3 1/2" - 8"**  
5 1/4" or 3 1/2" from only £18.95!  
Massive purchases of standard 5 1/4" and 3 1/2" drives enables us to present prime product at industry beating low prices! All units (unless stated) are BRAND NEW or removed from often brand new equipment and are fully tested, aligned and shipped to you with a 90 day guarantee and operate from standard voltages and are of standard size. All are IBM-PC compatible (if 3 1/2" supported on your PC).  
3 1/2" Panasonic JU363/4 720K or equivalent RFE £24.95(B)  
3 1/2" Mitsubishi MF355C-L 1.4 Meg. Laptops only £25.95(B)  
3 1/2" Mitsubishi MF355C-D 1.4 Meg. Non laptop £18.95(B)  
5 1/4" Teac FD-55GFR 1.2 Meg (for IBM pc's) RFE £18.95(B)  
5 1/4" Teac FD-55F-03-U 720K 4080 (for BBC's etc) RFE £29.95(B)  
5 1/4" BRAND NEW Mitsubishi MF501 360K £22.95(B)  
Table top case with integral PSU for HH 5 1/4" Flopp or HD £195.00(E)  
8" Shugart 800/801 8" SS refurbished & tested £195.00(E)  
8" Shugart 810 8" SS HH Brand New £195.00(E)  
8" Shugart 851 8" double sided refurbished & tested £250.00(E)  
Mitsubishi M2894-63 8" double sided NEW £275.00(E)  
Mitsubishi M2896-63-02U 8" DS slimline NEW £285.00(E)  
Dual 8" cased drives with integral power supply 2 Mb £499.00(E)

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

3 1/2" FUJIK FK-309-26 20mb MFM I/F RFE £59.95(C)  
3 1/2" CONNER CP3024 20 mb IDE I/F (or equiv.) RFE £59.95(C)  
3 1/2" CONNER CP3044 40mb IDE I/F (or equiv.) RFE £69.00(C)  
3 1/2" RODIME R03057S 45mb SCSI I/F (Mac & Acorn) £189.00(C)  
3 1/2" WESTERN DIGITAL 850mb IDE I/F Brand New £185.00(C)  
5 1/4" MINISCRIE 3-425 20mb MFM I/F (or equiv.) RFE £48.95(C)  
5 1/4" SEAGATE ST-238R 30 mb RLL I/F Repl. £69.95(C)  
5 1/4" CDC 94205-51 40mb HH MFM I/F RFE tested £89.95(C)  
5 1/4" HP 9754B 850 Mb SCSI RFE tested £89.00(C)  
5 1/4" HP C3010 2 Gbyte SCSI differential RFE tested £195.00(C)  
8" FUJITSU M2322K 160Mb SMD I/F RFE tested £195.00(E)  
Hard disc controllers for MFM, IDE, SCSI, RLL etc. from **£16.95**

**THE AMAZING TELEBOX**  
Converts your colour monitor into a QUALITY COLOUR TV!!  
TV SOUND & VIDEO TUNER CABLE COMPATIBLE  
The TELEBOX is an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by makers such as MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers' (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' UHF colour television channels. TELEBOX MB covers virtually all television frequencies VHF and UHF including the HYPERBAND as used by most cable TV operators. A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop computer video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level Hi Fi audio output are provided as standard.  
TELEBOX ST for composite video input type monitors £36.95  
TELEBOX STL as ST but fitted with integral speaker £39.50  
TELEBOX MB Multiband VHF/UHF/Cable/hyperband tuner £69.95  
For overseas PAL versions state 5.5 or 6 mhz sound specification.  
\*For cable / hyperband reception Telebox MB should be connected to a cable type service. Shipping code on all Telebox's is (B)

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

**Issue 13 of Display News now available - send large SAE - PACKED with bargains!**  
ALL MAIL & OFFICES  
Open Mon-Fri 9.00-5.30  
Dept WW, 32 Biggin Way  
Upper Norwood  
London SE19 3XF  
LONDON SHOP  
Open Mon - Sat 9.00 - 5.30  
215 Whitehorse Lane  
South Norwood  
On 68A Bus Route  
N. Thornton Heath & Selhurst Park Stn Rail Stations  
NEW DISTEL ©  
The Original FREE On line Database  
Info on 20,000+ stock items! RETURNING SOON!  
ALL ENQUIRIES  
0181 679 4414  
FAX 0181 679 1927

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

**IC's - TRANSISTORS - DIODES**  
OBSOLETE - SHORT SUPPLY - BULK  
6,000,000 items EX STOCK  
For MAJOR SAVINGS - CALL FOR SEMICONDUCTOR HOTLIST  
**VIDEO MONITOR SPECIALS**

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

Mitsubishi FA3415ETKL 14" SVGA Multisync colour monitor with fine 0.28 dot pitch tube and resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including IBM PCs in CGA, EGA, VGA & SVGA modes, BBC, COMMODORE (including Amiga 1200), ARCHIMEDES and APPLE. Many features: Etched faceplate, text switching and LOW RADIATION MPP specification. Fully guaranteed, supplied in EXCELLENT little used condition.  
Tilt & Swivel Base £4.75  
VGA cable for IBM PC types.  
External cables for other types of computers CALL  
As New - Used on film set for 1 week only!!  
15" 0.28 SVGA 1024 x 768 res. colour monitors.  
Swivel & tilt etc. Full 90 day guarantee. £145.00 (E)

Just in - Microvitec 20" VGA (800 x 600 res.) colour monitors. Good SH condition - from £299 - CALL for info  
PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with both RGB and standard composite 15.625 KHz video inputs via SCART socket and separate phono jacks. Integral audio power amp and speaker for all audio visual uses. Will connect direct to Amiga and Atari BBC computers. Ideal for all video monitoring / security applications with direct connection to most colour cameras. High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested - guaranteed  
Dimensions: W14" x H12 1/2" x 15 1/2" D.  
Only **£95 (E)**

PHILIPS HCS31 Ultra compact 9" colour video monitor with standard composite 15.625 KHz video input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested & guaranteed (possible minor screen burn) in attractive square black plastic case measuring W10" x H10" x 1 1/2" D. 240 V AC mains powered.  
Only **£79.00 (D)**

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

**20" 22" and 26" AV SPECIALS**  
Superbly made UK manufacture. PIL all solid state colour monitors, complete with 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)

**SPECIAL INTEREST ITEMS**  
MITS. FA3445ETKL 14" Industrial spec SVGA monitors 2kV to 400 kW - 400 Hz 3 phase power sources - ex stock £245  
IBM 8230 Type 1, Token ring base unit driver £950  
IBM 53F5501 Token Ring ICS 20 port lobe modules £750  
IBM MA Token ring distribution panel 8228-23-5050N £585  
AIM 591 Low Cost Oscillator 9Hz to 330kHz IEEE £550  
Trend DSA 274 Data Analyser with 5703(2M) 64 i/o. £600  
Marconi 6310 Programmable 2 to 22 GHz sweep generator £650  
HP1650B Logic Analyser £3750  
HP3781A Pattern generator & HP3782A Error Detector £950  
HP APOLLO RX700 system units £1800  
HP6621A Dual Programmable GPIB PSU 0-7 V 160 watts £175  
HP3081A Industrial workstation c/w Barcode swipe reader £675  
HP6264 Rack mount variable 0-20V @ 20A metered PSU £675  
HP54121A DC to 22 GHz four channel test set £1850  
HP7580A A1 8 pen HPGL high speed drum plotter £650  
EG+G Brookdeale 95035C Precision lock in amp £59.95(A1)  
Veng Eng. Mod 1200 computerised inspection system £200  
Ling Dynamics 2kV programmable vibration test system £1425  
Computer controlled 1056 x 560 mm X Y table & controller £3750  
Keithley 590 CV capacitor / voltage analyser £3750  
Rascal ICR40 dual 40 channel voice recorder system £9500  
Fluor 45KVA 3 ph On Line UPS - New batch Dec.1995 £2200  
ICI R5000 UV 34 Ultrasonic ultrasonic cleaning system £2200  
Marl Tally MT465 High speed line printer £1200  
Intel SBC 486/133SE Multibus 486 system. 8Mb Ram £1150  
Zeta 3220-05 AO 4 pen HPGL fast drum plotters £1450  
Nikon HFX-11 (Ephiphot) exposure control unit £550  
Motorola VME Bus Boards & Components List. SAE / CALL £1250  
Trilo 0-18 vdc linear, metered 30 amp bench PSU. New £1950  
Fujitsu M3041R 600 LPM band printer £3750  
Fujitsu M3041D 600 LPM printer with network interface £1250  
Perkin Elmer 2998 Infrared spectrophotometer £3750  
VG Electronics 1035 TELETEXT Decoding Margin Meter £950  
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager) £1995  
Sekonic SD 150H 18 channel digital Hybrid chart recorder £750  
TAYLOR HOBSON Tallysur amplifier / recorder £2485  
System Video 1152 PAL waveform monitor £300  
Test Lab - 2 mt square quietised acoustic test cabinets £650  
Kenwood 9601 PAL Vectorscope - NEW £650  
Please call for further details on the above items

**19" RACK CABINETS**  
Superb quality 6 foot 40U  
Virtually New, Ultra Smart  
Less than Half Price!  
Top quality 19" rack cabinets made in UK by Optima Enclosures Ltd. Units feature designer, smoked acrylic lockable front door, full height lockable half louvered back door and louvered removable side panels. Fully adjustable internal fixing struts, ready punched for any configuration of equipment mounting plus ready mounted integral 12 way 13 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: 7 1/2" H x 32 1/2" D x 22" W. Order as:  
OPT Rack 1 Complete with removable side panels. £335.00 (G)  
OPT Rack 2 Rack, Less side panels £225.00 (G)

**32U - High Quality - All steel RakCab**  
Made by Eurocraft Enclosures Ltd to the highest possible spec, rack features all steel construction with removable side, front and back doors. Front and back doors are hinged for easy access and all are lockable with five secure 5 lever barrel locks. The front door is constructed of double walled steel with a 'designer style' smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features fully slotted reinforced vertical fixing members to take the heaviest of 19" rack equipment. The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A mains distribution panel internally mounted to the bottom rear, provides 8 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 integral fans to the sub plate etc. Other features include: fitted castors and floor levelers, pre-punched utility panel at lower rear for cable / connector access etc. Supplied in excellent, slightly used condition with keys. Colour Royal blue. External dimensions mm=1625H x 635D x 603 W. (64" H x 25" D x 23 1/2" W)  
Sold at LESS than a third of makers price!!

**A superb buy at only £195.00 (G)**  
Over 1000 racks - 19" 22" & 24" wide  
3 to 44 U high. Available from stock!!  
Call with your requirements.

**TOUCH SCREEN SYSTEM**  
The ultimate in 'Touch Screen Technology' made by the experts - MicroTouch - but sold at a price below cost!! System consists of a flat translucent glass laminated panel measuring 25.5 x 23.5 cm connected to an electronic controller PCB. The controller produces a standard serial RS232 or TTL output which continuously gives simple serial data containing positional X & Y co-ordinates as to where a finger is touching the panel - as the finger moves, the data instantly changes. The X & Y information is given at an incredible matrix resolution of 1024 x 1024 positions over the entire screen size!! A host of available translation software enables direct connection to a PC for a myriad of applications including: control panels, pointing devices, POS systems, controllers for the disabled or computer un-trained etc. Imagine using your finger with 'Windows', instead of a mouse!! (A driver is indeed available!) The applications for this amazing product are only limited by your imagination!! Complete system including Controller, Power Supply and Data supplied at an incredible price of only **£145.00 (B)**  
Full MICROTOUCH software support pack and manuals for IBM compatible PC's £29.95 RFE - Tested

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

**SIMM SPECIALS**  
1 MB x 9 SIMM 9 chip 120ms £19.50 Only £16.50 (A1)  
1 MB x 9 SIMM 3 chip 80 ns £21.50 or 70ns £22.95 (A1)  
1 MB x 9 SIMM 9 chip £21.50 or 70ns £23.75 (A1)  
1 MB x 70 ns 72 pin SIMM - with parity - Only £95.00 (A1)  
INTEL 486-DX3 CPU £55.00 INTEL 486-DX66 CPU £69.00 (A1)  
FULL RANGE OF CO-PROCESSOR'S EX STOCK. CALL FOR LIST

**FANS & BLOWERS**  
EPSON DO412 40x40x20 mm 12v DC £7.95 10 / £65  
PAPST TYPE 612 60x60x25 mm 12v DC £8.95 10 / £75  
MITSUBISHI MMF-D6D12DL 60x60x25 mm 12v DC £4.95 10 / £42  
MITSUBISHI MMF-08C12DM 80x80x25 mm 12v DC £5.25 10 / £49  
MITSUBISHI MMF-09B12DH 92x92x25 mm 12v DC £5.95 10 / £53  
PANKAKE 12-3.5 92x92x18 mm 12v DC £7.95 10 / £69  
EX-EQUIP AC fans. ALL TESTED 120 x 120 x 38 mm spec 110 or 240 v £6.95 80 x 80 x 38 mm - spec 110 or 240 v £5.95  
IMHOV B26 1900 rack mnt 3U x 19" Blower 110/240V NEW £79.95  
Shipping on all fans (A). Blowers (B). 50,000 Fans Ex Stock CALL

SWITCH Market Leader VISA EST 25 YEARS  
All prices for UK Mainland. UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona fide account orders accepted from Government, Schools, Universities and Local Authorities - minimum account order £50. Cheques over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£4.00, (B)=£5.50, (C)=£8.50, (D)=£12.00, (E)=£15.00, (F)=£18.00, (G)=CALL. Allow approx 6 days for shipping - faster CALL. Scotland surcharge CALL. All goods supplied to our Standard Conditions of Sale and unless stated guaranteed for 90 days. All guarantees on a return to base basis. All rights reserved to change prices / specifications without prior notice. Orders subject to stock. Discounts for volume. Top CASH prices paid for surplus goods. All trademarks etc acknowledged. © Display Electronics 1996. E & O.E. 06/6

CIRCLE NO. 113 ON REPLY CARD

COMPUTER ICs	
TMS 9900NL-40 PULLS	£20 ea
S9900 NEW AMD EQUIVALENT	£30 ea
MC6802 PROCESSOR	£2 ea
MC68HC000PB	£5
P8271 BBC DISC CONTROLLER CHIP EX EOPT	£25
2817A-20 (2K X 8) EPROM ex eqpt	£2
D41256C-15 256K X 1 PULLS	9 FOR £5
8748 used/wiped	£4
MK48202-20 ZERO POWER RAM EQUIV 6116LP	£4
USED 4164-15	£60p
BBC VIDEO ULA	£10
8051 MICRO	£1.25
FLOPPY DISC CONTROLLER CHIPS 1771	£16
FLOPPY DISC CONTROLLER CHIPS 1772	£17.50
27C4001 USED EPROMS	£4
27C2001 USED EPROMS	£2.50
1702 EPROM NEW	£6
2114 EX EOPT	50p
4416 EX EOPT	70p
6264-15 8k STATIC RAM	£1.50
Z80A SIO-O	£1.25
7126 3 1/2 DIGIT LCD DRIVER CHIP	£2 ea
2816A-30 HOUSE MARKED	£2
USED TMS2532JL	£2.50
2708 USED	£2
HM6167LP-8	65p
8255-5	£1.40
2114 CMOS (RCA 5114)	£1.60
WD16C550-PC UART	£5
ZN448J	£11
TC5257BPL-85L 32K - 8RAM	£2.50
27C256-25 USED/WIPED	£1.30

REGULATORS	
LM338K	£6
LM323K 5V 3A PLASTIC	£3
LM323K 5V 3A METAL	£3
LM350K (VARIABLE 3A)	£3
78H12ASC 12V 5A	£5
LM317H 10S CAN	£1
LM317T PLASTIC TO220 variable	£1
LM317 METAL	£2.20
7812 METAL 12V 1A	£1
7805/12/15/24	30p
7905/12/15/24	30p
CA3085 TO99 variable reg	2/E1
78HGASC + 79HGASC REGULATORS	£30 ea
LM123 ST93 5V 3A TO3 REGS	£3 ea
UC3524AN SWITCHING REGULATOR IC	60p
78L12 SHORT LEADS	10/E1
LM2596A CDS	60p
STR451 SANKEN switch mode regulator	£10
78S05/78S24 2 TO-220	£1
78L05	5/E1

CRYSTAL OSCILLATORS	
307.2KHZ 1M000000 1M8432 2M457600 3M6864 4M000000	
5M000000 5M068000 5M760000 6M000000 6M1440 7M000000	
3M372800 7M5 8M000000 9M21610M000 10M0 12M000000	
14M318 14M3818 16M00 17M625600 18M000000 18M432 19M050	
19M2 19M440 20M000 20M0150 21M676 22M1184 23M587	
24M0000 25M1748 25M175 25M1889 27M + 36M 27M000000	
28M4322 32M000000 32M000000 /S/MOUNT 33M3330 35M4816	
38M100 40M000 41M539 42M000000 44M444 44M900 44M0	
48M00000 50M00 55M000 56M00920 64M000000 66M667 76M1	
80M0 84M0	£1.50 ea

CRYSTALS	
32K768 1MHZ 1M8432 2M000 2M1432 2M304 2M4576 3M000	
3M2768 3M400 3M579545 3M58564 3M600 3M6864 3M93216	
4M000 4M190 4M194304 4M2056 4M33614 4M608 4M9152 5M000	
5M0688 6M000 6M041952 6M200 6M400 7M37280 8M000 8M06400	
8M448 8M863258 8M8670 9M3750 9M8304 10M240 10M245	
10M368 10M70000 11M000 11M050 11M88135 12M000 12M5	
13M000 13M270 13M875000 14M000 14M318 14M7450 14M7456	
15M0000 16M000 17M6250 18M432 20M000 21M300	
21M400M15A 24M000 25M000 26M995 BN 27M045 RD 27M095 OR	
27M145 LB 27M145 YW 27M195 GN 28M4696 30M4696 31M4696	
31M4696 34M368 36M75625 36M76875 36M78125 36M79375	
36M80625 36M81875 36M83125 36M84375 36M900 48M000	
51M05833 54M1916 55M500 57M7416 57M7583 69M545 69M550	
96M000 111M800 114M8	£1 ea

TRANSISTORS	
MPSA42	10/E1
MPSA92	10/E1
2N2907A	10/E1
BC477, BC488	10/E1
BC107 BCY70 PREFORMED LEADS	
full spec	£1 £4/100 £30/1000
BC238C, BC308B	£1/30 £3.50/100
2N2907 WORKING CROPPED	£1/15 £4/100
BC548B SHORT LEADS	£3/100 £20/1000

POWER TRANSISTORS	
OC29	£2 ea
2SC1520 sim BF259	3/E1 100/222
TIP 140F	2/E1
1RF620 TO-220 5A 200V MOSFET	2/E1
SE9301 100V JDA DARL SIM TIP121	2/E1
BD680	4/E1
BUS48AP	£1
BUW13A	£2
2SC156 900V 6A 120W	£3
2SD1397 npn TV/MONITOR O/P TRANSISTOR	£2

TEXTUOL ZIF SOCKETS	
28 PIN USED	£3
ZIF 64 WAY SHRINK DIP SKT TEXTUOL 264-1300-00 1.78mm	
SPACING ON PCB WITH 4MHz RESONATOR	£10
SINGLE IN LINE 32 WAY CAN BE GANGED FOR USE WITH ANY DUAL IN LINE DEVICES... COUPLING SUPPLIED	2/E1.50

**KEYTRONICS**  
 TEL. 01279-505543  
 FAX. 01279-757656  
 e-mail keytronics@btinternet.com  
 PO BOX 634  
 BISHOPS STORTFORD  
 HERTFORDSHIRE CM23 2RX  
 http://www.btinternet.com/~keytronics

POWER FETS	
IXFH75N10 75A 200V 20 Mill-ohm 200 WATT Ideal for UPS	£5
IRFP450 500V 14A 0.4ohm 180 W	£2

SOLID STATE RELAYS	
zero volts switching, Control volts 3.5V to 26V DC	
50AMP 240V ac D2450-10	£15
80AMP 240V ac D240D80-10sp	£20
25AMP 240V ac	£10

MISCELLANEOUS	
AAA NICADS HI CAPACITY 240mA/HR 3 CELL PACK	£3
XENON STROBE TUBE	£1.60
OPTO ICS also available TLP550 TLP666GF	
68 way PLCC SKT 100 available	£1 each
100 wa PLCC SKT 100 available	£1.50 each
1250pF POSTAGE STAMP COMPRESSION TRIMMER	£1
LM324 (Quad 7411)	4/E1
MINIATURE FERRITE MAGNETS 4x4x3mm	10/E1
TL071 LO NOISE OP AMP	5 for £1
TL081 OP AMP	4 for £1
12 way dil sw	£3 for £1
10NF 63V X7R PHILIPS SURFACE MOUNT 100K available	
SWITCHED MODE PSU 40 WATT UNCASED QTY. AVAILABLE +5V 5A, +12V 2A, 12V 500mA FLOATING	£30/4000 £9.95 (E2)

CMOS 555 TIMERS	
2/3 AAA LITHIUM cells as used in compact cameras	2/E1.50
PASSIVE INFRA RED SENSOR CHIP + MIRROR + CIRCUIT	£2 ea
EUROCARD 96-WAY EXTENDER BOARD	£10 ea
290 x 100mm	
DIN 41612 96-WAY A/B/C SOCKET PCB RIGHT ANGLE	£1.30
DIN 41612 96-WAY A/B/C SOCKET WIRE WRAP PINS	£1.30
DIN 41612 64-WAY A/C SOCKET WIRE WRAP PINS	£1
DIN 41612 64-WAY A/C PLUG PCB RIGHT ANGLE	£1
DIN 41612 64-WAY A/B SOCKET WIRE WRAP (2-ROW BODY)	£1
BT PLUG + LEAD	3/E1
MIN. TOGGLE SWITCH 1 POLE o/c PCB type	5/E1
LCD MODULE sim. LM018 but needs 150 to 250V AC for display	
40 x 2 characters 182 x 35 x 13mm	£10
6-32 UNC 5/16 POZI PAN SCREWS	£1/100
NUTS	£1.25/100
PUSH SWITCH CHANGEOVER	2/E1
RS232 SERIAL CABLE D25 WAY MALE CONNECTORS	£5.90 ea (£1.30)
25 FEET LONG, 15 PINS WIRED BRAID + FOIL SCREENS	
INMAC LIST PRICE	£30
AMERICAN 2/3 PIN CHASSIS SOCKET	2/E1
WIRE ENDED FUSES 0.25A	30/E1
NEW ULTRASONIC TRANSDUCERS 32kHz	£2/pr
SMALL CYLINDRICAL MAGNETS	3/E1
SMALL MICROWAVE DIODES AE1 OC1026A	2/E1
D.I.L. SWITCHES 10-WAY E1 8-WAY 80p 4/5/6-WAY	80p
180VOLT 1 WATT ZENERS also 12V & 75V	20/E1
MIN GLASS NEONS	10/E1
RELAY 5V 2-pole changeover looks like RS 355-741 marked STC 47V80st	£1 ea
MINIATURE CO-AX FREE PLUG RS 456-071	2/E1
MINIATURE CO-AX PCB SKT RS 456-093	2/E1
PCB WITH 2N2646 UNIJUNCTION WITH 12V 4-POLE RELAY	4/E1
400 MEGOHM THICK FILM RESISTORS	£1
STRAIN GAUGES 40 ohm Foil type polyester backed balco grid alloy	£1.50 ea 10+
ELECTRET MICROPHONE INSERT	2/E1
Linear Hall effect IC Micro Switch no 613 SS4 sim RS 304-267	
£2.50 100+ £1.50	
1 pole 12-way rotary switch	4/E1
AUDIO ICS LM380 LM386	£1 ea
555 TIMERS E1 741 OP AMP	6/E1
ZN414 AM RADIO CHIP	80p
COAX PLUGS nice ones	4/E1
COAX BACK TO BACK JOINERS	3/E1
INDUCTOR 20H 1.5A	5/E1
1 25 inch PANEL FUSEHOLDERS	3/E1
12V 1.2W small w/e lamps fit most modern cars	10/E1
STEREO CASSETTE HEAD	£2
MONO CASS. HEAD E1 ERASE HEAD	50p
THERMAL CUT OUTS 50 77 85 120°C	£1 ea
THERMAL FUSES 220°C/121°C 240V 15A	5/E1
TRANSISTOR MOUNTING PADS TO-5/TO-18	£3/1000
TO-3 TRANSISTOR COVERS	10/E1
PCB PINS FIT 0.1 inch VERO	200/E1
TO-220 micas + bushes	10/50p 100/2
TO-3 micas + bushes	15/E1
POTS SHORT SPINDLES 2K5 10K 25K 1M 2M5	4/E1
LM335Z 10mV/degree C	£1
LM234Z CONST. CURRENT I.C.	£1
BNC TO 4MM BINDING POST SIM RS 455-961	£1
MIN PCB POWER RELAYS 10.5v COIL 6A CONTACTS 1 pole c/o	
LCD MODULE 16 CHAR. X 1 LINE (SIMILAR TO TOUCH LM10)	£5
OPTI264A 10KV OPTO ISOLATOR	£1.35 ea 100+ £1 ea
LOVE STORY CLOCKWORK MECHANISM BOX MECHANISM	
MADE BY SANKYO	£1 ea
Telephone cable clips with hardened pins	500/E2
10,000µF 16V PCB TYPE 30mm DIA x 31mm	2/E1
EC CHASSIS FUSED PLUG B-LEE L2728	3/E1
2A CERAMIC FUSE 1.25 inch OB	10/E1
46 WAY IDC RIBBON CABLE 100 FOOT REEL	£5 + CARR
20mm PCB FUSEHOLDER	5/E1
ASTEC MODULATOR VIDEO + SOUND UM1287	£2.25
BARGRAPH DISPLAY 8 RED LEDS	£1.50
NE567 PHASE LOCKED LOOP	2/E1
NE564	£1
TL084	4/E1
IR2432 SHARP 12 LED VU BAR GRAPH DRIVER	£1.25
10A CORCOM MAINS RFI FILTER EX. EOPT	£2 100 + £1.50
8 OHM NYLON CONE LOUDSPEAKER 55mm DIA x 10mm DEEP	2/E1
AD592AN Temperature sensor TO-92 package with 1.5m lead	2/E1
DC FANS 12V 50, 62, 80, 92mm	£5 each

DIODES AND RECTIFIERS	
A115M 3A 600V FAST RECOVERY DIODE	4/E1
1N5819 1A 60V SCHOTTKY wire ended	4 for £1
1N5407 3A 1000V	8/E1
1N4148	100/E1.50

MONOLITHIC CERAMIC CAPACITORS	
10n 50V 2.5mm	100/E4.50
100n 50V 2.5mm or 5mm	100/E6
100n ax short leads	100/E3
100n ax long leads	100/E5
100n 50V dil package 0.3 inch rad	100/E8
1µF 50V 5mm	8 for £1 £10/100

QUARTZ HALOGEN LAMPS	
12V 50watt LAMP TYPE M312	£1 ea HOLDERS 60p ea

RF BITS	
FX3286 FERRITE RING ID 5mm OD 10mm	10 for £1
ASTECC UM1233 UHF VIDEO MODULATORS (NO SOUND) 1250	
STOCK	£1.50
MARCONI MICROWAVE DIODES TYPES DC2929, DC2962	
DC4229F1/F2	£1 ea
XTAL FILTERS 21M4 55M0	£2 ea
ALL TRIMMERS	3 for 50p
VIOLLET	5-105pF
RED 10-110pF GREY 5-25pF SMALL MULLARD	
2 to 22pF	3 for 50p £10/100
TRANSISTORS 2N4427, 2N3866	80p ea
CERAMIC FILTERS 4M5/6M/9M/10M7	60p ea
FEED THRU CERAMIC CAPS 1000pF	10/E1
(BFY51 TRANSISTOR CAN SIZE)	
2N2222 METAL	5/E1
P2N2222A PLASTIC	10/E1
2N2369	5/E1
2N3866 + 2N4427	£1 ea
74N16 TACS CAR PHONE O/P MODULE	
EQUIV MHW806A-3 RF IN 40mW O/P6-8w 840-910MHz	£3 ea
VN10Km + VN10LM	4 for £1
BB405B, BB809B VARICAP DIODES	4 for £1 ea

SEND E1 STAMPS FOR CURRENT IC+ SEMI STOCK LIST - ALSO AVAILABLE ON 3 1/2 INCH FLOPPY DISK

**MAIL ORDER ONLY**  
 MIN. CASH ORDER £10.00. OFFICIAL ORDERS WELCOME  
 UNIVERSITIES/COLLEGES/SCHOOLS/GOVT. DEPARTMENTS  
 MIN. ACCOUNT ORDER £10.00. P&P AS SHOWN IN BRACKETS (HEAVY ITEMS) OTHERWISE 95p

**ADD 17 1/2% VAT TO TOTAL**  
**ELECTRONIC COMPONENTS BOUGHT FOR CASH**

MONOLITHIC CERAMIC CAPACITORS	
10n 50V 2.5mm	100/E4.50
100n 50V 2.5mm or 5mm	100/E6
100n ax short leads	100/E3
100n ax long leads	100/E5
100n 50V dil package 0.3 inch rad	100/E8
1µF 50V 5mm	8 for £1 £10/100

QUARTZ HALOGEN LAMPS	
12V 50watt LAMP TYPE M312	£1 ea HOLDERS 60p ea

RF BITS	
FX3286 FERRITE RING ID 5mm OD 10mm	10 for £1
ASTECC UM1233 UHF VIDEO MODULATORS (NO SOUND) 1250	
STOCK	£1.50
MARCONI MICROWAVE DIODES TYPES DC2929, DC2962	
DC4229F1/F2	£1 ea
XTAL FILTERS 21M4 55M0	£2 ea
ALL TRIMMERS	3 for 50p
VIOLLET	5-105pF
RED 10-110pF GREY 5-25pF SMALL MULLARD	
2 to 22pF	3 for 50p £10/100
TRANSISTORS 2N4427, 2N3866	80p ea
CERAMIC FILTERS 4M5/6M/9M/10M7	60p ea
FEED THRU CERAMIC CAPS 1000pF	10/E1
(BFY51 TRANSISTOR CAN SIZE)	
2N2222 METAL	5/E1
P2N2222A PLASTIC	10/E1
2N2369	5/E1
2N3866 + 2N4427	£1 ea
74N16 TACS CAR PHONE O/P MODULE	
EQUIV MHW806A-3 RF IN 40mW O/P6-8w 840-910MHz	£3 ea
VN10Km + VN10LM	4 for £1
BB405B, BB809B VARICAP DIODES	4 for £1 ea

MONOLITHIC CERAMIC CAPACITORS	
10n 50V 2.5mm	100/E4.50
100n 50V 2.5mm or 5mm	100/E6
100n ax short leads	100/E3
100n ax long leads	100/E5
100n 50V dil package 0.3 inch rad	100/E8
1µF 50V 5mm	8 for £1 £10/100

QUARTZ HALOGEN LAMPS	
12V 50watt LAMP TYPE M312	£1 ea HOLDERS 60p ea

RF BITS	
FX3286 FERRITE RING ID 5mm OD 10mm	10 for £1
ASTECC UM1233 UHF VIDEO MODULATORS (NO SOUND) 1250	
STOCK	£1.50
MARCONI MICROWAVE DIODES TYPES DC2929, DC2962	
DC4229F1/F2	£1 ea
XTAL FILTERS 21M4 55M0	£2 ea
ALL TRIMMERS	3 for 50p
VIOLLET	5-105pF
RED 10-110pF GREY 5-25pF SMALL MULLARD	
2 to 22pF	3 for 50p £10/100
TRANSISTORS 2N4427, 2N3866	80p ea
CERAMIC FILTERS 4M5/6M/9M/10M7	60p ea
FEED THRU CERAMIC CAPS 1000pF	10/E1
(BFY51 TRANSISTOR CAN SIZE)	
2N2222 METAL	5/E1
P2N2222A PLASTIC	10/E1
2N2369	5/E1
2N3866 + 2N4427	£1 ea
74N16 TACS CAR PHONE O/P MODULE	
EQUIV MHW806A-3 RF IN 40mW O/P6-8w 840-910MHz	£3 ea
VN10Km + VN10LM	4 for £1
BB405B, BB809B VARICAP DIODES	4 for £1 ea

SEND E1 STAMPS FOR CURRENT IC+ SEMI STOCK LIST - ALSO AVAILABLE ON 3 1/2 INCH FLOPPY DISK

**MAIL ORDER ONLY**  
 MIN. CASH ORDER £10.00. OFFICIAL ORDERS WELCOME  
 UNIVERSITIES/COLLEGES/SCHOOLS/GOVT. DEPARTMENTS  
 MIN. ACCOUNT ORDER £10.00. P&P AS SHOWN IN BRACKETS (HEAVY ITEMS) OTHERWISE 95p

**ADD 17 1/2% VAT TO TOTAL**  
**ELECTRONIC COMPONENTS BOUGHT FOR CASH**

COMMUNICATIONS

# Hands-on Internet

In addition to tips for helping you save time on the Internet, Cyril Bateman offers pointers to non-Spice electronics CAD software and details of a competent audio power amplifier design.

While searching Alta Vista for Smith chart software, following a link which turned out to be broken, to my surprise instead of the usual error message, I found myself at the 'Cern' site<sup>1</sup> in Switzerland, Fig. 1.

After a few moments I recalled that Tim Berners-Lee, the originator of the hypertext mark up language, was based at Cern in 1991 when the whole concept of the Internet Web page system was devised.

HTML is a method for linking to other relevant documents and forms the backbone of the present day World Wide Web.

Fig. 2. The WWW Consortium manages the WWW Virtual Library. Engineering sections of the WWW Virtual Library are supervised by NASA.

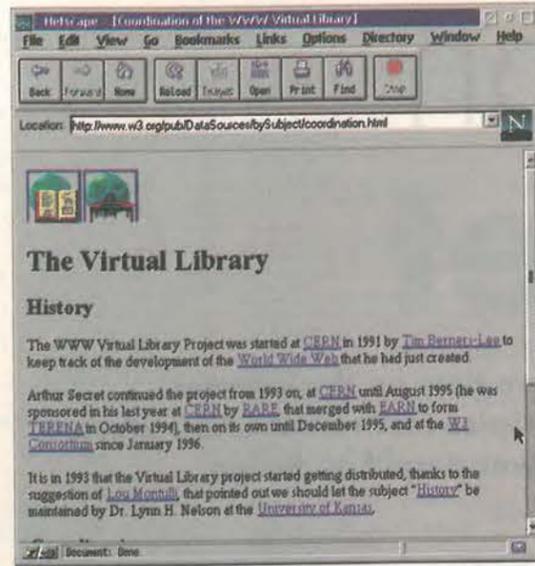


Fig. 3. Advanced techniques ensure the best search results. Find how to manage Alta Vista searches.

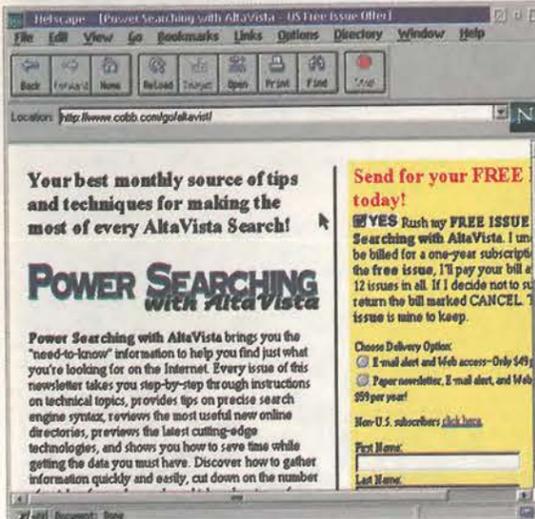


Fig. 4. Use a Meta-Search engine to maximise search information. Select your choice for multiple searches.

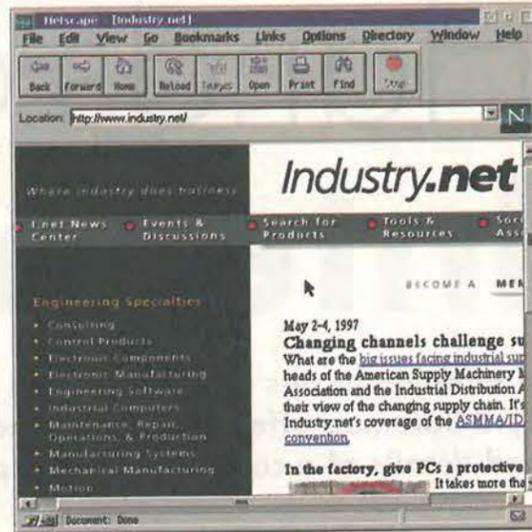
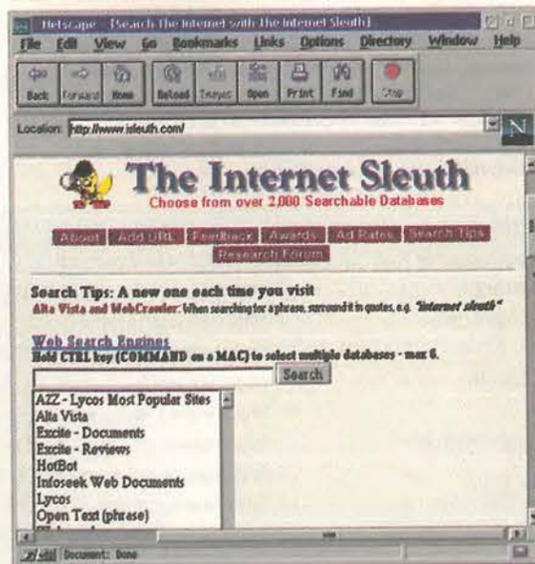


Fig. 5. Universal Engineering Manufacturing Forum. Excellent multi discipline engineering shareware repository.

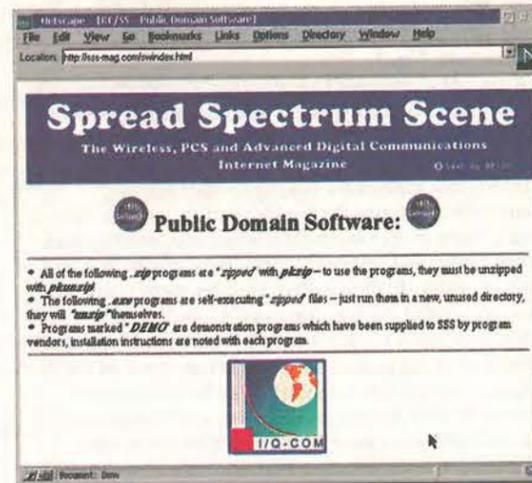


Fig. 6. Meeting place for all electronic designers - especially those involved in rf. Software library includes many hard to find utilities.

indexing 1Gbyte of text in an hour. However Scooter cannot update if the page is held on a computer behind a server gateway, or on one protected by a 'Firewall.' This explained my broken link.

The volume of 'hits' returned from searching a keyword index can be reduced using advanced search techniques. A newsletter publication 'Power Searching with Alta Vista'<sup>4</sup> from The Cobb Group claims to provide answers to search problems as well as using the Alta Vista Private Extensions software to access data within your own system, Fig. 3.

Even given the power of Alta Vista, it is not possible to ensure that any keyword search database is complete and up to date. Last month I covered use of the new limited area search engines. This can usefully target some engineering areas, but should both methods fail to locate the needed information, all is not lost.

The Internet Sleuth<sup>5</sup> provides the facility to search your choice of any six from over 2000 databases simultaneously. These include the popular Alta Vista,

Excite and Infoseek indexes, which should guarantee a successful result. A possible downside, due to the volume of data searched, is that each search takes longer and can result in large amounts of returned data to be sifted, Fig. 4.

**Simulation and design software**

Sources of Spice simulators have been well covered in past issues, but electronics design encompasses many problems that cannot be solved using Spice. Two such



Fig. 7. Design microstripline widths/impedances on-the-page. Another unique Max Froding rf utility.

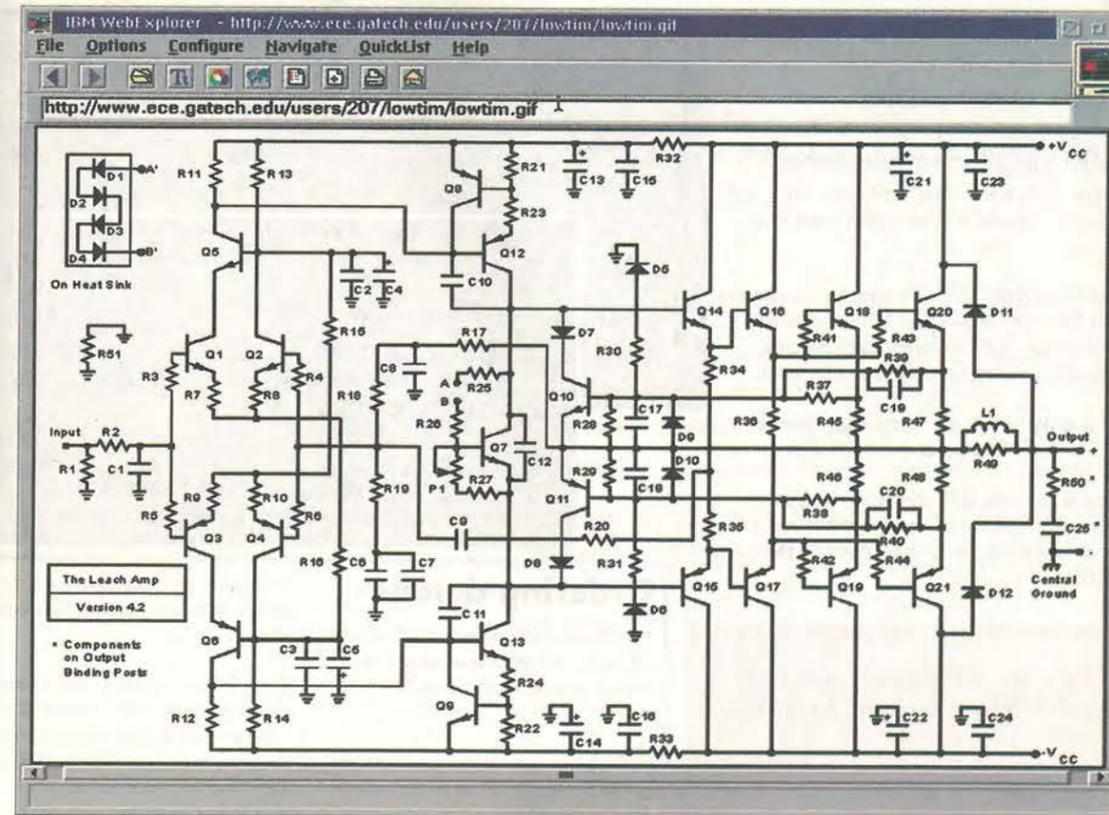


Fig. 8. Specialist supplier of low loss high-frequency laminates. Track widths designed using the laminate makers own utility, give maximum confidence.

involve metalwork of housings and radio frequencies circuit design. An excellent source of shareware solutions targeted to design engineers in the widest sense can be found at Industry.Net.<sup>6</sup> This is a forum for all industrial manufacturing, which has an excellent thirteen page selection of essential engineering packages, both for mechanical and electronic design, Fig. 5.

This month's electronic topic centres on rf design needs. *Spread Spectrum Scene*<sup>7</sup> is an Internet magazine

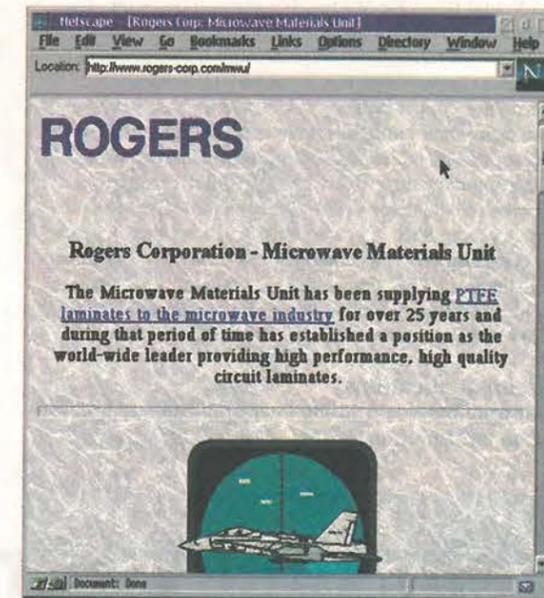


Fig. 9. The Marshall-Leach amplifier - an interesting well proven low-tim design. Fast slewing, low imd and full power into 4Ω, with this 120W version. Full constructional details for this design are published on this Web page.

embracing wireless, pcs and digital communication. Its public domain software page lists more than 150 useful packages that are easily downloaded.

Most packages are easy to find, but some are difficult. I spent some time trying to locate Motorola's excellent Smith Chart program on Motorola's page without success. I was able to download it immediately from SSS, Fig. 6.

In my November '96 Internet article, I outlined an add-on for generating net-lists from Max Froding.<sup>8</sup> It was produced for the ARRL rf circuit simulator. This month Max offers an on-the-page micro-stripline design tool in two versions. It uses JavaScript for the Netscape browser and Visual Basic for Microsoft's Internet Explorer. The Javascript version includes a useful table of dielectric constants for most common microstrip materials, Fig. 7.

Rogers Corporation<sup>9</sup> has supplied PTFE based microwave copper laminates for more than 25 years. In the past, using their laminates, I have relied on their excellent book of design tables when designing microstrip circuits.

The company now offers its MWL.ZIP microstrip impedance calculator which can be downloaded from the page, or from SSS. If you want to find out how successfully the company bonds its copper foils – as thin as 1/4 ounce – to a slippery PTFE glass substrate material, visit the page for a description. Included are micro photographs of both rolled and electro-deposited copper foils, Fig. 8.

**Circuit applications**

Following the recent strong interest in audio topics, a search on 'amplifier design' led me to some pages

written by Professor W. Marshall Leach, Jr<sup>10</sup>. He teaches both audio engineering and transistor circuit analysis at the Georgia Institute of Technology.

Professor Leach has contributed many published papers on audio, and on Spice models for loudspeakers and microphones. He is a Fellow of the AES, a senior member of IEEE and a member of the Acoustical Society.

His pages are particularly interesting since they include the circuit diagram together with full constructional detail for an interesting power amplifier. There is also a parts list with US sources.

The amplifier was originally designed some years ago following the vogue for designs achieving low transient intermodulation distortion. Over the years, countless versions have been built by his students, and all bugs have been worked out. The current version 4.2 is thus well proven and represents the results of many detail design refinements

This amplifier uses a cascode input stage together with feedback split into two separate high and low frequency paths. It also has feed-forward frequency compensation above 150kHz around the driver and paralleled transistor complementary output stages.

The design supplies 120W into 8Ω with SMPTE intermodulation distortion of less than 0.01% below clipping. It can drive a 4Ω load to full power without current limiting. Further features are an 8.5MHz gain-bandwidth product and a 70V/μs large-signal slew rate. It is also stable with capacitive loads, Fig. 9.



a **powerful** combination

For the past ten years Weir Electronics has been part of the Lambda Group – the largest power supply company in the world. Weir are now trading under the name Weir Lambda, to show that Weir is part of this major worldwide force. Same company, same people, same trusted power supplies and power systems, but with all the benefits of being part of the largest power supply company in the world – a partnership that packs a powerful punch.

Call us today to find out how Weir Lambda can provide your next power solution

Weir Electronics Ltd Durban Road Bognor Regis Sussex PO22 9RW

Tel: 01243 865991 Fax: 01243 841628

e-mail sales@weirlambda.com http://www.weirlambda.com



CIRCLE NO. 115 ON REPLY CARD

# Nine year index – new update

Hard copies and floppy-disk databases both available

\*\* Includes over 600 circuit idea references \*\*

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

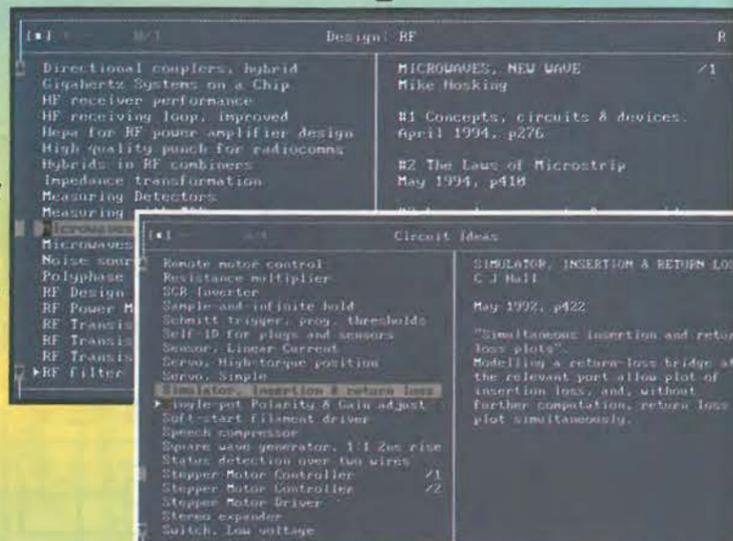
The computerised index of *Electronics World* magazine covers the nine years from 1988 to 1996, volumes 94 to 102 inclusive is available now. It contains almost 2000 references to articles, circuit ideas and applications – including a synopsis for each.

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

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

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

Hard copy *Electronics World* index  
Indexes on paper for volumes 100, 101 and 102 are available at £2 each, excluding postage.



**Ordering details**

The EW index data base price of £20 includes UK postage and VAT. Add an extra £1 for overseas EC orders or £5 for non-EC overseas orders.

Postal charges on hard copy indexes and on photocopies are 50p UK, £1 for the rest of the EC or £2 worldwide.

For enquiries about photocopies, etc, please send an sae to SoftCopy Ltd at the address below.

Send your order to SoftCopy Ltd., 1 Vineries Close, Cheltenham GL53, tel 01242 241455, or e-mail at softcopy@compuserve.com. Please make cheques payable to SoftCopy Ltd – not EW or Reed Business Publishing. Please allow up to 28 days for delivery.



# Camcorder dubber

As every camcorder owner knows, a car engine sound track does nothing to enhance scenery filmed from a moving vehicle. Ian Hickman's mixing circuit is designed not only to remove unwanted sound but also to replace it with whatever you want.

On a winter holiday recently, we took a camcorder with us, for the first time. Not wanting to tie up the expensive Hi8 metal tapes for ever, and have to play holiday movies through the camcorder, the obvious step was to transfer the material to VHS tapes. But that raised the question of what to do about the sound.

In earlier times, with 8mm home movies, usually there was no sound, or at least it was added afterwards, by 'striping' the film. The camcorder, by contrast, gives one stereo sound, whether you want it or not. This is fine when shooting a street carnival, or for catching everything but the smell of a loco in steam. But often - as when shooting snow covered mountains through the windscreen of a car for example - the sound is more of a nuisance than a help.

## A simple applique box

What was needed was a gadget to permit the sound on the VHS tape to originate from either the camcorder, or from a cassette recorder, at will.

Further consideration made it clear that it should be possible to 'cross fade' the two sound sources, to avoid any clicks due to switching transients. And a further useful facility would be a microphone input, so that comments, or at least a simple introduction, could be added to the soundtrack. To avoid further switching arrangements, the microphone input should operate a 'ducking circuit', to reduce the volume of the background music when speaking.

The outcome was an applique box, interconnecting the various items of kit as illustrated in Fig. 1.

## The circuitry

Figure 2 shows the circuit of the applique box. Unity-gain buffers are provided for the camcorder sound and the input from the cassette recorder's DIN connector. These turned out to be at much the same level. A gain of 30dB is provided by the microphone input buffer.

The microphone and tape inputs are summed at the virtual earth, pin 13, of IC<sub>1</sub>, and applied to one end of 1kΩ linear potentiometer, R<sub>18</sub>. Buffered stereo sound from the camcorder connects to the other end, the wiper of R<sub>18</sub> being connected to volume control R<sub>19</sub> which is a 4.7kΩ logarithmic potentiometer.

Thus the sound output from buffer IC<sub>1</sub> pin 7 can be cross faded at will between the stereo output and tape/microphone inputs, and its level adjusted from normal down to zero. The

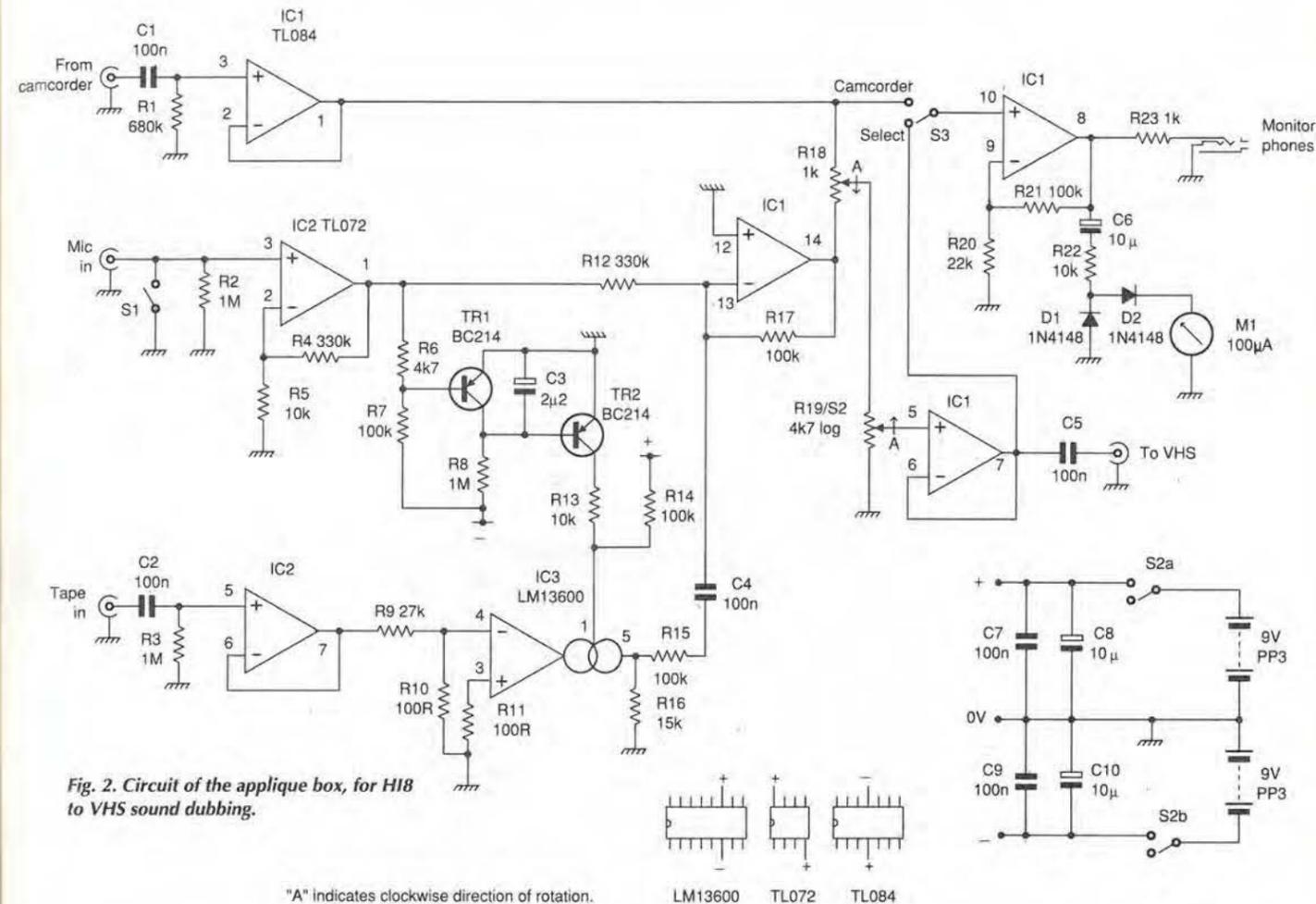


Fig. 2. Circuit of the applique box, for Hi8 to VHS sound dubbing.

"A" Indicates clockwise direction of rotation.

LM13600 TL072 TL084

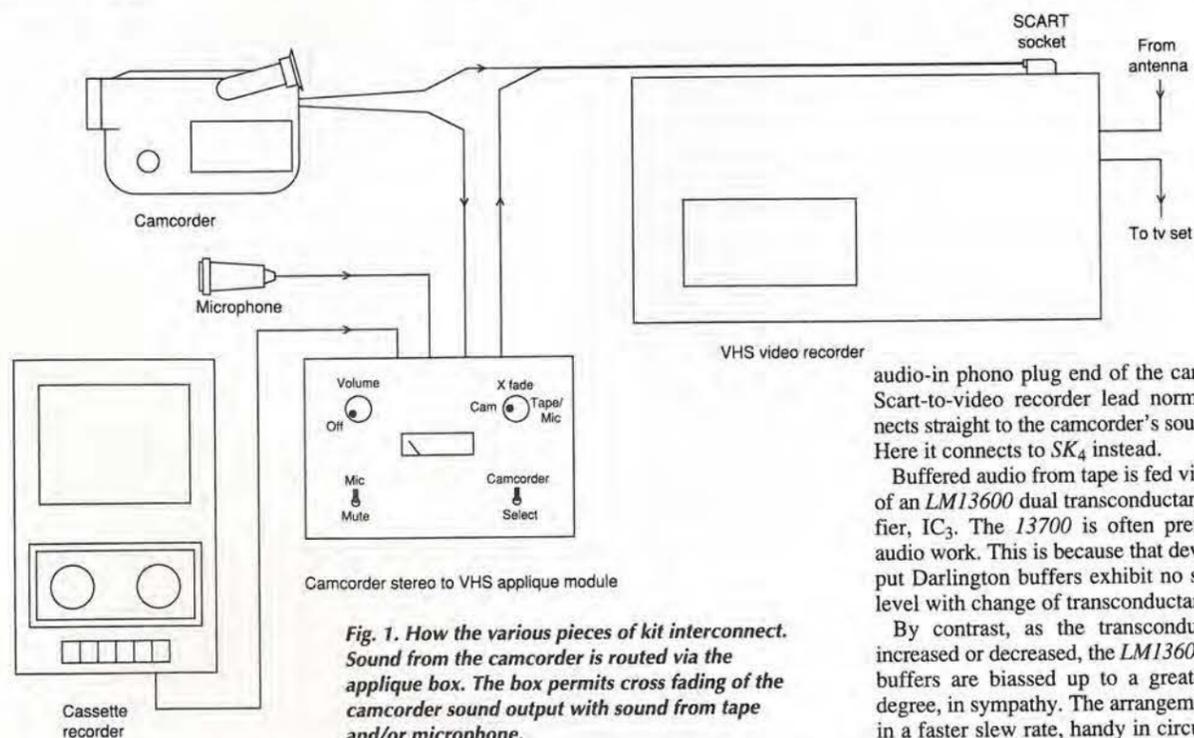


Fig. 1. How the various pieces of kit interconnect. Sound from the camcorder is routed via the applique box. The box permits cross fading of the camcorder sound output with sound from tape and/or microphone.

fast settling is needed. But it can result in 'pops' in an audio circuit, when there are rapid changes in gain. However, in this application the Darlington output buffers are not used, so either device will do.

The transconductance of IC<sub>3</sub>, and hence its gain, is set by the bias current I<sub>ABC</sub> injected into pin 1. This consists of two components, the larger proportion coming via R<sub>13</sub> - Tr<sub>2</sub> is normally bottomed - with about another 25% or so coming from the positive rail, via R<sub>14</sub>. When a voice-over output from the mike appears, the negative-going peaks at pin 1 of IC<sub>2</sub> bottom Tr<sub>1</sub>. This discharges C<sub>3</sub> and removes the base current from Tr<sub>2</sub>. The gain of IC<sub>3</sub> thus drops by some 12dB or more, this proving a suitable degree of ducking.

The microphone used was a small dynamic type with a 50kΩ output impedance. In fact, it needed only 20dB of gain to raise its output to the same level as that from the camcorder and cassette.

The extra gain, together with a little forward bias for Tr<sub>1</sub> via R<sub>7</sub>, was incorporated to provide reliable operation of the ducking function. The extra microphone circuit gain was simply disposed of by making R<sub>12</sub> 330kΩ, as opposed to 100kΩ at R<sub>15</sub> and R<sub>17</sub>.

Switch S<sub>1</sub> shorts the mike when not needed, preventing adventitious extraneous noises appearing on the soundtrack of the dubbed

tape. Output from the fourth section of IC<sub>1</sub>, at pin 8, acts as a buffer to drive monitor phones, which can be plugged into SK<sub>5</sub>. It also drives a simple level monitor indicator, M<sub>1</sub>. Switch S<sub>3</sub> draws the output monitor/meter buffer's input either from the camcorder stereo input or from the current 'select' input, be it camcorder stereo, cassette or microphone. In a stereo version of the dubber, potentiometers R<sub>18</sub> and R<sub>19</sub> could be ganged.

In my prototype, power is supplied by two PP3 9V batteries, the on/off switch being ganged with R<sub>19</sub>. Capacitors C<sub>7</sub> and C<sub>9</sub> were duplicated adjacent to each IC, in accordance with good practice.

## Using the dubber

When transferring video from a camcorder to VHS tape in the video recorder, the latter is set to use the Scart socket as the programme source. On our video recorder, this is achieved by setting its channel number to 0, which brings up the legend 'AV' in the channel number display - a fairly standard arrangement, I imagine.

When we view video tapes, our tv is usually supplied with baseband video via a Scart interconnection. This avoids the picture degradation caused by transferring the video via the rf modulator and demodulator.

While dubbing is taking place, the Scart

socket is not available as it is required for the lead from the camcorder and applique box. But tuning the tv receiver to the recorder's rf channel enables visual monitoring of the Hi8 output as it is recorded. It also enables sound to be sourced via the dubbing box's 'select' setting. Thus the main use for the phone monitor is to keep an ear on the original camcorder sound track, ready to cross fade to it when appropriate.

Figure 2 is configured for my particular collection of kit. Depending on your particular microphone and cassette recorder, cd player, or even record deck, different gain settings of the input buffers may be needed. Here, the level meter M<sub>1</sub> is handy, as it indicates the typical level of stereo sound from the camcorder.

Stereo enthusiasts with a suitable video recorder can double up on IC<sub>1</sub> and use a quad op-amp in place of a dual at IC<sub>2</sub>, to provide stereo working. A second transconductance amplifier is of course already available in IC<sub>3</sub>. Stereo working for the voice-over channel seems a little over the top.

Instead of cross fading the two sound sources, R<sub>19</sub> may alternatively be used in conjunction with R<sub>18</sub> to fade one out and then the other in, if preferred. If voice-overs are going to be fairly infrequent, S<sub>1</sub> can usefully be a biased toggle, so that the microphone input is permanently muted, except when required. ■

# ANCHOR SUPPLIES Ltd



The Cattle Market Depot  
 Nottingham NG2 3GY, UK  
 Telephone: +44 (0115) 986 4902/  
 +44 (0115) 986 4041 24hr answerphone  
 Fax: +44 (0115) 986 4667



## SPECTRUM ANALYSER SPECIAL OFFERS

MARCONI TF2370 SPECTRUM ANALYSERS + TK2373 Frequency Extenders 1250Mhz Range  
 Digital readout and Memories... Bandwidth down to 5Hz. Resolution 20Hz to 10Mhz per division  
 ONLY £1495 (TF2370 + TF2373)

Extender available alone £995 (TK2373)

Important Note: We have a large quantity of these systems available BUT only a very small quantity of 3 way connecting leads for the extenders. The leads we have will be included free of charge with COMPLETE systems only, on a first come, first served basis...  
 Wiring diagrams for the leads will be issued with later sales and the extenders alone.

## OSCILLOSCOPE SPECIAL OFFERS

TEK 7000 Series Oscilloscope Main Frames (NO Plug-In's)  
 7603 (100Mhz) ONLY £225    7633 (100Mhz) ONLY £250  
 7704 (250Mhz) ONLY £300    7844 (400Mhz) ONLY £350    7904 (100Mhz) ONLY £450  
 Many other Oscilloscopes in stock... Please Phone to check stock.

## SIGNAL GENERATOR SPECIAL OFFERS

Farnell DSG2 Synthesised Sig Gens 0.1mHz (milli Hertz) to 110Khz..Sine/Square. ONLY £175  
 FARNELL PSG 520 Synthesised to 520Mhz ONLY £325  
 MARCONI TF 2015 10Mhz to 520Mhz AM/FM. ONLY £195  
 MARCONI TF 6055 820Mhz TO 2150Mhz ONLY £195  
 HP 8614 800Mhz TO 2.4Ghz ONLY £95  
 HP 8663A 2.3Ghz to 6.5Ghz ONLY £499  
 GIGA GR 1128 2.0Ghz to 8.0Ghz Digital Readout of Frequency and RF level ONLY £595  
 GIGA GR 1118 8.0Ghz to 18.5Ghz Digital Readout of Frequency and RF level ONLY £595

## DIGITAL FREQUENCY COUNTER SPECIAL OFFERS

Racal Dana 9904M 7 Digit LED to 50Mhz TXO HiStab Oscillator ONLY £50  
 Racal Dana 9915 8 Digit LED to 520Mhz TXO HiStab Oscillator ONLY £60  
 Racal Dana 9916 8 Digit LED to 560Mhz TXO HiStab Oscillator ONLY £60  
 Racal Dana 9918 9 Digit LED to 560Mhz TXO HiStab Oscillator ONLY £75  
 Racal Dana 9921 9 Digit LED to 3000 Mhz TXO HiStab Oscillator ONLY £175  
 EIP 451 Microwave Pulse Counter 7 Digit LED 925Mhz to 18Ghz ONLY £275

## RF EQUIPMENT SPECIAL OFFERS

BIRD 4385 Digital RF Power Analysers. Accepts 2 standard Bird Elements. Digital Display of:  
 CW (fwd/rev).. PEP (fwd/rev).. dbM (fwd/rev).. Return loss... Min/Max levels.. % Mod.. SWR  
 Limited Quantity available... BE QUICK these sell FAST... ONLY £150  
 BIRD Elements... Models available as follows:  
 5B (5W 200Mhz-500Mhz) £20.. 10A (10w 25Mhz-60Mhz) £20.. 10B (10W 50Mhz-125Mhz) £20..  
 50D (5W 200Mhz-500Mhz) £25.. 100D (100w 200Mhz-500Mhz) £25.. 1KP (1kW 0.45-2.5Mhz) £25  
 Genuine Leather BIRD Element Cases for 12 elements... ONLY £10  
 MARCONI TF2300S Mod meter 3.5Mhz-1000Mhz 0-500Khz FM and 0-100% AM ONLY £75  
 SAYROSA 252 Automatic Modulation meter to 2Ghz 0-100Khz FM 0-100% AM ONLY £195  
 DYMAR 2081/100 RF Power Meters 1Mhz-560Mhz 30mW-100W fsd in 8 Ranges ONLY £95

CCD SURVEILLANCE EQUIPMENT IN STOCK AS USUAL  
 PLEASE SEE PREVIOUS ADVERTS OR A FIRST CLASS SAE FOR LATEST CATALOGUE.

OPEN 6 DAYS A WEEK  
 Mon-Fri 9am-6pm Sat 8am-4pm  
 NO APPOINTMENTS NEEDED. CALLERS ALWAYS WELCOME  
 NATIONAL AND INTERNATIONAL MAIL ORDER A SPECIALITY  
 VISIT OUR NEW WEB SITE  
<http://www.anchor-supplies.ltd.uk>  
 e-mail [sales@anchor-supplies.ltd.uk](mailto:sales@anchor-supplies.ltd.uk)



Please note: Requests for catalogues MUST be accompanied by a first class SAE



# Sound from all angles

## Home theatre and surround sound

Domestic audio systems are becoming increasingly mixed-media installations – combining hi-fi loudspeakers allied to direct view or projection video. Described as home theatre, or home cinema, these systems include surround sound capability from video and non-video programmes. Stereo, two channel sources, range from traditional vinyl disc and analogue tape, predominately cassette, to RDAT digital tape, cassette-based data reduced digital tape known as DCC, compact disc, data reduced mini disc, and radio tuner. There is also videotape, laser disc, DVD, broadcast television and video disc, plus cable and satellite transmissions.

An increasing proportion of software – particularly video based – is multi-channel encoded. Where the installation gives surround sound, a full sound field is available all around the audience. In addition, audio processors are available which can extract and/or synthesise surround sound information from suitable sources.

The most popular home theatre format at present is five channel, and typically includes a centre channel speaker; this is often called the dialogue channel because it generally carries the vital speech components of a movie.

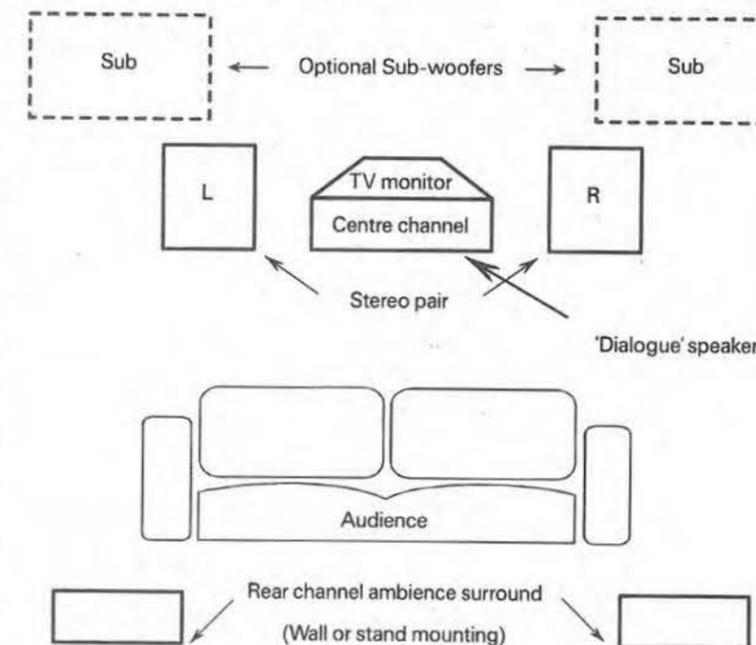
The development of a sound stage, with characteristics of width and depth, is the responsibility of the front left and right audio channels. These are generally conventional high quality loudspeaker systems, often full-range types flanking, or placed relatively close to, the television monitor or projection screen. In some cases projection screens are acoustically transparent so that the centre-channel speaker may be hidden behind them. A superior blend of sound and visual image results, with better entertainment value, Fig. 1.

In basic installations, a pair of small ambience speakers located near the back of the room, preferably elevated to reduce localisation effects. Ambience channels should not draw too much attention to themselves; excessive level or proximity to the listeners can easily disturb the sound field balance.

The rear-channel speakers may reproduce a common, mono ambience channel, which may or may not be served by individual amplifier channels, as with Dolby Pro-Logic. More recent systems for digital discrete, multi-channel encoding, including DTS and the industry standard Dolby

Martin Colloms explains the benefits and pitfalls of home cinema sound options in this article, which is based on a section of his newly updated book *High Performance Loudspeakers*.

Fig. 1. Basic home theatre surround sound system – a five-speaker layout using speakers with good low frequency performance for front left/right. Dotted sub-woofer(s) are optimal, only required if the 'stereo' pair have limited bass. Ambient speakers may be mounted on the side walls.



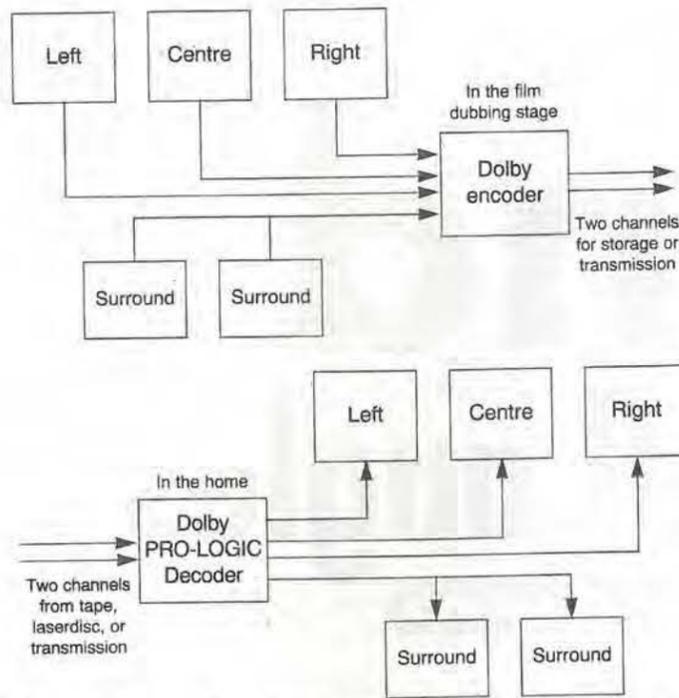


Fig. 2. Dolby surround Pro-Logic. Four channels are matrixed/encoded to two channels which reproduce as stereo. When decoded, especially with Pro-Logic steering circuitry, improved separation is achieved for four output channels. Optional fifth channel for the sub-woofer is not shown (after Harley).

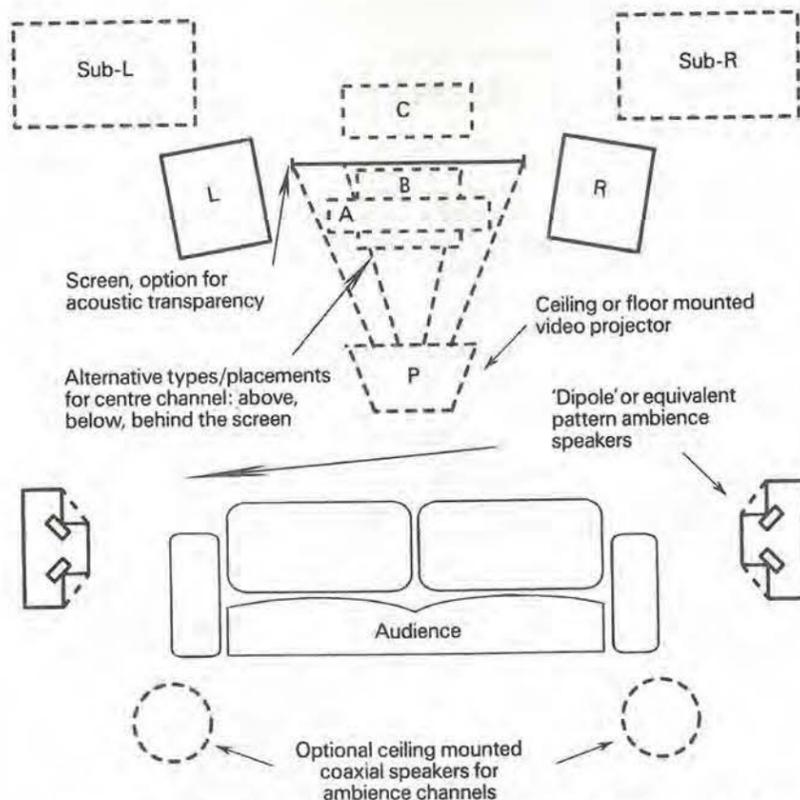


Fig. 3. THX based home theatre system. Projection video or large screen monitor, powerful sub-woofer(s) and THX style dipole or equivalent local ambience speakers. THX specification defines directivity; stereo, centre channel and ambience speakers. High sound levels typically used generally overcome the disadvantage of projector fan noise.

AC-3, can deliver discrete signals on five channels or more with the right processing – and up to eight in some instances.

Smaller, neater speaker arrangements can be used without compromising bass performance by adding a sub-woofer. In home theatres, bass is important in view of the powerful low-frequency effects commonly found on film sound tracks. Sub-woofers are generally recommended for all good home theatre installations.

Most popular surround systems incorporate decoders for Dolby Pro-Logic coded sound tracks. Decoders are available over a very wide price range and are often conveniently incorporated into multi-channel amplifiers. A specially filtered sub-woofer feed may be available, Fig. 2.

**Stereo compatibility**

It is possible to configure very good multi-channel systems, but there is always a degree of conflict between the requirements for best quality stereo reproduction. The best sound for a pair of high-performance speakers is obtained when they are the only significantly sized speakers in the listening room. Precision and power in the bass are diluted by the presence of additional speakers.

Furthermore, a direct view television frequently contains its own speakers and is placed in the centre stage position. It also constitutes a large acoustic obstacle, reflecting and redistributing the sound field formed between left and right-hand speakers. In addition, the speaker placement for optimal two-channel stereo is generally wider than that defined for good video-based multi-channel working. However, when a television monitor is replaced by a projection screen, this has rather less impact on the local acoustics and may be set farther back away from the stereo pair, Fig. 3.

Given the present state of the art, the fidelity of multi-channel electronics, processors and amplifiers in home theatre is not as high as that of discrete component stereo systems. Some compromise in respect of two-channel high-fidelity performance is inevitable.

**Multi-channel advantage**

It may be argued that multi-channel working conveys additional information and that the greater sensory experience resulting from surround sound working balances the loss in absolute fidelity when compared with pure stereo.

Greater versatility will be demanded from surround-sound systems as the new digital coding systems are introduced. These include the discrete channel Dolby AC-3. By comparison Pro-Logic is a two-channel system using matrix techniques for coding the additional directional information, Fig. 4.

**THX and cinema-quality sound**

The THX sound laboratory has set specifications, and provides design recommendations, relating to home theatre sound. These are intended to promote the production of a tonal balance and sound field in the home which more closely mirrors professional cinema practice.

In theory, the guidelines make for a closer sonic match with the film production intentions. Higher sound system cost and performance is the result, together with some divergence from normal Dolby surround practice.

THX-compatible decoders provide shaped audio signals, while speaker design also has some special features which will emerge in the following sections.

**Speaker design**

Specific requirements and acoustic environments for the different types of speaker system in a multi-channel installation

need careful consideration. The objective should be a well-distributed sound field of uniform quality and tonality, such that no speaker or room region draws undue attention to itself and thus impairs the stability of the surround sound effect.

Equipment critics have found many instances of poor matching of the sound characters of the various speakers in a multi-channel system.

Design rules follow good speaker engineering practice. But in addition, they incorporate some specific factors, outlined below. Top quality systems conforming to the THX specification have their own set of standards and systems must qualify via direct evaluation at the THX laboratory.

**Speakers for front left and right.** Almost any good stereo speaker – floor or stand mounted – will serve for the front stereo pair. If the application does not include a sub-woofer, then full-range speakers with more powerful bass are advisable, probably of floor standing design.

Front speakers are likely to be close to each other, near to the monitor, and potentially not far from the rear wall. As a result, the bass alignment should be somewhat overdamped, for example with a Q of 0.5. This avoids excess energy in the 50-100 Hz range.

If the speakers are not properly damped, the reproduction of normal television speech, whether mono or two channel, may sound unnaturally heavy and boomy. This could cause early aural fatigue – even if the results are impressive on movies.

For THX working, a vertical driver array is favoured. This reduces the reverberant contribution from the floor and ceiling reflections. Mid-range tonal balance may also benefit from some subtle adjustment to take account of the proximity of the television monitor casing, and its likely supporting cabinet.

**Rear channel.** For simply reproducing ambient effects, an extended frequency response is unnecessary and compact slim-line enclosures are favoured. These are typically sealed-box types with a bass driver and treble unit with an alignment balanced for wall boundary location, possibly a downwards directed polar response. In some cases just a full-range single cone driver is used.

A maximum level of 100dB, an 85-90dB/W sensitivity and a 90Hz to 12kHz bandwidth is usually satisfactory, provided that the general quality, colouration standard, etc. match the primary system. Rear speaker bandwidth need only be a little wider than that imparted by the processor, Fig. 5.

In some installations ceiling-mounted speakers have been used successfully. These are usually coaxial types, which have the advantage of a symmetrical radiation pattern. Complications include the acoustics of the ceiling and the lack of a defined enclosure, which results in some variations in performance. The advantage is almost perfect concealment, while the additional height above the listeners aids dispersion of the ambient sound field, Fig. 6.

With digital multi-channel sound, the rear channel feed may be discrete, well localised, of higher quality and full bandwidth. For top quality systems superior 'ambience' speakers will be worthwhile, Fig. 7.

**Centre-channel or dialogue speaker.** For projection systems, acoustically transparent screens are available and any suitable high quality speaker may be concealed behind them.

Where a television monitor is involved, the dialogue speaker should be placed centrally to optimise the acoustic/optical alignment. Since the image cannot be obstructed it must be

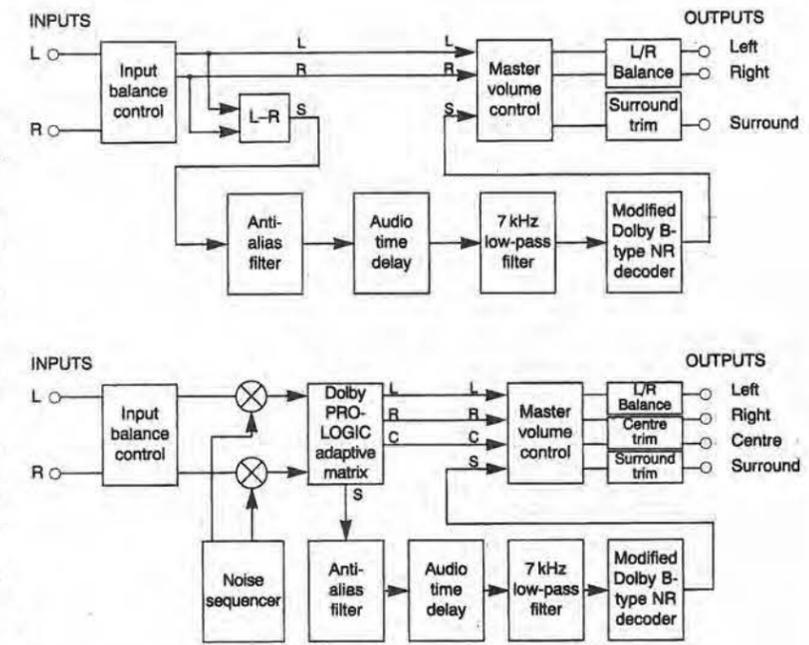


Fig. 3. Comparing the passive decoding of Dolby Surround with the active matrix system used for Pro-Logic for home theatre. Note that both systems include bandwidth limiting for the surround channel, specified at 100Hz to 7Hz -3dB. In practice, this reduces the demands made on rear channel speakers; a single full-range driver may be sufficient.

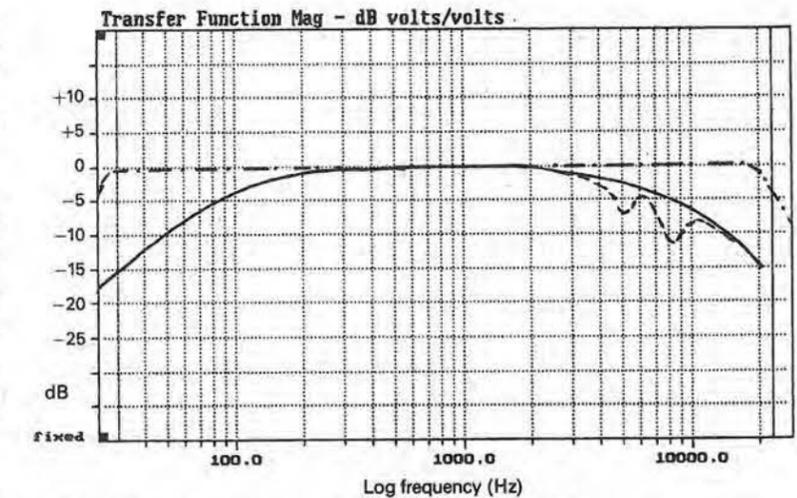


Fig. 5. Frequency responses for decoded rear channel signals. Pro-Logic (—) has a 100Hz to 7kHz bandwidth, THX augments with extra filtering (---) while AC-3 digital decoding offers discrete rear channels with an additional user option – full bandwidth 20-20kHz (-.-.-).

located directly above or below the faceplate.

Vertically orientated drivers offer the best angle of horizontal directivity for the audience. Many THX speakers are vertically mounted. But aesthetic considerations generally dictate a low profile, slim-line, horizontally disposed enclosure, matching the monitor as closely as possible.

However, a horizontal driver disposition is the least favourable arrangement for audience coverage. Conventional two-driver designs have been tried, but inevitably the responses in one direction are unbalanced relative to the other due to asymmetry.

Symmetrical arrangements are favoured, and use a centre, preferably narrow chassis dome tweeter, slimmed by the use

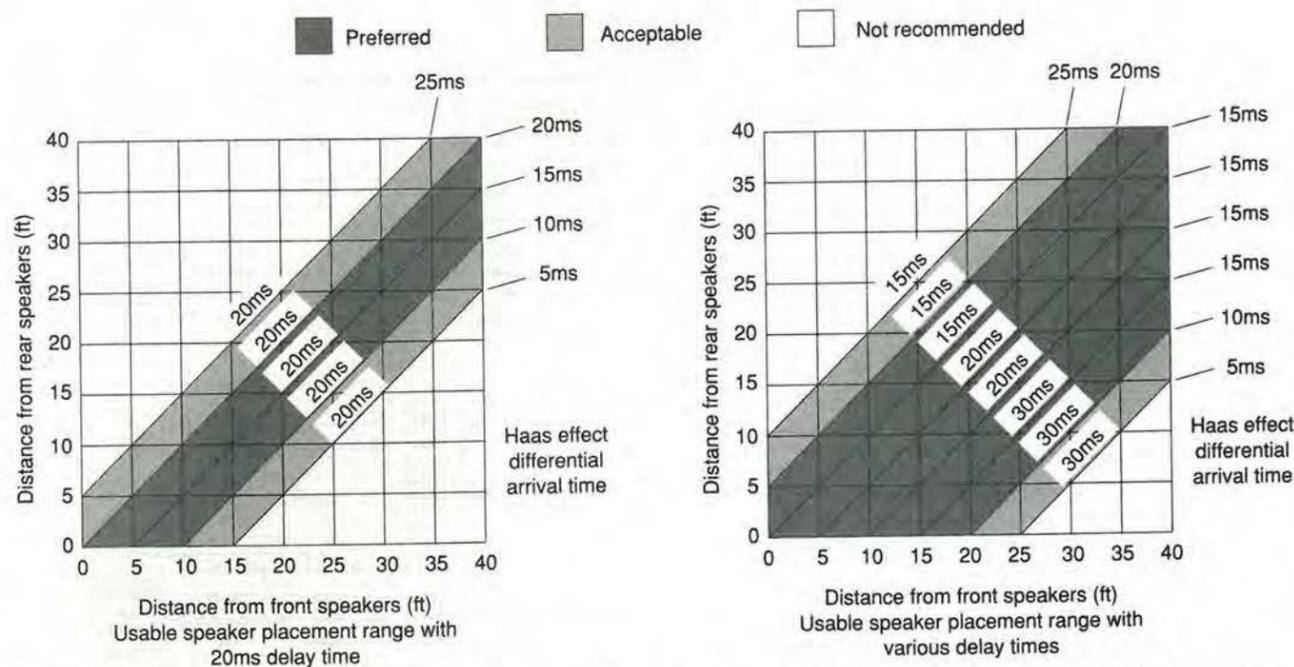
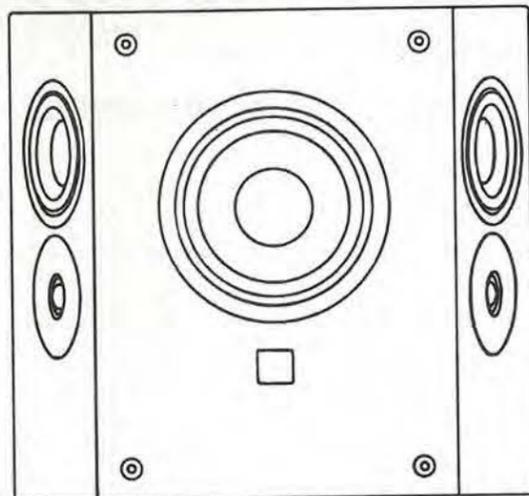


Fig. 6. Recommendations for speaker placement – rear channel relative to front – to allow good frontal localisation but avoid 'echo' effect from ambience channel feed. Some systems provide programmable delay for greater versatility but 20ms is a standard delay.

Fig. 7. An example of a dipole ambience field speaker system. Angled driver pairs operate in anti-phase above 300Hz. The centre driver gives omnidirectional radiation below 300Hz. Drivers are 170mm, 100mm and 25mm. THX application, after Aerial Acoustics Corporation, for side wall placement.



of a closed field, and thus magnetically screened, miniature magnet made from neodymium alloy. On each side is a bass-mid unit typically of 80-120 mm chassis size. The overall enclosure height is held in the region of 160mm.

Factors that help widen the radiation angle in the crossover range are high slope crossovers, and a lower than usual crossover frequency of around 2kHz instead of the usual 3kHz and 4kHz.

The use of a driver baffle structured to angle the bass drivers away from the central treble unit, for example by 10° or 20° helps to widen the acoustic lobe in the crossover range. This also needs to be well screened magnetically.

Note that these horizontal designs have another notch in their response, this time due to the relative delay, for the two mid sections appearing off-axis. This notch may be 12dB deep in the 1kHz region and adds a further complication.

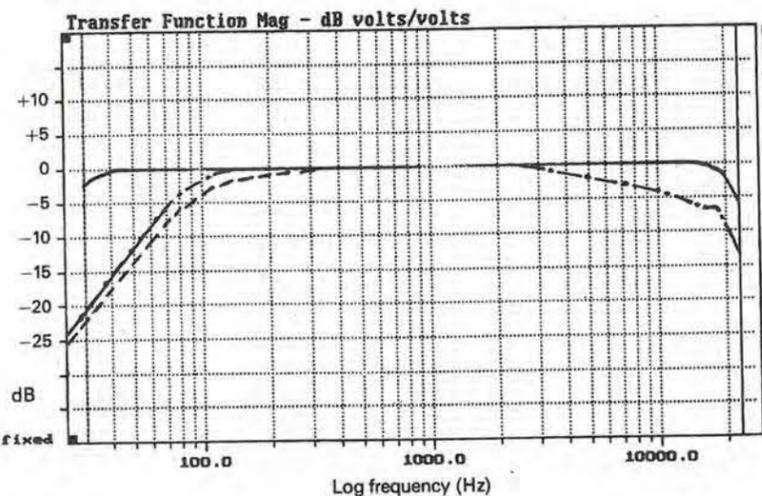
A frequency range of 80Hz to 15kHz is worthwhile. Reflex loading, despite the small enclosure volume, is common to help improve the power handling. The centre channel may need to play loudly – at 103dB or more – and needs an 88-92dB/W sensitivity with up to 100W power handling.

Fine centre channel speakers have also been made with concentric drivers, such as the UNI-Q or the ICT. Such drivers have good directivity on all axes.

Specific voicing may be applied to a centre channel speaker. The proximity of the television screen also requires consideration. In addition, high clarity, intelligibility and articulation are paramount – even at high sound levels. The actor's words must be heard clearly, no matter how complex the mix of sound effects.

On balance there is a trend towards a taut, fast upper bass, occasionally some midrange and presence-range prominence

Fig. 8. Frequency response for decoded outputs of surround-sound processors, centre channel. Pro-Logic offers full bandwidth and high-pass -3dB at 100Hz options (—). Processing via THX, aimed at producing a tonal quality close to cinema sound, also filters the bass and softens the treble (- - - -).



of a few decibels, and an upper treble which does not draw undue attention to itself. For THX's narrow bandwidth setting, a range of only 60Hz to 10kHz is required, Fig. 8.

Screening problems

Magnetic screening is now recommended for the front left and right speakers in addition to the centre channel units, in view of the magnetic sensitivity of the larger direct view television monitors.

Steel plates may be required to line the cabinet sides. These may be bonded with an appropriate visco-elastic adhesive to improve resonance damping. Even screened speakers may result in some colour shifts when placed on a monitor and this matter needs careful checking at the design stage.

Low frequency power

Considerable output is required in the bass for a suitably impressive film playback. It is rumoured that many of the 'foley' originated low frequency sound effects are simply shaped and/or gated bursts of third octave pink noise at 30Hz! These can reach peak level, which accounts for the THX requirement for 105dB, 30Hz at 1m for moderate listening rooms.

Two sub-woofers sound rather better than one – more than their arithmetic sum would suggest. Placement in the room corners generally gives the smoothest and most powerful bass. Good boundary matching is important because it reduces the demands made on the woofer, resulting in improved performance and a higher dynamic range.

Multi-channel discrete processors

Speaker systems for home theatre have evolved around matrix processed signals, often band limited to reduce the audibility of spurious processing artefacts. Such practice also makes good economic sense. There is no point in over-specifying the auxiliary speaker systems, centre and rear, if the result is to price the system out of the market.

However, with the introduction of discrete multi-channel processors, the European MPEG variants, the US designed DTS and Dolby AC-3 systems plus multi-channel (rather than synthesised) surround sound, all the audio channels may have a discrete, wide band, high quality identity.

Potentially, with the right replay system, the sound producer will be able to place a virtual acoustic image anywhere in the listening room, anywhere in the defined sound field. Even at this early stage, systems such as DTS can reproduce a full circle 'walkaround' with stable geometry, using a sound as complex and transient rich as closely miked orchestral chimes.

With such a potential for high quality, it is obvious that the more costly home theatre and surround sound systems are going to need better speaker systems for all quadrants of the sound field. Revisions may be anticipated with regard to existing practice, performance specifications, response shaping and required bandwidth to meet these new demands. ■

Further reading

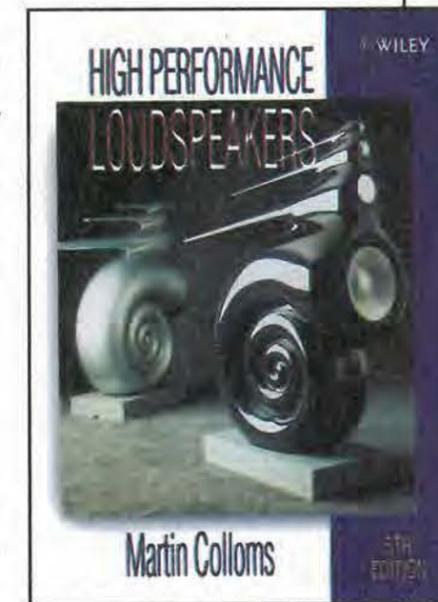
- Dressier, R, 'The (Near) Future of multi-channel Sound,' Dolby Labs S94/1009, 1994.
- Haxley, R, 'The Complete Guide to High-End Audio,' Acappella Publishing, 1994.
- Holman, T, 'New factors in sound for cinema and television', J. Audio Eng Soc., July/August (1991).
- Holman, T, 'Home THX: Lucasfilm's approach to bringing the theatre experience home', Stereo Review, April 1994.
- Smyth, M and S, 'DTS coherent acoustics: The future of audio', Widescreen Review, 14, 16, 18, Parts 1, 2, 3.

High Performance Loudspeakers: completely revised and updated

With 478 pages, the fifth edition of Martin Colloms' book High Performance Loudspeakers has been completely updated and revised. Features of the new edition are,

- First technical assessment of bending-wave panel speaker technology (NXT), reverse horn loudspeakers (Nautilus) and flat plane speakers.
- Major section on digital speaker design, optimised digital filters, system requirements and digital active speakers.
- Unique and non-partisan interpretation of manufacturers' technologies and claims.

The work includes chapters on diaphragm theory, transducer technology, room analysis, driver types and choices, crossovers, enclosures and speaker assessment.



Please mail this coupon to Electronics World, together with payment. Alternatively fax credit card details with order on 0181 652 8111. You can also telephone your order on 0181 652 3614, but only Mondays, Tuesday's or on Friday mornings. Address orders and all correspondence relating to this order to, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

Use this coupon to order your copy of High Performance Loudspeakers

Please send me ..... copies of Dictionary of Communications Technology. Each copy of the book costs £24.95 plus £4 UK p+p, £8 Europe, £12 ROW per book.

Total amount £.....

Name  
Company (if any)  
Address

Phone number/fax  
Make cheques payable to Reed Business Information Group. Or, please debit my Master, Visa or Access card.

Card type (Access/Visa)  
Card No  
Expiry date

The right card for every occasion

R.S.V.P.

PC Card  
Member Company

Contact Card Professionals for the most advanced portfolio of PCMCIA PC Cards, StarCards, 38edge Cards and compatible interface solutions

Centennial: major franchised stocking distributor for Centennial PCMCIA cards

ITT Canon: authorised stocking distributor for 38pin StarCards, 38pin StarCard connectors and 68pin PC Card connectors

Calluna: authorised stocking distributor for Calluna's type III ATA PC card range

Centennial: 38 edge card flash memories and connectors

A wide range of Reader/writers are available with ISA, SCSI, parallel and serial host interfaces for cards in our portfolio



**Card Professionals**  
Limited

Card Professionals Limited, Cedarmount House,  
Owlsmoor Road, Owlsmoor, Sandhurst, Berkshire, GU47 0SS.  
Tel: +44 (0) 1344 779632.  
Fax: +44 (0) 1344 779633.  
www.card-professionals-uk.com

Data Acquisition  
Environmental Monitoring  
Virtual Instrumentation ▶

Pico Technology

**'Pico's Virtual Instrument is the most powerful, flexible test equipment in my lab.'**

Pico's virtual instruments emulate the functions of traditional instruments such as Oscilloscopes, Spectrum Analysers and Multimeters. Controlled using the standard Windows interface, the software is easy to use with full on line help.

**NEW 100 MS/s**

**ADC-200**  
Dual Channel High Speed

- ▼ 100, 50 or 20 MS/s sampling.
- ▼ 50, 25 or 10 MHz spectrum analysis.
- ▼ Advanced trigger modes - capture intermittent one-off events.
- ▼ Less than half the cost of a comparable benchtop scope.

ADC 200-100 £549.00  
ADC 200-50 £499.00  
ADC 200-20 £359.00  
Supplied with cables and power supply.

**ADC-100**  
Dual Channel 12 bit resolution

The ADC-100 offers both a high sampling rate 100kS/s and a high resolution. Flexible input ranges ( $\pm 50\text{mV}$  to  $\pm 20\text{V}$ ) make the unit ideal for audio, automotive and education use.

ADC-100 with PicoScope software £199.00  
ADC-100 with PicoScope & PicoLog software £219.00

**ADC-40/42**  
Single Channel - low cost

- ▼ 20 kS/s sampling.
- ▼ 10 kHz spectrum analysis.
- ▼  $\pm 5\text{V}$  input range.

ADC-40 8 bit resolution £59.00  
ADC-42 12 bit resolution £85.00

Call for free demo disk or download our web site:  
<http://www.picotech.com>  
All prices exclusive of VAT.

Broadway House, 149-151 St Neots Rd,  
Hardwick, Cambridge. CB3 7QJ UK  
Tel: (0)1954 211716 Fax: (0)1954 211880  
E-mail: post@picotech.co.uk

**PICO**  
Technology Limited

CIRCLE NO. 117 ON REPLY CARD

ELECTRONICS WORLD September 1997

# Genetically designed. yagi

**Richard Formato explains how a natural-selection like design process produces better antennas, and provides evidence in the form of a three-element Yagi example for 50MHz work.**

Genetic algorithms, or GAs, are a class of optimisation techniques that mimic natural selection, i.e. 'survival of the fittest'. Such algorithms are applicable to many types of problems, and they are becoming increasingly useful in antenna design<sup>1,2</sup>. This note describes a genetically designed three-element Yagi that provides very good performance and illustrates how effective genetic algorithms can be.

Unlike deterministic optimisation schemes, GAs are based on random selection. A binary-coded genetic algorithm starts by creating a population of 'chromosomes' which are random one and zero bit sequences. Each chromosome contains a complete antenna

design - in this example - a complete three-element Yagi antenna.

The chromosome is made up of 'genes' which are strung together one after another. Each gene corresponds to one of the antenna's design parameters.

The Yagi gene relationship appears in Table 1. A design is fully specified by eight genes: reflector length and radius *REF*, driven element length and radius *DE*, director length and radius *DIR*, and location along the boom *DE/DIR*. Gene length is its length in bits - for example, *REF* length is five bits.

The minimum and maximum values of each design parameter also appear in the table, and all dimensions are in wavelengths, 'waves'. The *DE* length, for example, cannot be longer than 0.6 wave or shorter than 0.4 wave.

Since each design parameter is a decimal number, not a bit sequence, the actual value of the parameter is computed by decoding its binary gene using the following transformation equation,

$$X = X_{\min} + \left( \frac{X_{\max} - X_{\min}}{2^L - 1} \right) \times D$$

where *X* is the decimal value of the parameter, *D* is the decimal value of the gene's binary sequence, and *L* is the gene's length.

To illustrate how this decoding scheme works, consider the 37-bit chromosome that contains the design for the Yagi discussed below:

001011100001101111001011100010111100

The *DE* length is coded in gene No 3, which starts at bit No 10 and ends with bit No 14. The binary sequence for the *DE* length gene is 00110, and its decimal value is,

$$0(2^0) + 0(2^1) + 1(2^2) + 1(2^3) + 0(2^4) = 12$$

Since gene No 3 is five bits long, the denom-

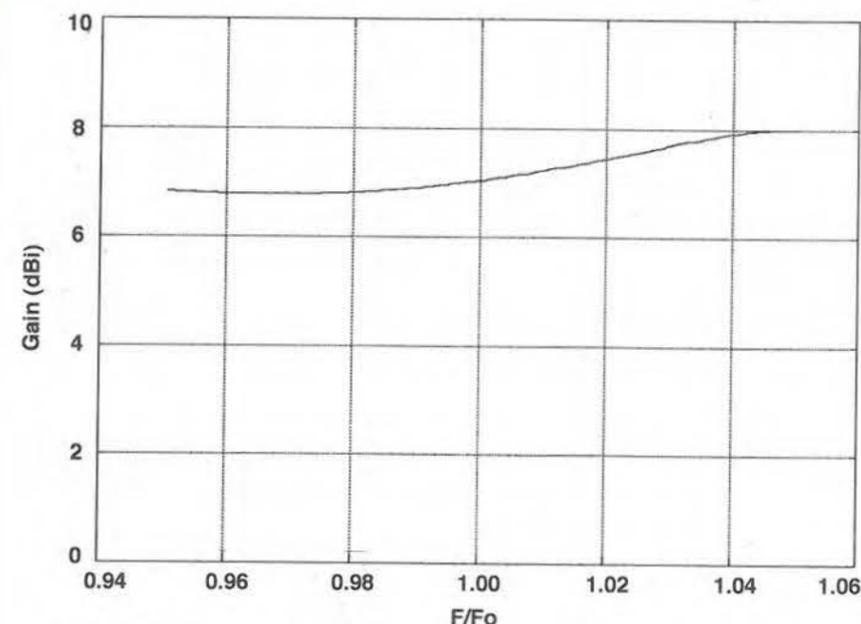


Fig. 1. Main lobe gain for the genetically-designed Yagi example.

Table 1. Gene table for three-element Yagi.

Gene #	Name	Length	Min	Max
1	REF Length	5	0.4	0.6
2	REF Radius	4	0.0005	0.002
3	DE Length	5	0.4	0.6
4	DE Radius	4	0.0005	0.004
5	DE Separation (from ref.)	5	0.05	0.3
6	DIR Length	5	0.4	0.6
7	DIR Radius	4	0.0005	0.002
8	DIR Separation (from DE)	5	0.05	0.3

\* PO Box 747, Boylston, MA 01505-0747, tel. (508) 869-6077, fax (508) 869-2890

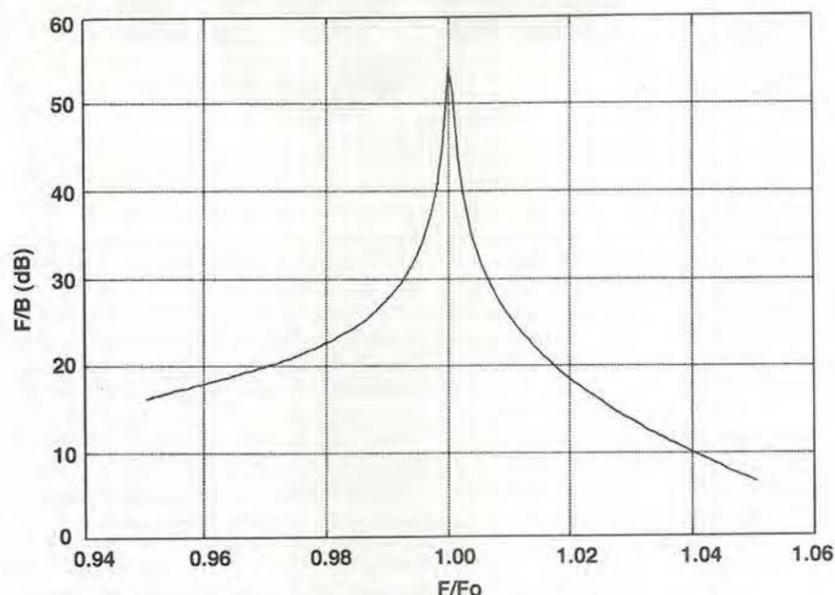


Fig. 2. Front-to-back ratio for the genetically-designed Yagi example.

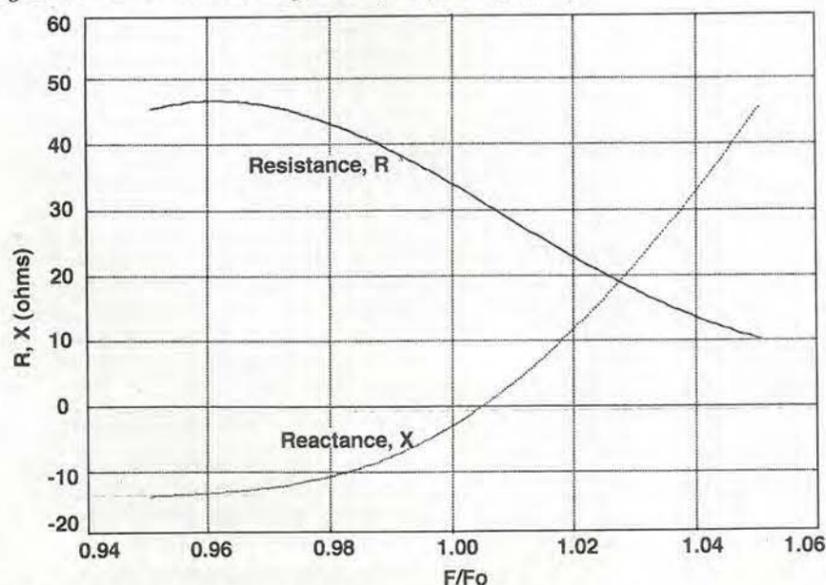


Fig. 3. Genetically-designed Yagi's input impedance.

inator in the transformation equation is  $2^5 - 1 = 31$ . This makes the DE length,

$$\frac{0.4 + (0.6 - 0.4)12}{31} = 0.477419355$$

wavelengths. Because the computer model used to calculate the Yagi's performance inputs the half-length of DE instead of its overall length, this value is divided by two and rounded to three places to give 0.239 wave. This decoding scheme is used to evaluate each of the Yagi's design parameters. The DIR radius, gene No 7, for example, evaluates to 0.0015 wave, and so on.

The genetic algorithm begins by creating an initial population of random 37-bit chromosomes. It then applies the operators of 'selection', 'crossover', and 'mutation' to filter out 'unfit' designs while retaining the better ones.

Successive applications of these operators create 'generations' of antenna designs, with each subsequent generation hopefully containing better designs than the previous one. But, because of the algorithm's inherently random nature, there is no guaranty of obtaining better designs. They may actually become worse from one generation to another.

Well-designed genetic algorithms, however, usually produce progressively better designs, at least on the average. Every new run holds the intriguing possibility of producing a previously unseen 'best' design.

The selection operator determines which chromosomes are fit enough to survive to the next generation. Some may be automatically discarded - for example, the worst 10% - while others are typically 'killed' at random, as they would be in nature. Others may be automatically retained - the best 5%, for example.

The algorithm designer is free to implement whatever selection process seems best. The crossover operator 'mates' two chromosomes, or 'parents', to produce two new chromosomes, or 'children', which become members of the next generation. Child chromosomes usually maintain a constant population from one generation to the next, although the population could grow if desired.

Each parent's chromosome is split at a gene boundary, usually randomly selected, and the pieces are swapped (concatenated together) to form two different chromosomes. This is the primary process by which genetic algorithm propagate 'good' genes from one generation to the next.

Finally, the mutation operator randomly flips a bit here and there with some small probability. This simulates the genetic mutation that occurs randomly in Nature.

#### Deciding which is best

In each generation, all of the designs, or chromosomes, are ranked from best to worst using a figure-of-merit. The figure-of-merit combines various antenna performance measures

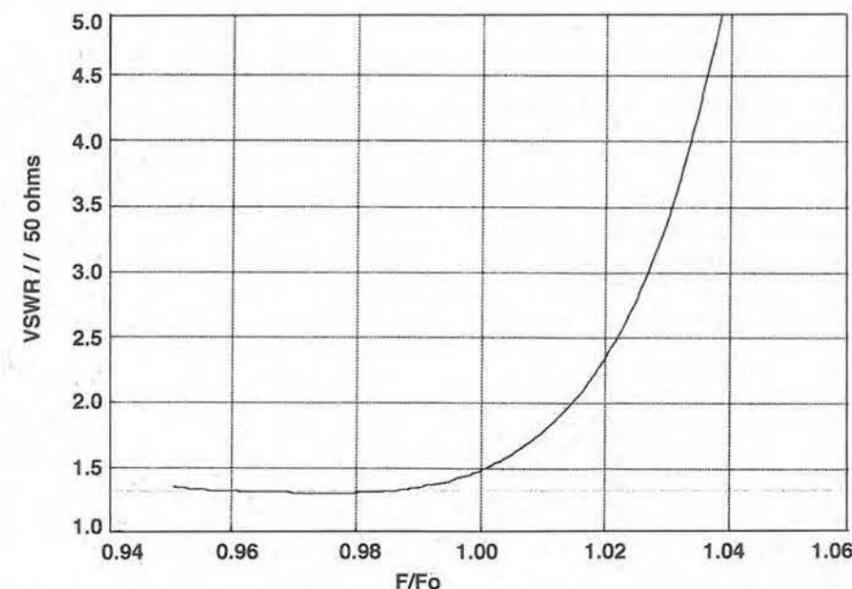


Fig. 4. Standing-wave ratio performance.

computed by a modelling engine, which is another computer program separate from the genetic algorithm.

Individual antenna performance parameters, for example, can be calculated with any suitable antenna modelling program. The figure-of-merit used for the Yagi described below is

$$\frac{5(G) + 4(FB) - SWR}{10}$$

This particular figure of merit gives slightly more weight to the main lobe gain  $G$  than to the front-to-back ratio  $FB$ , and relatively less weight to the input standing-wave ratio  $SWR$ .

The algorithm designer is free to define any figure of merit that reflects the relative importance of different performance measures, including even non-electrical parameters such as cost or time to build, or amount of material required, and so on. This feature is a major distinction between genetic algorithm and deterministic optimisations, which frequently cannot optimise arbitrary figures of merit.

Other significant differences are that genetic algorithms produce groups of designs with similar figures of merit, instead of the single 'best' design, and they usually require much less computer time than deterministic algorithms.

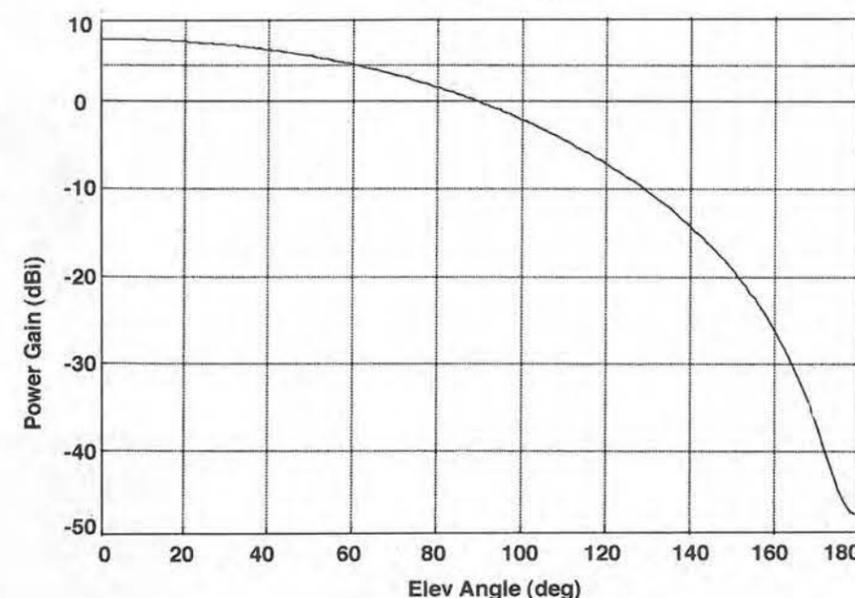
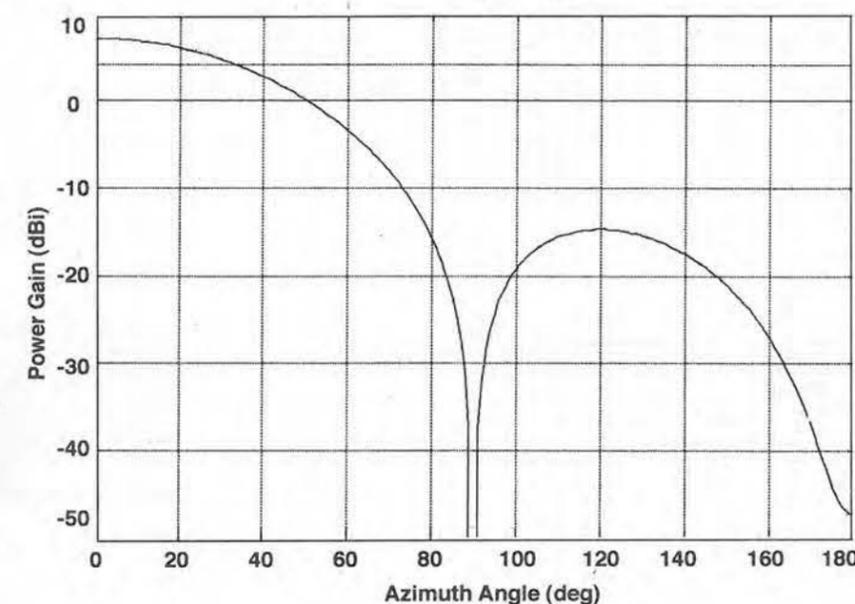
The genetically optimised three-element Yagi has the following dimensions, in wavelengths at the design frequency  $F_0$ :

Reflector length	0.530
Reflector radius	0.0008
Driven element length	0.478
Driven element radius	0.004
DE distance from REF	0.123
Director length	0.446
Director radius	0.0015
DIR distance from DE	0.106

The boom length - the sum of DE/DIR separations - is only 0.229. This is less than a quarter-wave, which is quite short. At the 6m amateur band frequency of 51MHz, for example, this Yagi is only 53in long. The REF, DE and DIR lengths are 122.66, 110.62, and 103.22in, respectively, with diameters of 0.37, 1.85, and 0.694in.

Gene DE is located 28.47in from REF, while DIR is located 24.53in from DE. It is interesting that the genetic algorithm converged to the maximum allowable value for the DE radius, because it is known from analytical considerations that increasing DE diam-

Fig. 5. Azimuth, a), and elevation pattern, b), of the antenna.



RF DESIGN

eter can improve Yagi performance substantially<sup>3</sup>.

Free-space main lobe gain, front-to-back ratio, input impedance (resistance and reactance), and standing-wave ratio relative to 50Ω are plotted in Figs 1-4, respectively. These parameters were computed over a 10% band centred at the design frequency  $F_0$ .

The azimuth and elevation patterns at  $F_0$  appears in Figs 5a) and b). Key performance measures are shown in Table 2.

The band-centre gain of 7dBi is typical of well-designed three-element Yagis, and the optimised antenna's  $FB$  of 54dB is exceptionally good. For comparison, this  $FB$  figure is more than 16dB better than the best  $FB$ s of typical quarter-wave designs described in W2PV's treatise on Yagi antennas<sup>4</sup> (see especially Fig. 2.9).

The optimised antenna also exhibits good  $FB$  bandwidth, with values exceeding 20dB from  $0.97F_0$  to  $1.017F_0$ , which equates to 4.7%. The optimised Yagi is nearly resonant at  $F_0$  at an input reactance of 3Ω capacitive, which is less than 10% of the input resistance.

From  $0.95F_0$  to  $1.015F_0$ , a difference of 6.5%, the standing wave ratio is less than two. If desired, this antenna can be fed directly with 50Ω coaxial cable, eliminating the insertion loss introduced by a matching network or antenna tuner.

Table 2. Performance of the genetically designed Yagi.  
Gain FB  $Z_{in}$  SWR HPBW  
7dBi 54.2dB 33.9-j3Ω 1.49 66°az, 122° el

Of course, a balun should be used to maintain feed system balance. But it would be interesting to build this antenna with and without a balun to see how much difference it makes.

For the 51MHz design, the standing-wave ratio is below two, and the  $FB$  is greater than 20dB, from 49.47 to 51.76MHz – a bandwidth of 4.5%. The lower band edge can be shifted up to 50MHz by increasing the design frequency to  $F_0=51.55$ MHz and recalculating the dimensions. Note that the wavelength is computed as  $299.7956/F_{MHz}$ , which is more accurate than the commonly used formula  $300/F_{MHz}$ .

The optimised Yagi's E-plane azimuth pattern has a characteristic two-lobe structure with a deep broadside null. The -3dB half-power beamwidth is 66°. The rear lobe is about 22dB down, which is quite low. The H-plane elevation pattern is plotted in Fig. 5b). It has a single, broad lobe with half-power beamwidth at 122°.

The genetically optimised, three-element Yagi is a very compact antenna that provides

excellent performance. This example illustrates that genetic algorithms can produce very good antennas indeed. Such algorithms are easily implemented on a pc and can provide significant advantages over deterministic techniques.

Communications engineers will probably hear more and more about the genetic design approach. It certainly merits serious consideration by designers who are interested in antennas. ■

References

1. Weile, D S, and Michielssen, E, 'Genetic Algorithm Optimisation Applied to Electromagnetics: A Review', *IEEE Transactions on Antennas and Propagation*, 45, 3, March 1997, p. 343.
2. Cohen, Nathan, N1IR, 'Antennae Exotica: Genetics Breeds Better Antennas', *Communications Quarterly*, Fall 1996, p. 55.
3. Formato, Richard A, K1POO, 'Improving Impedance Bandwidth of VHF/UHF Yagis by Decreasing the Driven Element L/D Ratio', *VHF Communications (UK)*, 26, Autumn, 3/1994, p. 142.
4. Lawson, James L, W2PV, 'Yagi Antenna Design', ARRL, Newington, CT, 1986.

With the UK now committed to digital television on terrestrial, satellite and cable channels, Pat Hawker looks at the technology – discussing both its benefits and drawbacks.



# Digital tv broadcasting

The BBC and ITC are now actively working towards an early launch of digital terrestrial television, or DTT for short.

Current viewers have a massive investment in analogue television receivers, many of which will last a good few years. Will they want to buy further equipment that will last them well into the 21st Century? Now is a good time to review the technology being held as opening a new era of multiple-choice television programming – and some of its inherent problems.

Unquestionably, the recent ETSI standards for digital video broadcasting, or dvb, represent an ingenious, if complex, means of squeezing many more programme channels into the available bandwidth. But you can take many of the claims made relating to the quality of digital tv broadcasting with a pinch of salt.

Picture quality will not be perfect, but subject to a new impairment caused when the data rate is reduced. As for wide-screen pictures, analogue PALplus has already been relegated to the back burner because British viewers are reluctant to accept 'letter-box' formats on 4:3 receivers.

Sound quality may be at compact disk levels, but then so is the current Nicam system. Picture resolution will be high too, but it is a pity that the millions spent on developing HD-MAC have largely been flushed down the drain along with the other MAC/packet systems.

Benefits of digital tv broadcasting

But we must put away the suspicion that dvb has been developed by a multitude of committees and may turn out to be a camel rather than a horse. The attraction of dvb to governments is the eventual freeing up of sellable vhf and uhf spectrum; to broadcasters dvb means extra channels available for pay-tv with a convenient conditional access system for terrestrial channels; for viewers, dvb will offer near unlimited 'choice' to those willing to pay subscriptions or pay-per-view. And for industry there will be the incentive of new set-top timers/decoder equipment that will be offered in advance of fully integrated terrestrial-satellite-cable receivers.

It is also worth noting that funding for the BBC will come from the Government

ordered sale of its transmitters to the US firm Castle Television for £244-million.

Background to digital tv

As early as 1992, authorities in many countries were beginning to accept that digital television broadcasting systems were the way forward. This meant the eventual demise of enhanced hybrid analogue/digital systems such as MAC/packet or HD-MAC for satellites. In addition, only limited use is likely to be made in the UK of PALplus. This system can provide wide-screen displays with a 16:9 aspect ratio on compatible terrestrial receivers. It also offers less cross-colour impairment than conventional PAL, but involves the unpopular 'letter box' display on traditional receivers designed for 4:3 aspect ratio. But then digital 16:9 will also involve 'letter box' until receivers with wide-screen picture tubes become the norm.

In the early 1990s, research work funded by IBA showed that cofdm, short for coded orthogonal frequency division multiplex, was a multi-carrier modulation system that could overcome the long recognised problem that multipath reception seriously affects high-

**LANGREX SUPPLIES LTD**  
DISTRIBUTORS OF ELECTRONIC VALVES  
TUBES, SEMICONDUCTORS AND I.C.S.  
PHONE 0181 684 1166 FAX 0181 684 3056  
1 MAYO ROAD • CROYDON • SURREY CR0 2QP  
24 HOUR EXPRESS MAIL ORDER SERVICE ON STOCK ITEMS

AZ31	5.00	EL86	2.75	PH500A	4.00	6BA7	5.00	6SK7	3.00
CL31	12.00	EL91	2.00	PH500	1.50	6BE6	1.50	6SL7GT	4.50
CL33	10.00	EL95	1.50	PH501	1.50	6BH6	2.50	6SN7GT	4.50
DY86/7	1.50	EL509	12.00	QDV02-6	12.00	6B16	2.25	6SS7	3.00
EB8CC Mull	8.50	EM34	15.00	QDV03-10	5.00	6BN6	2.00	6U8A	1.50
E180F	3.50	EM81	4.00	QDV03-20A	15.00	6B07A	3.50	6W6GT	4.25
E810F	22.00	EM84	4.00	QDV06-40A	17.50	6BR7	6.00	6X4	3.00
F4BC80	2.00	EM87	4.00	QV03-12	10.00	6BR8A	6.00	6X5GT	2.50
EB91	1.50	EN51 Mull	7.50	U119	10.00	6BS7	10.00	12A77	3.00
EBF80	1.50	EY51	2.50	U4BC80	1.50	6BW6	4.50	12AU7	3.00
EBF89	1.50	EY86	1.75	UBC41	4.00	6BW7	1.50	12AX7	3.50
EBL31	15.00	EY88	1.75	UBF89	£1.50	6BZ6	2.50	12AX7A GE	7.00
ECC33	7.50	EZ80	3.50	UC42	4.00	6C4	2.00	12BA6	2.50
ECC35	7.50	EZ81	3.50	UCL82	2.00	6C6	5.00	12BE6	2.50
ECC81	3.00	EY501	3.00	UCL83	3.00	6CB6A	3.00	12BH7A GE	7.50
ECC82	3.00	GZ32 Mull	8.50	UF89	4.00	6CD6GA	5.00	12BY7A GE	7.00
ECC83	3.50	GZ33	6.00	UL41	12.00	6C16	3.75	12E1	15.00
ECC85	3.00	GZ34 GE	7.50	UL84	2.50	6CG7	7.50	12HG1/12GN7	6.50
ECC88 Mull	6.00	GZ37	6.00	UY41	4.00	6CH6	3.00	30P11/2	1.50
ECC91	2.00	KT61	10.00	UY85	2.25	6CWA	8.00	30P19	2.50
ECH80	1.50	KT66	10.00	VR105/30	2.50	6D5	5.00	300B(PR)	118.00
ECH81	3.50	KT88	15.00	VR150/30	2.50	6DQ5 GE	17.50	57ZB	70.00
ECH82	3.00	N78	9.00	Z759	25.00	6DQ5B	12.50	805	50.00
ECL80	1.50	OA2	2.70	Z8030	25.00	6E8B	3.50	807	5.75
ECL82	3.00	CC3	2.50	ZD21	3.50	6F6	1.85	811A	18.50
ECL83	3.00	DD3	2.50	ZB28	15.00	6F7	£7.50	812A	65.00
ECL86 Mull	35.00	PCF80	2.00	4CX250B STC	55.00	6G6	4.00	813	27.50
ECL1800	25.00	PCF82	1.50	SR4GY	6.00	6G6A	3.00	833A	85.00
EF37A	3.50	PCF86	2.50	SU4G	3.25	6H6	3.00	866A	25.00
EF39	2.75	PCF87	2.50	SV4G	4.00	6H6S	4.55	877A	20.00
EF40	5.00	PCF802	2.50	SY3GT	2.50	6I5	3.00	931A	25.00
EF41	3.50	PCL87	2.00	SZ4GT	4.00	6J7	4.00	2050A GE	12.50
EF42	4.50	PCL83	3.00	SAH6	4.00	6J7A	4.00	5751	10.00
EF80	1.50	PCL84	2.00	SAN5	3.25	6J8A GE	18.00	5763	10.00
EF85	1.50	PCL85	2.50	SAN5	3.25	6J8C	20.00	5764	5.00
EF86	10.00	PCL86	2.50	SAN5A	25.00	6J8C GE	20.00	5842	12.00
EF91	2.00	PCL805	2.50	SAN5B	1.00	6K7	3.00	60R0	17.50
EF92	2.00	POS00	6.00	SAN5C	5.00	6K7	4.00	6146B GE	15.00
EF183	2.00	PL36	2.50	SAN5D	3.25	6K8	4.00	6550A GE	20.00
EF184	2.00	PL81	1.75	SAN5E	3.25	6L6G	10.00	6883B GE	16.00
EL32	2.50	PL82	1.50	SAN5F	3.50	6L6GCSYL	12.50	7025 GE	17.00
EL33	10.00	PL83	2.50	SAN5G	3.50	6L6G Siemens	7.50	7027A GE	12.00
EL34 Siemens	8.00	PL84	2.00	SAN5H	9.50	6L7	3.50	7199	12.00
EL36	4.00	PL504	2.50	SAU5GT	5.00	6L7	3.50	7360	25.00
EL41	3.50	PL508	3.50	SAU6	2.50	6LQ5	20.00	7581A	15.00
EL180	25.00	PL509/PL519	6.00	SAN5A	4.00	6Q7	4.00	7586	15.00
EL81	5.00	PL802	6.00	SAN5B	4.00	6RH6B/6KNB	12.00	7587	23.00
EL84	2.25	PY81	1.50	6B7	4.00	6S7	3.00	7668	12.00
EL84 Mull	6.00	PY88	2.00	6B8	4.00	6S7	2.50		
				6BA6	1.50	6S17	3.00		

Prices correct when going to press

**CVC CHELMER VALVE COMPANY**

If you need Valves/Tubes or RF Power Transistors e.t.c. ... then try us!

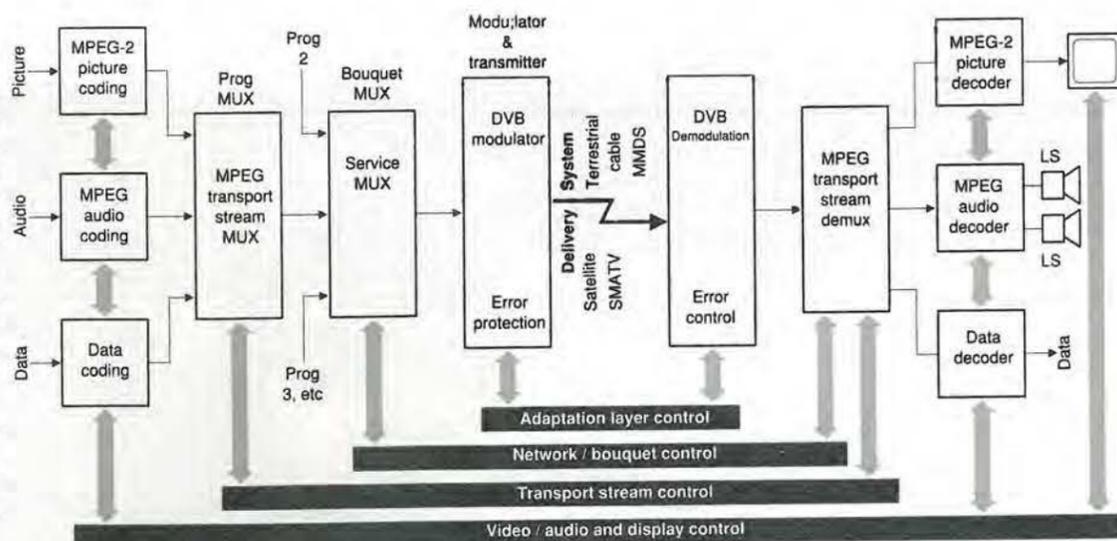
We have vast stocks, widespread sources and 33 years specialist experience in meeting our customers requirements.

Tuned to the needs of the Professional User

Chelmer Valve Company, 130 New London Road, Chelmsford, Essex CM2 0RG, England

44-01245-355296/265865  
Fax: 44-01245-490064

Fig. 1. Overall view of the European digital video broadcasting systems. Each delivery system provides a data container, best described as housekeeping (service information), and a multiplexed 'bouquet' comprising programmes and any other service offered by the provider.



speed digital data signals on terrestrial channels. When combined with bit-rate reduction, cofdm offered a realistic prospect of multiplexing a number of programmes within a single channel. Earlier, in the 1980s, British and European engineers had shown that 216Mbit/s 625-Line component video, described in ITU-R Recommendation 601, could be reduced to about 34Mbit/s with virtually no degradation of picture quality. It could also be successfully applied to microwave and satellite contribution, as well as distribution links.

**A turning point**

Then, at IBC-1990 in Brighton, General Instruments demonstrated, using a short computer simulation, that its 'Digicipher system held the promise that much greater bit-rate reduction factors seemed feasible by using complex digital signal processing that took

full advantage of the very large amount of redundancy in typical video material. It was soon shown that such results were not confined to computer simulations. An ITU-R 601 216Mbit/s component bit stream can be reduced to 5Mbit/s or less, while still providing a picture quality subjectively no worse than analogue 625-line PAL.

A digital video broadcast project in Europe was formally set up in the autumn of 1993. It grew to contain over 200 members, representing broadcasters, programme production houses, transmitter companies, satellite operators, consumer electronics manufacturers, regulatory bodies and government representatives from over 25 countries.

The European Broadcasting Union in Geneva provided project management. In the USA, an advanced tv standard has been developed from a grand alliance based on the merger of several different proposals for advanced

tv. This standard describes a system capable of providing high-definition pictures within the standard American 6MHz terrestrial channels. But it differs from the standards stemming from the European DVB Project in not accepting the use of cofdm.

The aim of Project DVB has been to formulate, with the maximum degree of commonality, practical digital transmission specifications for all forms of programme delivery. These include satellite using the DVB-S service, cable using DVB-C, terrestrial systems involving DVB-T and satellite master-antenna tv, or SMATV with DVB-CS. A multi-media system, namely MMDS will use DVB-MS and have an interactive channel.

**Dual subsystems**

Two sub-systems common to all forms of delivery are service information, or SI, and fixed-format teletext, or DVBTXT. It is envisaged that a digital specification for an interactive channel will also be developed. All systems use the broadcast video and audio bit-rate compression systems of the Motion Picture Experts Group system MPEG.

It is claimed that much emphasis has been given to market requirements. This was not so with the earlier MAC/packet work, which reflected primarily the initiative of broadcast engineers.

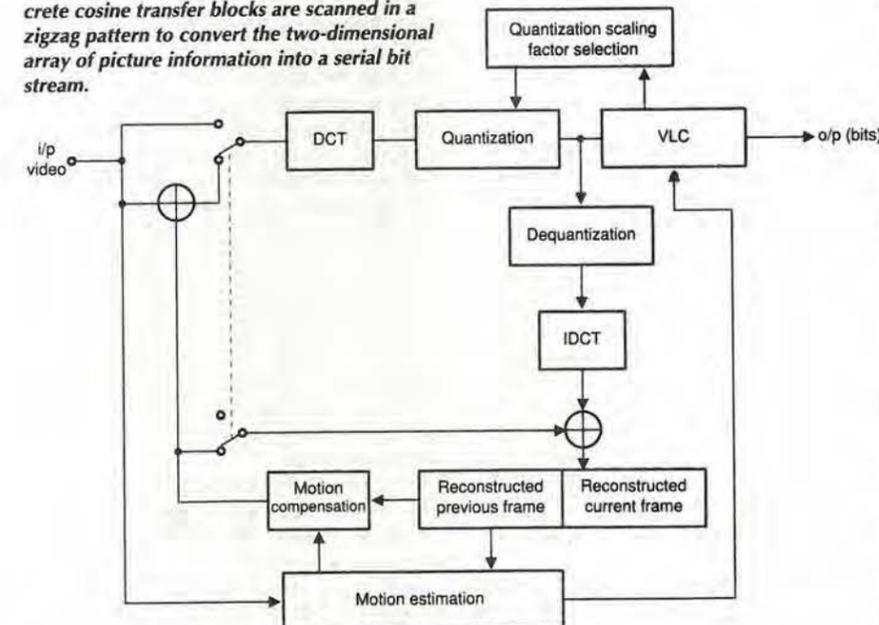
For each class of delivery system, appropriate ETSI specifications have been developed, linked, initially, to MPEG-2 bit-rate-reduction coding. Each delivery system provides a 'data container' with a multiplexed 'bouquet' of programmes and any other data services offered by the service provider. An overview of the DVB system is shown in Fig. 1.

**MPEG-2 bit-rate-reduction**

Initially a Working Group of ISO/IEC JTC1, MPEG began life in 1988 with the aim of defining standards for digital compression of video and audio signals.

The group's first task was to define a video coding algorithm for digital storage media - in particular cd rom. In 1993 this system,

Fig. 2. Simplified block diagram of an MPEG-2 encoder. After quantisation, 8 by 8 blocks of discrete cosine transfer blocks are scanned in a zigzag pattern to convert the two-dimensional array of picture information into a serial bit stream.



MPEG-1, was published in three parts as ISO/IEC 11172. It is restricted to non-interlaced video formats, primarily used for pc applications. MPEG-1 supports video coding at bit-rates under 1.5Mbit/s.

In 1990, MPEG began work on an algorithm capable of coding interlaced pictures directly, and suitable for high-quality applications at bit rates up to about 10Mbit/s. It was later extended to cover high-definition formats in the range of about 15-30Mbit/s. This system, MPEG-2, is specified in ISO/IEC 137132. It was published in 1994.

Programme-dependent bit-rate adaption is provided for in MPEG-2. For standard-definition 625-line broadcast tv with MPEG-2 bit-rate-reduction, cinema film requires a data rate of 2.5 to 4Mbit/s. Film with only 24 frames a second can look better than electronically-generated interlaced tv pictures at equivalent bit rates. Educational programmes are allocated 2-4Mbit/s, general programmes 3-7Mbit/s, sport 5-11Mbit/s and audio 64-256kbit/s.

It has been claimed that MPEG-2 coding can provide high quality pictures and sound with data rates as low as 1.5 Mbit/s. For transmission however, additional forward error correction bits, etc, need to be added. Further research into sophisticated signal coding algorithms is leading to systems such as MPEG-4. These will permit hdtv pictures to be transmitted in the American 6MHz terrestrial channels.

**How does MPEG work?**

Video bit-rate reduction, i.e. digital compression, removes redundant and less important information from a video signal prior to transmission. Then, the receiver reconstructs an approximation of the original images from the information reaching the decoder.

In practice, there are three main forms of redundancy and all are exploited in MPEG-2. First are spatial and temporal redundancies. Pixel values are not independent but are correlated with neighbouring pixels both within the same frame and across frames. This implies that for most images, the value of any pixel is predictable.

Second comes entropy redundancy. In any

non-random digitised signal, some code values occur more frequently than others. This enables shorter codes to be used for the more frequently occurring values. Compare this with Morse telegraphy, where frequently used letters have short symbols. The letter E for example is a single dot.

Lastly there is psycho-visual redundancy. By exploiting the limitations of the human eye and brain, information beyond the limits of spatial resolution - fine detail which the eye cannot resolve - and temporal resolution which is the limited ability of the eye to track fast-moving images.

For MPEG-2 an assemblage of compression techniques are used in practice. However, unlike for MPEG-1, reduction of the horizontal sampling rate is not advisable for luminance or chrominance signals. Nor is temporal sub-sampling. Nevertheless, the frequency of the vertical chrominance can be halved with MPEG-2 suitable for 4:2:0 as well as 4:2:2 and 4:4:4 component video.

**Removing redundancy**

There are two main methods of exploiting redundancy. In discrete-cosine transform, or dct, an orthogonal transform similar to a discrete Fourier transform assists the processing that removes spatial redundancy. It does so by concentrating signal energy into relatively few coefficients. With the second method, motion compensated interframe prediction is used to remove temporal redundancy. This technique is similar to differential pulse-code modulation, dpcm. An outline of a MPEG-2 encoder is shown in Fig. 2.

After quantisation, the 8 by 8 blocks of dct coefficients are scanned in a zigzag pattern to convert the two-dimensional array into a serial string. They are then coded by counting the number of zero coefficients preceding a non-zero coefficient. This is run-length encoding. Finally they are combined with the non-zero coefficients and coded as a variable-length code, or vlc.

The discrete cosine transform coefficient quantisation, the run-length coding and the variable-length coding processes produce a varying bit-rate. The variation depends on the

complexity of the picture information and the amount and type of motion in the picture.

To achieve the constant bit-rate needed for transmission, a buffer is required to smooth out the variations. To prevent overflow or underflow of this buffer, its occupancy is monitored with feedback applied to the coding processes to control the input.

An important feature is that the final bit rate at the output of the encoder can be freely varied; if this is reduced, the buffer will empty more slowly. The encoder compensates for this by making the dct coefficient quantisation coarser, reducing the quality of the decoded picture. Increasing the final bit rate improves the decoded picture quality. There is no requirement to lock input sampling rate to channel bit-rate or vice versa.

You should appreciate that this is only a bare outline of an extremely sophisticated bit-rate-reduction system which includes several methods for motion-compensation prediction. These involve both forward and backward prediction from other frames, or interpolation by averaging a forward and a backward prediction.

**Where MPEG falls down**

While MPEG-2 processing is well suited for the final distribution and broadcast transmission, it is far from ideal for contribution links. Here, further editorial processes, such as chroma keying, are likely to be required at the studio centre. For international satellite links etc an international 34Mbit/s standard has been agreed (ETS 300 174/ITU-T J81).

According to the ITC specification for UK television broadcasting, video encoding has to conform to ISO/IEC 13818-2 with the additional guidelines of ETSI-54. Mandatory video parameters include a frame rate of 25Hz and an aspect ratio of 4:3 or 16:9.

Mandatory audio parameters of ISO/IEC 13818-3 and guidelines ER 154 involve stereo at a sampling frequency of 48kHz with no pre-emphasis. Bit rates recommended for stereo are 256kbit/s and for joint stereo 192kbit/s.

The transport-stream multiplexing feature of MPEG allows a large number of video, audio and data services to be merged into a single

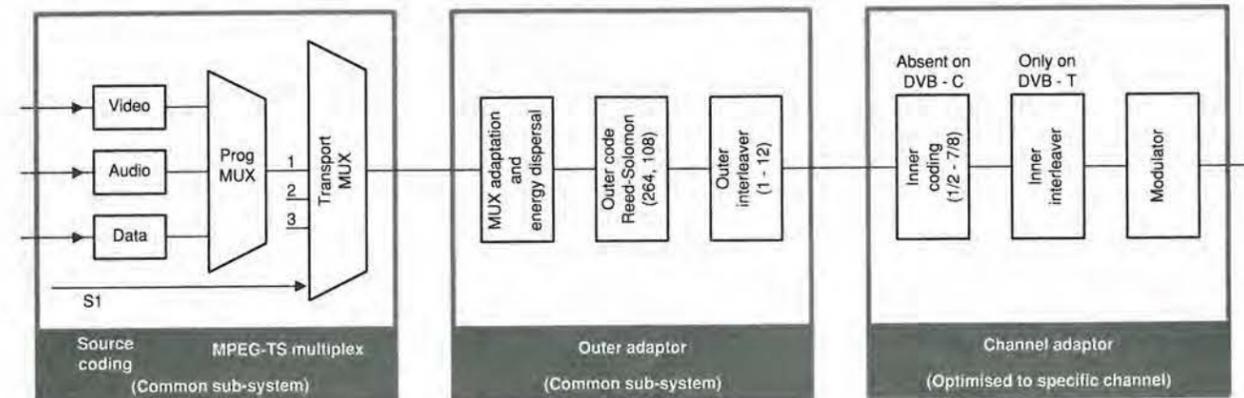


Fig. 3. Basic transmission chain for digital-video broadcast systems, showing how the error protection is added to output from the MPEG transport stream multiplexer. The first two blocks are common to all channels. The channel adaptor is optimised depending on the type of information that the channel is carrying.

transmission stream. Packets are 188 bytes long and delimited by a sync byte.

Since no error protection is provided rugged forward error protection must be added to provide as near possible an error-free data stream to the receiver decoder. Figure 3 shows how the MPEG-2 data stream is further encoded to provide the degree of error protection required by the various delivery systems.

In brief, all first-generation Project DVB systems use the common MPEG-2 transport-stream multiplex. They also use a common service information system providing the decoder with details of the transmission system, and the services being broadcast. All systems incorporate common Reed-Solomon forward error correction system. Where needed by the delivery system, they also have a common punctured convolutional code forward error correction system. Digital video broad-

cast service information - mandatory and optional - is specified in prETS 300 468, plus guidelines on its implementation and use.

**MPEG housekeeping**

Figure 3 shows how error protection is added to the MPEG transport stream multiplex with an outer adapter which is common to all systems and then a channel adapter optimised to the specific delivery channel. The programme-specific information within the service information includes the programme association table, programme map table and the conditional access table.

Service information also conveys the packet and transport packet layer guidelines, the time and date and three tables. The network information table represents the actual delivery system, the service description table is the actual delivery stream) and the event infor-

mation table describes present/following events only.

Transmission parameter signalling, or tps, in effect tells the receiver which of the many options is in use. Since broadcasters are unlikely to change the modulation options frequently however, it is not essential to decode this information. Broadcasters are more likely to re-configure their multiplex to carry more or fewer programmes by changing the bit rates allotted to individual channels.

Pilot information is provided in two forms. A few carriers - called continual pilots - always have defined amplitudes and phases and are used primarily for synchronisation. Additional 'scattered pilots' are inserted in a regular pattern to facilitate coherent demodulation. ■

In a subsequent article, Pat will describe digital delivery systems.

**Digital television glossary**

- ACATS - Advisory Committee on Advanced Television Systems (USA)
- ATV - advanced television
- BAT - bouquet association table (part of SI)
- BER - bit error rate
- B-pictures - bidirectionally predictive pictures (motion compensation)
- BRR - bit-reduction rate.
- CA - conditional access
- CAT - conditional-access table (part of SI)
- COFDM - coded orthogonal frequency-division multiplexing
- CPE - common phase error
- DAB - digital audio broadcasting
- DBPSK - differential binary phase-shift keying.
- DCT - discrete cosine transform
- DPCM - differential pulse-code modulation
- DTT - digital terrestrial television
- DVB - digital video broadcasting, suffixed S for satellite, C for cable, T for terrestrial, CS for SMATV, TXT for fixed-format teletext and MS for MMDS.
- EBU - European Broadcasting Union
- EIT - event information table (part of SI)
- EPG - electronic programme guide
- ETS - European Telecommunication Standard
- ETSI - European Telecommunication Standards Institute
- FEC - forward error correction
- FFT - fast Fourier transform
- GOP - group of pictures (motion compensation)
- IBC - International Broadcasting Conference
- ICI - inter-carrier interference
- IDCT - inverse discrete cosine transform
- IEC - International Electrotechnical Commission
- I-pictures - intra pictures (motion compensation)
- IRD - integrated receiver decoder

- ISO -International Standardisation Organisation
- ITU - International Telecommunication Union
- MMDS - multichannel, multipoint distribution system, alternatively, multipoint microwave distribution system
- MPEG - video bit-rate reduction systems determined by the Moving Picture Experts Group
- NIT - network information table (part of SI)
- OFDM - orthogonal frequency division multiplexing
- PAT - programme association table (part of SI)
- PMT - programme map table (part of SI)
- P-pictures - predictive pictures
- PPV - pay-per-view
- PRBS - pseudo random binary sequence
- PSI - programme-specific information (part of SI)
- PSP - programme service provider
- QAM - quadrature amplitude modulation
- QEF - quasi-error-free
- QPSK - quadrature phase-shift keying
- RLC - run-length coding
- RS - Reed Solomon error protection
- RST - running status table (part of SI)
- SDH - synchronous digital hierarchy
- SDT - service description table (part of SI)
- SFN - single-frequency network
- SI - service information, or housekeeping details added on to the video, audio and/or multi-media data stream
- SMATV - satellite master antenna television
- SMS - subscriber management system
- ST - stuffing table (part of SI)
- TDT - time and date table (part of SI)
- TOT - time offset table (part of SI)
- TPS - transmission-parameter signalling
- TS - transport stream
- VLC - variable-length coding



The Home of *Hi-Finesse*. Its not what you do, its HOW you do it that counts!.

Hart Audio Kits and factory assembled units use the unique combination of circuit designs by the renowned John Linsley Hood, the very best audiophile components, and our own engineering expertise, to give you unbeatable performance and unbelievable value for money.

We have always led the field for easy home construction to professional standards, even in the sixties we were using easily assembled printed circuits when Heathkit in America were still using tagboards! Many years of experience and innovation, going back to the early Dinsdale and Bailey classics gives us incomparable design background in the needs of the home constructor. This simply means that building a Hart kit is a real pleasure, resulting in a piece of equipment that not only saves you money but you will be proud to own.

Why not buy the reprints and construction manual for the kit you are interested in to see how easy it is to build your own equipment the HART way. The FULL cost can be credited against your subsequent kit purchase.

'AUDIO DESIGN' 80 WATT POWER AMPLIFIER.



This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hi-fi system. This kit is your way to get £K performance at bargain basement prices. Unique design features such as fully FET stabilised power supplies give this amplifier World Class performance with startling clarity and transparency of sound, allied to the famous HART quality components and ease of construction. Standard model comes with a versatile passive front-end giving 3 switched inputs, with ALPS precision 'Blue Velvet' low-noise volume and balance controls, no need for an external preamp! Construction is very simple and enjoyable with all the difficult work done for you, even the wiring is pre-terminated, ready for instant use! All versions are available with Standard components or specially selected Super Audiophile components and Gold Plated speaker terminals and all are also available factory assembled.

- K1100 Complete STANDARD Stereo Amplifier Kit, £415.21
- K1100S Complete SLAVE Amplifier Kit, £353.52
- K1100M Complete MONOBLOC Amplifier Kit, £271.20
- RLH11 Reprints of latest Audiophile articles, £1.80
- K1100CM Construction Manual with full parts lists, £5.50

ALPS 'Blue Velvet' PRECISION AUDIO CONTROLS.



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

- MANUAL POTENTIOMETERS
- 2-Gang 100K Lin, £15.67
- 2-Gang 10K, 50K or 100K Log, £16.40
- 2-Gang 10K Special Balance, zero crosstalk and zero centre loss, £17.48

- MOTORISED POTENTIOMETERS
- 2-Gang 20K Log Volume Control, £26.20
- 2-Gang 10K RD Special Balance, zero crosstalk and less than 10% loss in centre position, £26.98

TOROIDAL MAINS & OUTPUT TRANSFORMERS for EL34, 32W VALVE AMPLIFIER

Special set of toroidal transformers, 2 output & 1 mains for the 'Hot Audio Power' valve amplifier design described in the Oct. 1995 issue of 'Wireless World'. Total Wt 4.8Kg. Special price for the set, £99, Post £8

PRECISION Triple Purpose TEST CASSETTE TC1D.

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

- Test Cassette TC1D. Our price only, £9.99

SHUNT FEEDBACK PICKUP PREAMPLIFIER



If you want the very best sound out of vinyl discs then you need our high quality preamplifier with Shunt Feedback equalisation. The K1450 also has an advanced front end, specially optimised for low impedance moving coil cartridges as well as moving magnet types. Selected discrete components are used throughout for ultimate sound quality. The combination of John Linsley Hood design, high quality components and an advanced double sided printed circuit board layout make this a product at the leading edge of technology that you will be proud to own. A recent review in 'Gramophone' magazine endorsing this view. Bought in kit form our step by step instructions it is very easy and satisfying to assemble, or you can buy a factory assembled version if you wish.

This magnificent kit, comes complete with all parts ready to assemble inside the fully finished 228 x 134 x 63mm case. Comes with full, easy to follow, instructions as well as the Hart Guide to PCB Construction, we even throw in enough Hart Audiograde Silver Solder to construct your kit!

- K1450 Complete Kit, £116.58
- K1450SA Audiophile Kit, £138.94
- A1450SA Factory assembled Audiophile unit, £188.94

'CHIARA' HEADPHONE AMPLIFIER.



Highest quality, purpose designed, 'single ended' class 'A' headphone amplifier for 'stand alone' use or to supplement those many power amplifiers that do not have a headphone facility. Easy installation with special signal link-through feature, the unit uses our 'Andante' Ultra High Quality power supply. Housed in the neat, black finished, Hart minibox it features the wide frequency response, low-distortion and 'musicality' that one associates with designs from the renowned John Linsley Hood. Volume and balance controls are Alps 'Blue Velvet' components. Very easy to build, or available factory assembled, the kit has very detailed instructions, and comes with Hart audiograde silver solder. A valuable personal listening option and an attractive and harmonious addition to any hi-fi system.

- K2100 Complete Standard Kit, £112.50
- K2100SA 'Series Audiophile' Kit with selected audiophile components, £115.46
- A2100SA 'Series Audiophile', Factory Assembled, £115.46
- CM2100 Construction Manual, £2.50

'Andante' Linear Technology AUDIOPHILE POWER SUPPLIES

The HART 'Andante' series power supplies are specially designed for exacting audio use requiring absolute minimum noise, low hum field and total freedom from mechanical noise. Utilising linear technology throughout for smoothness and musicality makes it the perfect partner for the above units, or any equipment requiring fully stabilised ±15v supplies. There are two versions, K3550 has 2 ±15v supplies and a single 15v for relays etc. K3565 is identical in appearance and has one ±15v. Both are in cases to match our 'Chiara' Headphone Amplifier and our K1450 'Shunt Feedback' Pickup preamp.

- K3550 Full Supply with all outputs, £94.75
- K3565 Power Supply for K1450 or K2100, £84.42
- A3550 Factory Assembled Full Supply, £147.25

SPEAKER DESIGN SOFTWARE.

VISATON 'Speaker Pro 6' is a complete speaker design program for use on IBM machines. Covers cabinet and crossover design and contains a full expandable database of drive units. Earning a 'most recommendable' accolade it tests this program is ideal for the professional speaker builder or serious audiophile.

- 0303 Speaker Pro 6. 3.5"Disk, £45.51
- 0309 Demo Version with Database, £9.28

SPEAKER DAMPING MATERIALS

Polyester Wool and Pure Lambs Wool both have optimal damping properties and are pleasant to handle. Standard 125g bag is sufficient for 20 litres enclosure volume.

- 5070 Polyester Wool. 125g, £3.20
- 5069 Pure Lambs Wool. 125g, £6.73

**ROARING SUBWOOFER.**  
A full revised kit will be available soon for this excellent and imaginative design from Russel Bredon (WW Feb.97). The latest design will use the 30mm maximum cone displacement of the 10" VISATON GF250 Driver to give even better performance at slightly reduced cost. Featuring a rubber suspended fibreglass cone, extended pole plate, vented magnet, Kapton carrier and dual 4ohm voice coils the GF250 is unbelievably good value at only £111.45 each.

**SPECIAL OFFER! SOLENOID CONTROLLED FRONT LOAD CASSETTE DECK SFL800**

High quality (0.08%W&F) cassette mechanism with capability of using standard or downstream monitor R/P head. Offers all standard facilities under remote, logic or software control. The control requirements are so simple that for many applications not needing all functions manual switches will suffice. Power requirements are also simple with 12v solenoids and 12v speed controlled Motor, total power requirement being under 300mA. Logic control and wiring circuits are included free with each deck.

- SFL800 Deck with Standard stereo head, £29.50
- SFL800D Fitted with High Quality Downstream monitor head, £44.90 (The Head alone is normally over £50!)

**HART TECHNICAL BOOKSHELF**  
Try us for- Bigger Range of Books, Better Prices, NO '28 Day Wait'

- "AUDIO ELECTRONICS" John Linsley Hood, £18.99
- "THE ART OF LINEAR ELECTRONICS" John Linsley Hood, 1994, £16.95
- "THE ART OF ELECTRONICS" Horowitz & Hill, £35.00
- "DIGITAL AUDIO AND COMPACT DISC TECHNOLOGY" 3rd. Edn. 0-240 51397 5, £19.95
- "INTRODUCING DIGITAL AUDIO CD, DAT AND SAMPLING" ISBN 1870775 22 8, £7.95
- "ACTIVE FILTER COOKBOOK" Don Lancaster, £19.95
- "THE ART OF SOLDERING" 0-85935-324-3, 0, £3.95
- "TOWERS' INTERNATIONAL TRANSISTOR SELECTOR" 0-572-01062-1, £19.95
- "AUDIO" F.A. Wilson, BP11, £3.95
- "HOW TO USE OSCILLOSCOPES & OTHER TEST EQUIPMENT" R.A. Penfold, BP267, £3.50
- "THE HART PRINTED CIRCUIT BOARD CONSTRUCTION GUIDE", £2.50
- "A SIMPLE CLASS A AMPLIFIER" J.L.Linsley Hood M.I.E.E. 1969, RLH12, £2.75
- "CLASS-A POWER" Single Ended 15W Amp. J.L.Linsley Hood M.I.E.E. 1996, RLH13, £2.50

- LOUDSPEAKERS; THE WHY AND HOW OF GOOD REPRODUCTION. G Briggs, 1949, £8.95
- "THE LOUDSPEAKER DESIGN COOKBOOK" Vance Dickason, (5th Edn.), £23.95
- ELECTROSTATIC LOUDSPEAKER DESIGN AND CONSTRUCTION Ronald Wagner BKT6, £15.95
- "THE ELECTROSTATIC LOUDSPEAKER DESIGN COOKBOOK" Roger P.Sanders, 1995, £24.95
- "BULLOCK ON BOXES" Bullock & White, £10.95
- "AN INTRODUCTION TO LOUDSPEAKERS & ENCLOSURE DESIGN" V. Capel, BP256, £3.95
- "LOUDSPEAKERS FOR MUSICIANS" BP297, £3.95
- "THEORY & DESIGN OF LOUDSPEAKER ENCLOSURES" J.E.Benson, £21.95
- "QUICK & EASY TRANSMISSION LINE SPEAKER DESIGN" Larry D.Sharp, £8.95
- "THE COUPLED CAVITY HANDBOOK" David Purton, £4.90
- "VISATON, HOME HI FI CATALOGUE." Full Specifications and Thiele Small Data on all Drive Units, £4.50
- "VISATON, CAR HI FI CATALOGUE." In car guide, £3.50
- "VISATON, CABINET PROPOSALS" Book 1. In GERMAN, £6.50
- "VISATON, CABINET PROPOSALS" Book 2. In GERMAN, £6.50
- "SPEAKER PRO 6." VISATON Cabinet Design Software, £45.51
- "SPEAKER PRO 6." Demo Version with drive unit database, £9.28

- "VALVE AMPLIFIERS" Morgan Jones, 1995/6, £24.50
- THE VTL BOOK David Manley 1994, BKVT1, £17.95
- MULLARD TUBE CIRCUITS FOR AUDIO AMPLIFIERS BKAA27, £11.95
- "THE WILLIAMSON AMPLIFIER." 0-9624-1918-4, £6.95
- AN APPROACH TO AUDIO FREQUENCY AMPLIFIER DESIGN. GEC 1957, £17.95
- AUDIO ANTHOLOGIES, articles from Audio Engineering. Six volumes covering the days when audio was young and valves were king! BKA3/1 to 6. All £12.95 each
- "THE RADIOTRON DESIGNERS HANDBOOK" (CD), £49.00
- "PRINCIPLES OF ELECTRON TUBES" H.D.Reich PH.D., £25.95
- "POWER AMP PROJECTS" Anthology, 1970-1989, £15.50
- "WORLD TUBE DIRECTORY" 1996-7 Sourcebook of valve related products, £5.95
- Fuller descriptions of the contents of all our books is given in our full catalogue, price, £4.50

Postage on all books, unless starred, is only £2 per book, maximum £4.50 for any number, any sized. Starred items are heavy books costing £3.50 to send.

Don't forget No waiting at HART! All listed books are normally in stock! Just ring with your Credit Card Number for instant despatch!

POSTAGE on UK Orders up to £20 is £2. Over £20 is £4.50. OVERSEAS Please Enquire. Fuller Details of ALL kits are given in our List, FREE on request.

Send for Your FREE copy of our LISTS 24 Hr. ORDERLINE 01691 652894 Fax. 01691 662864 All Prices include UK/EC VAT.

**HART**  
HART ELECTRONIC KITS LTD.  
1 Perylan Mill, OSWESTRY, Shropes, SY10 9AF, UK

# Changing times

**For very little outlay, Ed Buckley's atomic clock interface takes the rather unfriendly serial data from an MSF receiver module and turns it into an RS232 time and data stream using a Basic Stamp. Output is a bcd data stream containing year, month, date, day, hour and minutes.**

The Basic Stamp is a versatile, easy to programme microcontroller. As well as a stand alone unit the Stamp is also a very handy interface device - reading in non-standard data, performing some manipulation and then passing the data on in a more usable format.

The following design illustrates this function by combining a Stamp 1 module with a readily available atomic clock module. To finish up, I will then describe how you can have your cake and eat it too - achieve low software development time by using the Stamp 1 and low production costs by using a standard PIC.

### Design overview

We recently needed to fit a data logger to a series of truck-trailers. The data needed time stamping - no pun intended - but there was a serious risk of interruption of power to the real-time clock module.

The obvious solution was to incorporate an operator keypad to allow for clock resetting. As well as being expensive, this solution allowed the opportunity for operator error.

So we decided to look for a different solution. After looking at the atomic clock module

now available, we decided to go down this route. Costs would be about the same as a keypad interface, but this alternative has the advantage that it is fully automatic.

### Atomic clock summary

Atomic clock modules were featured in *Electronics World* March 1996. Here I will summarise the important features.

The off-air data stream is repeated every minute. High speed data is sent in the first 17 seconds, followed by null data that can be discarded. Next, low speed data is transmitted at 1bit/s. There is always a unique data format at the end of the minute period, which is 01111110<sub>2</sub>. Data timing is shown in Fig. 1 and the minute's data format in Table 1.

The circuit diagram with Stamp/Clock hook-up is shown in Fig. 2.

### Writing the software

For our application, we require a burst of correct time data at 2400baud once a minute. The main system processor - a Stamp 2 in this case - polls the signal line from the Stamp 1 clock module. If valid data is present, it updates the system real-time clock.

The Stamp 1 interfacing with the atomic clock is dedicated to reading and checking the validity of the incoming radio data. It only transmits the data if it proves valid.

We envisaged that the main problem would be loss of radio signal as the trailer moved around. For this reason the software always counts the number of data bits received from the last required data set until the unique format byte is received - in our case seven. If the counter is anything but seven, then a bit has been lost or found, the data is suspect and there is no transmission to the main system.

List 1 is the program listing. The input and output pins are allocated names to ease programme tracing and ram space allocated to the programme variables. The Stamp 1 has up to 14 bytes of ram which may be addressed as bytes, for example b<sub>3</sub> or b<sub>7</sub>, or words, as w<sub>0</sub> or

w<sub>3</sub>, where w<sub>3</sub>=b<sub>6</sub>+b<sub>7</sub>. Further, two bytes may be addressed by their individual bits, that is bytes b<sub>0</sub> and b<sub>1</sub> provide bits bit<sub>0</sub> to bit<sub>15</sub>.

The dirs statement sets the pins to either input if zero or output if logic one; the msb comes first.

We initially look for the 01111110<sub>2</sub> signature by reading the individual data bits using the Get\_bit routine into the variable signal. The variable counter is incremented every time a new bit is read.

Once the signature has been received we now know where we are and proceed to 'continue' where the good\_data flag is set to false. Here we check to see if we have a good data set by looking at counter. If counter is does not hold seven, then the data is bad. If the counter does hold seven then the data is good and the good\_data flag is set to true. This condition allows transmission of the time data ten times during the fast data period at the beginning of the minute period.

Now begins the slow speed data section. The first 16 seconds are unused and discarded. Next we log the year, month, day of month, day of week - which we discard - hour of day and minute.

Now the program returns to the beginning. If all is well the next eight data bits should be the unique signature and counter should return seven to allow transmission.

Most of the grunt work is handled by two subroutines - Get\_bit and Read\_convert.

**Get-Bit.** Get\_bit decodes the data from the atomic clock module.

The data falling edge is first detected. Once detected, the programme pauses for 150ms before reading the data - if logic one is returned the data is zero and if zero, a one is returned. Note that the clock gives inverted data, which we correct in the line bit0=clk+1. The program then waits a further 200ms to ensure the clock data is in the stable high portion of its cycle before continuing.

**Read\_convert.** At the end of each chunk of received data we take the opportunity to convert it into a decimal and then a binary-coded decimal format for easy reading by the system processor. Our main system clock uses bcd format so using bcd minimises the calculations later on.

### Rounding up

To aid fault finding and add value, we included several leds - the i/o pins were there unused so why not spend 15p? The three leds have the following functions.

- Sync\_flag led is on when the good\_data flag is set, ie the previous minute's data was good.
- Bit\_read flashes every two seconds - a stable on or off here indicates loss of incoming signal.
- Data\_bit indicates whether the data bit received was a one or zero data.

Check\_sum is a byte variable. It is cleared every minute and all data is added to give a

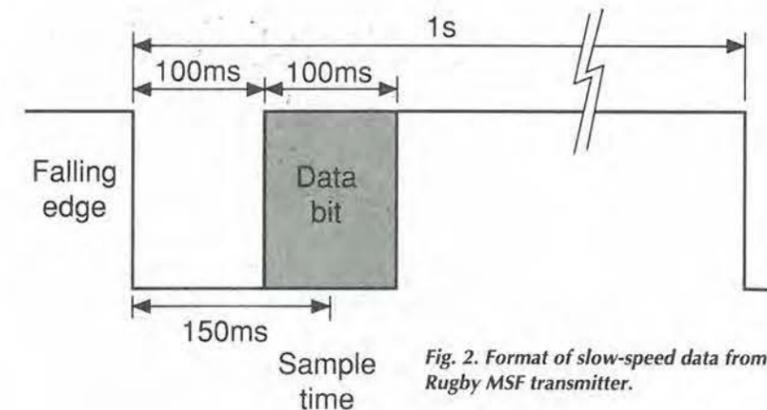
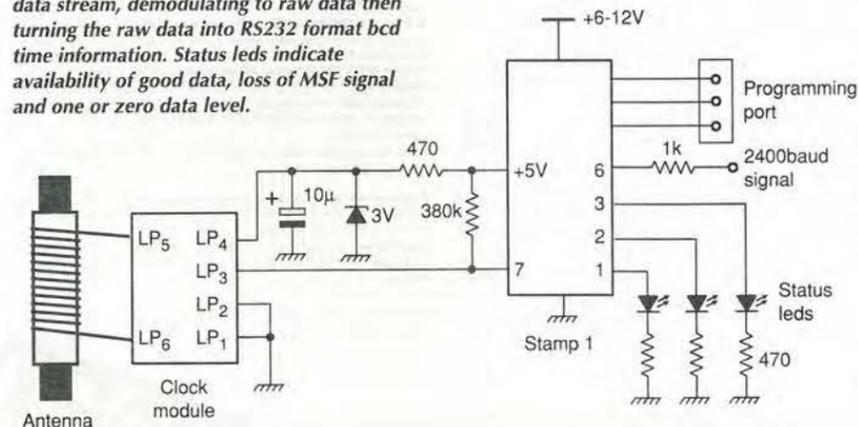


Fig. 2. Format of slow-speed data from the Rugby MSF transmitter.

Table 1. Time telegram of MSF transmitter - binary code for seconds 17 to 30 and data for March 1996. Note that each second value is one or zero. A one in second 17 for example represents 80 and a one in second 18 represents 40.

Second	Function	Value	Detail
0	Fast code	Not used in modules	
1	DUT1 code	Not used in modules	
2-16	-		
17	year (tens)	80	year 00-99, bcd
18	year (tens)	40	
19	year (tens)	20	
20	year (tens)	10	
21	year (units)	8	
22	year (units)	4	
23	year (units)	2	
24	year (units)	1	
25	month (tens)	10	month 01-12, bcd
26	month	8	
27	month	4	
28	month	2	
29	month	1	
30	day of month (tens)	20	day of month, bcd
31	day of month (tens)	10	
32	day of month	8	
33	day of month	4	
34	day of month	2	
35	day of month	1	
36	day of Week	4	day of week 1-7, bcd
37	day of Week	2	
38	day of Week	1	
39	hour (tens)	20	hour 00-23, bcd
40	hour (tens)	10	
41	hour (units)	8	
42	hour (units)	4	
43	hour (units)	2	
44	hour (units)	1	
45	minute (tens)	40	minute 00-59, bcd
46	minute (tens)	20	
47	minute (tens)	10	
48	minute (units)	8	
49	minute (units)	4	
50	minute (units)	2	
51	minute (units)	1	
52	always set to '0'	0	
53-58	always set to '1'	1	
59	always set to '0'	0	

Fig. 1. Complete circuit for receiving the MSF data stream, demodulating to raw data then turning the raw data into RS232 format bcd time information. Status leds indicate availability of good data, loss of MSF signal and one or zero data level.



resulting checksum which is used to detect errors between the Stamp 1 and the main system processor - unsophisticated but works.

**What about the cake?**

We have demonstrated the versatility of the Stamp 1 as an interface. The Stamp scores over raw PICs in terms of speed of producing and debugging a simple programme.

If the application only requires a small number of units the Stamp is fine, either in its IC or discrete chip set format. For larger numbers however, the costs start to look a little heavy.

Realising this, Parallax, the manufacturers of the Basic Stamp has recently introduced a neat solution for Stamp 1 users. By using the latest Stamp 1 software and the Parallax PIC programmer, it is possible to programme a standard PIC16C58 with both the Stamp

interpreter and your programme. This gives low-cost development coupled with low cost production.

This system only works with the Stamp 1, 16C58 and Parallax's programmer, but it is a very useful tool for those quickie programmes that will fit into a Stamp 1.

Galleon, distributor of the clock modules, can be reached on 0121 359 0981.

**List 1. Stamp 1 program to read and decode the Rugby MSF time clock.**

```

MSFCLCK.BAS
Milford Instruments Original version dated March 1997

Stamp decodes the one second pulses using Get_bit and
keeps adding them to signal until the sync byte is received.
First 17 seconds are ignored and remainder are clocked into
relevant bytes. Results are converted to BCD format before
storing in bytes. Time is only transmitted at the start of
the minute - if data is judged to be OK. Program counter
holding number of seconds from last valid time data
until sync byte is received.. should be 7.

Symbol clk      =pin7  'clock signal on pin 7
symbol rs232    =6     'rs232 signal on pin 6
symbol signal   =b1   'byte to receive data
symbol counter  =b11  'general counter variable
symbol good_data =bit1 'good time message flag, 0=false
symbol checksum =b7   'data checksum variable
symbol sync_flag =pin3 'in sync led
symbol bit_read  =2   'data bit received led
symbol data_bit  =pin1 'data bit rec. led, on for log. 1

dirs=%01001110 'set up the pin directions

'First look for the 01111110 signature
start:
counter=0
signal=0
loop:
gosub get_bit ' go and get a bit
signal=signal*2+bit0 ' add it to signal
if signal=%01111110 then continue 'Sync byte received?
continue if not and increase counter by one
counter=counter+1
goto loop

continue: ' sync byte now received
good_data=0 ' reset valid data flag
if counter<>7 then skip1 'check that we've kept in step
'if good data captured then set flag
good_data=1
skip1:
counter=0
sync_flag=good_data ' light the in_sync led

'Now send the good data transmission whilst waiting to get
'past the fast code section at the start of the minute
'Total loop period approximately 1.4s
for counter=1 to 10 'send the good data at min.start
if good_data<>1 then loop2 'check for good data flag
Transmit if good data
serout rs232,n2400,("T",b2,b3,b4,b5,b6,b7)
loop2: 'if not jump to here
bit3=good_data+1
b9=bit3*35+100
pause b9 'get past the fast data section
next

'now discard the first 16 seconds of info
for counter=1 to 16
gosub get_bit
next

'Now start to read wanted data
'Reset the checksum variable
checksum=0
'Now read the year data
b8=7
gosub read_convert
b2=b10 'result in b10 written to b2
checksum=checksum+b2

'Now get the Month
b8=4
gosub read_convert
b3=b10 'result in b10 written to b3
checksum=checksum+b3

'Now get day of month
b8=5
gosub read_convert
b4=b10 'result in b10 written to b4
checksum=checksum+b4

'Now get the day of the week - and discard
b8=2
gosub read_convert

'Hour of Day
b8=5
gosub read_convert
b5=b10 'result in b10 written to b5
checksum=checksum+b5

'And the Minute reading
b8=6
gosub read_convert
b6=b10 'result in b10 written to b6
checksum=checksum+b6

goto start 'return for the next minute

'=====
' Sub-Routine to retrieve a bit
'=====

Get_bit:
Marker:
if clk=0 then read_bit 'detect falling
edge
goto marker

read_bit:
pause 150 'wait until the
middle of the A bit
toggle bit_read 'read the value on
bit0=clk+1
clk into bit0
data_bit=bit0
pause 200
return

'=====
' Read and Convert Routine
'=====

Read_convert:
b9=0 'Clear b9
for counter= b8 to 0 step-1 'one bit at a time
gosub get_bit
lookup counter,(1,2,4,8,10,20,40,80),b10 'Get the
appropriate scalar
b9=b10*bit0+b9 'Convert to true decimal
next
b10=b9/10*16 'now convert to
bcd- first the high byte
b10=b9//10+b10 'now add the low byte
return
    
```

**Reduce your controller application design time and get a 20% EW reader discount**

The phenomenal rise in popularity of PIC microcontrollers is evidence that many designers rate ease of use and low cost ahead of device sophistication. In terms of ease of use, the Basic Stamp goes a step further by allowing you to program a microcontroller in familiar Basic code via a pc's COM port.

Simply hook the chip to your pc, download the Basic code into the Stamp's memory, and watch the Stamp's i/o lines follow your code. To make the Stamp do something else, just load new code.

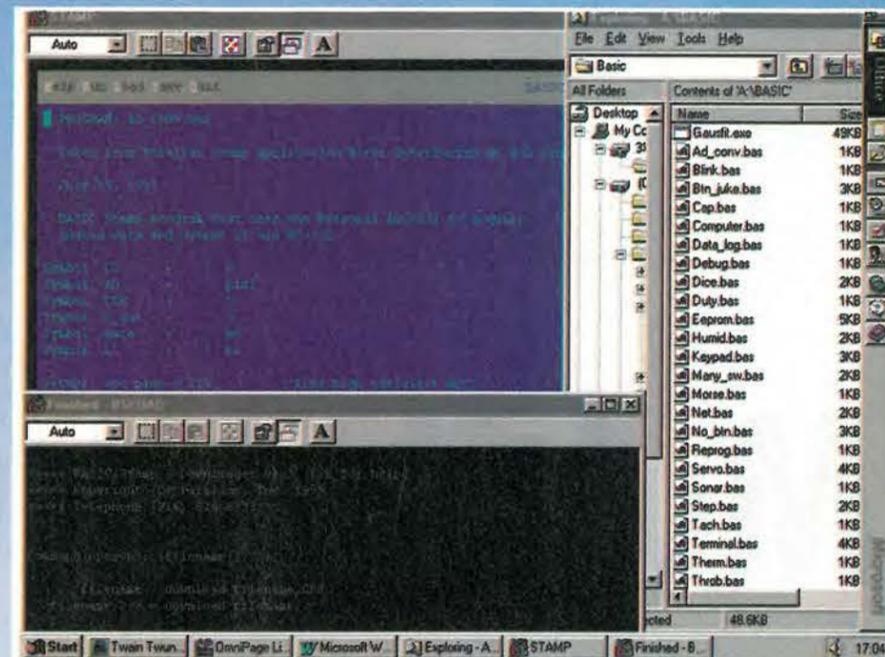
Until 31 October, Milford Instruments is offering *Electronics World* readers an exclusive 20% discount on both Stamp 1 and Stamp 2 development kits. This makes the Stamp 2 only £99 exclusive instead of £119 and the Stamp 1 £79 as opposed the usual £99.

Both development kits include programming software pack, programming cables, project board, manuals including application examples and either Stamp 1 or Stamp 2, depending on the kit.

Overseas readers can also obtain this discount but details vary according to country. Please ring, contact fax Milford at the address on the coupon, or fax on 01977 681465 or telephone on 01977 683665.

**Features of Basic Stamp**

- Basic language includes instructions for serial i/o, pwm, potentiometer input, pulse measurement, button debounce, tone generation, etc.
- Stamp 1 has 8 i/o lines, Stamp 2 has 16, each programmable as an input or output. Each can sink 25mA and source 20mA.
- Programs are stored in EEPROM so they are retained if power is removed and can be changed as often as required.
- Stamp 2 EEPROM holds 2K code for up to 600 instruction lines while Stamp 1 has a 256 byte EEPROM.
- Stamp 2 operates code at 10000 lines per second, Stamp 1 at 2000 lines a second.
- Stamps need connection to PC only during programming. Thereafter they run independently.
- Powered by 5-12V DC or 9V battery.
- Consume down to just 2mA, typ., or 20µA in sleep mode.)
- The Stamp 1 IC comes in convenient 14-pin SIP package.
- The Stamp 2 package has expanded i/o, more program memory and faster execution speed; all conveniently housed in a 24-pin DIP format package.



**Use this coupon to order your Basic Stamp**

Please send me:

Stamp 1 Development Kit at £98.70

Stamp 2 Development Kit at £122.20

Please tick. Prices are fully inclusive.

Name  
Company (if any)  
Address

Phone number/fax

Total amount £.....

Make cheques payable to Milford Instruments, or, please debit my Master, Visa or Access card:

Card type (Access/Visa)

Card No

Expiry date

Please mail this coupon to Milford Instruments at Milford House, 120 High Street, South Milford, Leeds LS25 5AQ, together with payment. Alternatively fax credit card details with order on 01977 681465 or telephone on 01977 683665.

Address orders and all correspondence relating to this order to Milford Instruments at the above address.

# Multilayer air-cored coils

If you want to calculate the inductance of a coil and you know all the coil's other specifications, Wheeler's equation provides a simple and accurate solution. But the designer's task is usually the reverse. Robert Kesler describes the return path.

The most practical way to calculate the inductance of an air-cored multilayer coil is via Wheeler's formula.<sup>1</sup>

$$L = \frac{7.87N^2M^2}{3M+9B+10C} \quad (1)$$

This formula is claimed to be accurate to within 1%, if the numbers in the denominator are about equal, that is, if the shape of the coil is similar to that shown in the diagram. Of course, the accuracy in practice is also determined by the tolerances on the coil's dimensions.

A given piece of wire, wound in a coil, yields the highest inductance value, if its proportions are,  $3M=9B=10C$ . It can be proved that this shape yields the highest inductance for a coil, wound from a given piece of wire, or the highest inductance/resistance ratio for a given weight of copper.

The Wheeler formula is fine for calculating the inductance of a coil when everything else is known. But usually, the designer's task is the opposite: at the outset, only the inductance is known. In addition to the four other parameters in the formula, the wire diameter has to be found too.

## Working back

A coil's dc resistance can be expressed using the diameter and the length of the copper wire, which can be expressed using the number of turns, and the mean diameter of the coil,

$$R = \frac{NM}{14250W^2} \quad (2)$$

The relationship between the number of turns that can be packed into the cross section of the coil and the wire diameter is,

$$N\left(\frac{W}{P}\right)^2 = BC \quad (3)$$

Considering only the ideal shape, there are two more useful equations,

$$B_i = \frac{M_i}{3} \quad (4)$$

$$C_i = 0.3M_i \quad (5)$$

In this case, formulas 1 and 3 become simpler,

$$L = 0.875N_i^2M_i \quad (6)$$

$$N\left(\frac{W}{P}\right)^2 = 0.1M_i^2 \quad (7)$$

Now the parameters can be expressed, using the formulas 2, 6 and 7,

$$M_i = 0.354\sqrt{\frac{L}{R}} \quad (8)$$

$$N_i = 1.07\sqrt{\frac{L}{M_i}} \quad (9)$$

$$W_i = 0.253\frac{M_i}{\sqrt{N_i}} \quad (10)$$

the inner and the outer diameter of the coil,

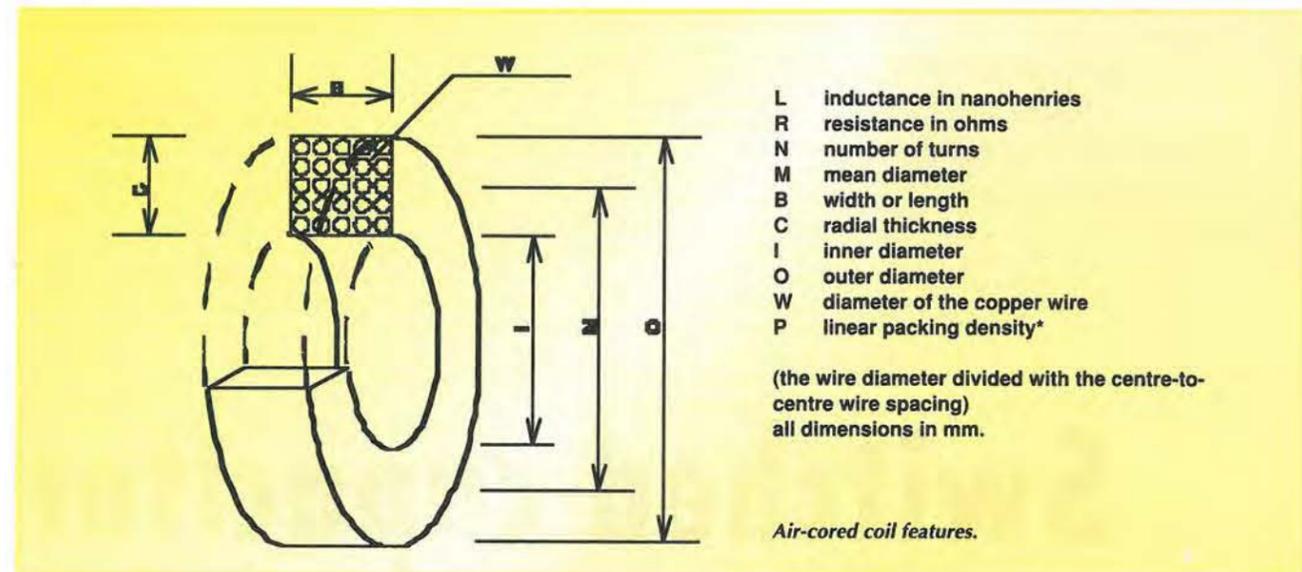
$$I = M - C = 0.7M \quad (11)$$

$$O = M + C = 1.3M \quad (12)$$

and two more useful relationships,

$$M_i = 3.08L^{0.2}W_i^{0.8} \quad (13)$$

$$N_i = 0.61\left(\frac{L}{W_i}\right)^{0.4} \quad (14)$$



Note that formulas containing 'i' subscripts are valid only for ideally shaped coils.

## Tips for designing multilayer coils

The above formulas are useful tools for designing multilayer air-cored coils. Two starting points are possible. With the first, the dc resistance is initially specified. For the second, dimensions of an available coil former need to be known.

If the coil is to be used in a high power circuit such as a loudspeaker crossover network, start by specifying the maximum allowable losses in terms of the dc resistance. Calculate the theoretical wire diameter using formulas 8, 9 and 10. Choose the nearest available standard wire size.

The calculated diameter need not be adhered to rigidly, bearing in mind that increasing the diameter will decrease the resistance, but increase the dimensions, and vice versa.

Use the chosen wire diameter to calculate the dimensions and the number of turns with formulas 1, 4, 5, 11, 12 and 14.

When working out from a given coil former, calculate the number of turns and the wire diameter, using formulas 1 and 3, with the dimensions of the former. Choose the nearest standard wire size. Using these new dimensions, recalculate the radial thickness and the mean diameter of the coil, then the number of turns.

Calculate the dc resistance and decide whether or not it is acceptable. Note that in all the calculations, the linear packing density is assumed to be 0.8. Any errors that may arise from this assumption and other causes can be corrected at the final stage.

Measure the diameter of the ready wound coil. Before cutting the wire, calculate the inductance using formula 1 and correct the number of turns, as necessary.

## Design examples

This first example shows how to proceed when the initial known quantity is the dc resistance of the coil. The inductance required is 200µH and the resistance assumed is 0.3Ω.

For mean diameter, number of turns and wire diameter,

$$M_i = 0.354\sqrt{\frac{200 \cdot 10^{-3}}{0.3}} = 28.9\text{mm} \quad (8)$$

$$N_i = 1.07\sqrt{\frac{200 \cdot 10^{-3}}{28.9}} = 89 \quad (9)$$

$$W_i = 0.253\frac{28.9}{\sqrt{89}} = 0.775\text{mm} \quad (10)$$

At this point, the calculated wire diameter can be modified to suit available sizes, provided that you understand the consequences. Let the new wire diameter be 1mm. Use this diameter in the subsequent calculations,

$$M_i = 3.08 \times 200000^{0.2} \times 1^{0.8} = 35.4 \quad (11)$$

$$B_i = \frac{35.4}{3} = 11.8 \quad (4)$$

$$C_i = 0.3 \times 35.4 = 10.6 \quad (5)$$

$$I = 35.4 - 10.6 = 24.8\text{mm} \quad (11)$$

$$O = 35.4 + 10.6 = 46\text{mm} \quad (12)$$

$$N_i = 0.61\left(\frac{200000}{1}\right)^{0.4} = 132 \quad (14)$$

Having finished the winding, remember to measure the outer diameter of the coil before cutting the wire. Calculate the inductance from formula 1, and correct the number of turns, if necessary.

The second design example is for when you are working from a specified coil former.

Inductance required is 2mH. Assume that the former has an inner diameter,  $I$ , of 12mm, a width,  $B$  of 16mm and a rim,  $C$ , of 6mm.

$$2 \times 10^6 = \frac{7.87 \times N^2 \times 18}{3.18 + 9.16 + 10.6} \quad (1)$$

$$N = 450 \quad (3)$$

$$450\left(\frac{W}{0.8}\right)^2 = 18.6 \quad (3)$$

$$= 0.392\text{mm.}$$

Choose the next available smaller wire diameter,  $W$ , of 0.35mm then calculate the radial thickness of the coil,

$$450\left(\frac{0.35}{0.8}\right)^2 = 16C \quad (3)$$

$$C = 5.4\text{mm.}$$

The new value for the radial thickness – and the mean diameter – may call for re-calculation of the inductance and correction for the number of turns. Alternatively, it may be left to the final correction, before cutting the wire.

Check the dc resistance,

$$R = \frac{17.6 \times 450}{14250 \times 0.35^2} = 4.54\Omega \quad (2)$$

Decide whether this value is acceptable. If too high, choose a former of bigger diameter and/or cross section. ■

## Further reading

H. A. Wheeler, Simple Inductance Formulas for Radio Coils, *Proc. IRE*, Vol. 16, p. 1398, Oct. 1928.  
F. E. Terman, Radio Engineer's Handbook, McGraw-Hill, 1943, p. 62.

**Can the switched-capacitor technique eliminate inductors in dc-to-dc converters? Ian Hegglun thinks it can, and explores how the technique can be applied.**

# Switched capacitor power supplies

Switching power supplies normally use inductors and/or transformers for voltage conversion. But this is not the only way to transform voltage efficiently. Voltage multipliers and voltage dividers are another option.

Voltage dividers are less well known. They are simply multipliers reconfigured for voltage step down. There are lots of similarities. Like multipliers, they need no inductors and like multipliers they are limited, mainly because they are difficult to regulate efficiently over a wide range of input or output voltages.

Pulse-width modulation can certainly vary the average voltage of inductorless circuits but the losses in the smoothing process are hardly any different to linear regulation. This is because the equivalent circuit of a switching capacitor arrangement is a low-pass RC filter which is inefficient when pulse modulated at low duty cycles. However, my earlier work showed efficient regulation is possible if a small value air-cored inductor is added to ac input of a full wave multiplier<sup>1</sup>. Regulation is then achieved by varying frequency.

This article looks at step down switched capacitor converters. In particular, converters that are capable of delivering tens of watts at 3V and converters delivering hundreds of

watts at around 50V output. When cascades, these converters could form the basis for computer power supplies, but how practical is this?

## 240V Mains to 3V without inductors?

Breaking the task into two stages with an intermediate voltage at around 30 or 50V helps. This would work in well with the distributed supply technique where one main power supply delivers only one voltage which then supplies various boards, each board has their own converter for their particular needs.<sup>2,3</sup> This solves a number of problems and makes it relatively easy to add batteries to the intermediate voltage for an uninterruptible supply.

Each converter requires a step-down ratio of at least 8:1. Since there are so many stages, each stage must be very efficient. If you aim for, say, 70% overall efficiency then each of two converters need to be around 85% efficient. With two or three cascades within each converter, efficiency for each stage must be no less than 95%.

Although difficult, this is not impossible. The increasing use of synchronous rectifiers such as the MA767 can give this efficiency even at the 3V level.<sup>4</sup> Recent developments

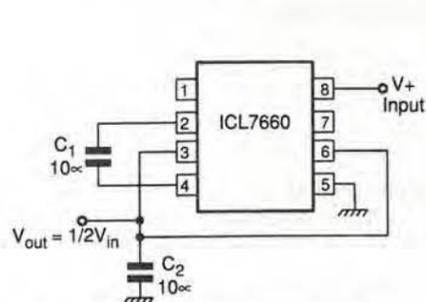


Fig. 1. Voltage divider using a popular IC.

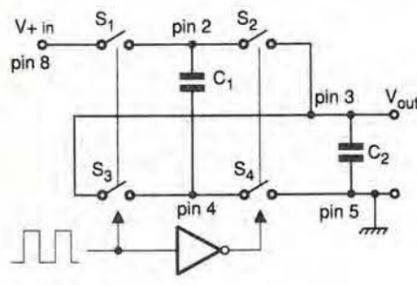


Fig. 2. Voltage divider internal circuit.

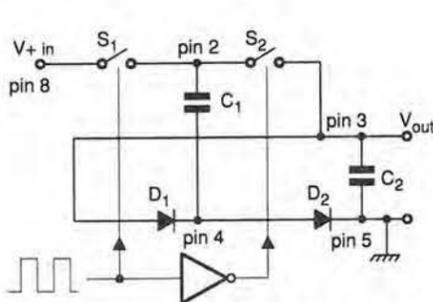


Fig. 3. Diodes being used in place of S3 and S4.

with mosfets, namely Philips' *Trenchmos* and SGS-Thompson's mesh overlay, should reduce the cost of the silicon needed for low losses.

Other necessities for mains conversion are power factor correction and an earthable or non-floating output. Both of these can be provided without using an inductor or transformer.

## Literature on voltage dividers

One reference to a voltage divider can be found in the ICL7660 data sheet.<sup>4,5</sup> Figure 1 shows the connections required and Fig. 2 shows the internal switching with mosfets.

In the first half cycle when S1 and S3 are closed, the supply voltage divides across the capacitors in a conventional way proportional to their value. In the next half cycle when S2 and S4 are closed, the capacitors switch from a series connection to a parallel connection. This forces the capacitors to have the same voltage; the charge redistributes to maintain precisely 1/2 V+, across C1 and C2.

A Linear Technology application note describes using four discrete mosfets to convert 12V to 5V at 1A without using an inductor in a similar way<sup>6</sup>. Regulation over a small range is achieved by varying the charge duration while S1 and S4 are on.

Two of the switches, S3 and S4, can be replaced with diodes, Fig. 3. With diodes, efficiency is reduced for light loads. This is because mosfets acting as synchronous rectifiers in Fig. 2 can have a low forward voltage drop at low currents, unlike normal diodes.

In the diode version, the output capacitor can be removed and the circuit still operates. Ripple voltage increases, as expected, but the ripple frequency halves -

something not expected.

Investigating further, it appears that a minimum output capacitance is needed to pull the ripple voltage average of the first phase to the same level as the second phase. Simulation on *Tina* showed this effect. The minimum capacitance appears to be around 1/3 C1, although in tests the ripple current rating requires a minimum of 1/2 C1.

I also tried simulation on *Electronics Workbench V4*. Although the simulation ran, it did not give the correct waveforms using the same models as *Tina*. In these simulations, the mosfet switches were simply voltage-controlled switches with a series resistance to simulate mosfet on resistance. Doing this speeds up simulation considerably and is obviously acceptable with *Tina*.

Simplifying the switches in this way may explain why *Workbench* gave incorrect results, but I am unable to repeat the analyses with proper mosfets since I no longer have access to the software. Anyone interested in seeing the *Workbench* file can do so by sending an stamped, self-addressed envelope to *Electronics World's* editorial offices.

## Using an equivalent circuit

The equivalent circuit is useful for predicting output voltage, ripple voltage and efficiency of a converter. Figure 4 shows the equivalent circuit. The derivation is given in a separate panel. The voltage source is 1/2 Vin and there is a VD diode drop with a triangular ac ripple voltage (ΔVpp) superimposed on the output.

Ripple voltage is determined mainly by C1. Bear in mind that C1 supplies output current for both phases in this type of converter. Therefore is best to place most of the available capacitance at C1.

Finally, there is a series resistance of RDS(on) for the mosfet

## ESR of aluminium electrolytic capacitors

Losses in a capacitor are represented by an equivalent series resistance, or esr. Low esr is needed in switching power supplies. A low esr means low internal heating due to ripple current and low ripple voltage. It is common to parallel two or more small capacitors to give an esr lower than a single capacitor of the same total value.

Electrolytic losses vary with frequency and temperature. The graph shows the impedance of several aluminium electrolytic capacitors. At higher frequencies the capacitor becomes net inductive. Some capacitors have a flat region over one or two decades of frequency.

Minimum esr is also related to voltage and capacitance. In general, the same cans size fixes the esr and hence ripple current rating. This can be seen by scanning through the ripple current ratings for various capacitors of the same size within the same brand range.

For non-solid electrolytic capacitors reliability is related to

power loss (average  $P_{esr}$ ) and the ambient temperature.

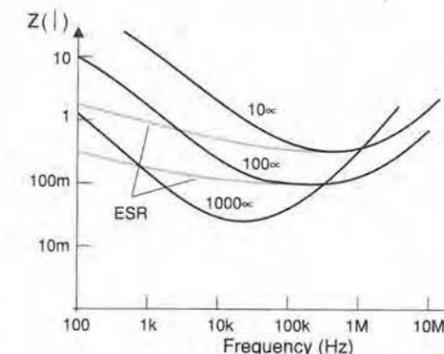
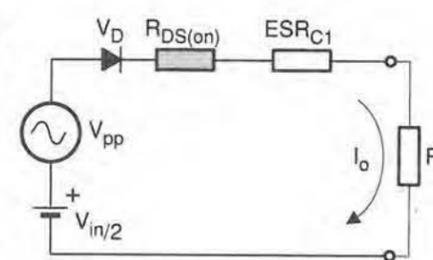
Philips' electrolytic capacitor data book 8 states that a 50% drop in reliability can be expected for each 10°C increase in temperature. Solid electrolytics are not degraded by temperature to the same extent and offer much longer life. Philips quotes a failure rate of 10<sup>-9</sup> hours for solid electrolytics compared to 10<sup>-6</sup> hours at a 60% confidence level for their non-solid electrolytics.

The company also gives an equation for calculating ripple current

$$I_R = \sqrt{\frac{P}{ESR}} = \sqrt{\frac{\alpha S(T_C - T_{amb})}{ESR}}$$

where  $I_R$  is the ripple current (A),  $P$  is heat dissipation (W),  $\alpha$  is the heat-transfer coefficient (W/m<sup>2</sup>/°C),  $S$  is surface area (m<sup>2</sup>),  $T_C$  is the case temperature (°C) and  $T_{amb}$  is the ambient temperature (°C).

Fig. 4. Equivalent circuit for Fig. 3, and curves showing the variation of impedance with frequency for various aluminium electrolytic capacitors.



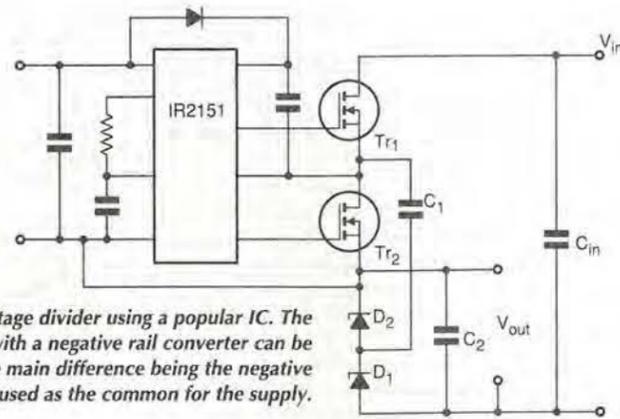


Fig. 5. Voltage divider using a popular IC. The similarity with a negative rail converter can be seen – the main difference being the negative rail is used as the common for the supply.

switches plus  $ESR_{C1}$ , as in the diagram in the panel. With significant dead time the losses must be increased according to the form factor.

**A 30 to 15V converter**

Figure 3 is a relatively easy circuit to implement. Test circuit Fig. 5 uses an IR2151 to drive two mosfets. Three 6.8µF, 20V tantalum capacitors measuring 7 by 5 by 4mm were paralleled for  $C_1$ . Each capacitor has an esr of 400mΩ at 100kHz. Two of these capacitors are used for the output  $C_2$ . The input capacitor consists of three 22µF, 50V YXB aluminium electrolytics. These allowed the circuit to deliver 5A continuously. The input voltage was adjusted to give 15V output, requiring 34.9V.

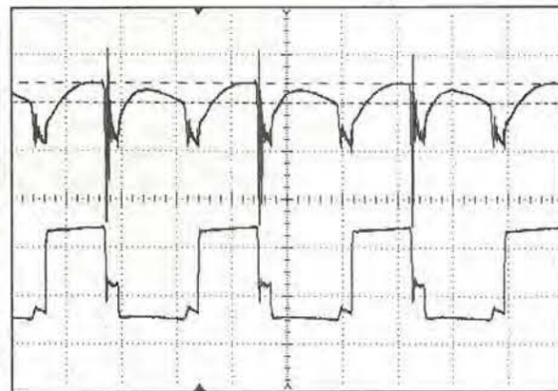
Efficiency is easily calculated by  $2 \times 15 / 34.9$ , giving 87% efficiency. This calculation is possible because the ratio of output current to input current is precisely 2, due to charge conservation and current used by the driver is negligible at full load.

Analysing losses, 2W is lost in diodes, 2W in capacitors, mainly  $C_1$ , and 4W in the mosfets. This gives a total of 8W for 75W output.

Figure 6, top trace, shows output ripple voltage with a 5A load: the average of this ripple is offset 15V above ground. The lower trace shows the voltage at the output of the mosfets feeding  $C_1$ . Note that the ripple frequency is twice the oscillator frequency.

Dead time can also be seen. It totals about 2µs which means about 40% more current is required causing 40% more ripple and losses. Current through  $C_1$  is 10A peak falling to 5A or 7.5A average. You may notice the similarity with a negative rail converter. The main difference is that the negative rail is used as the common for the supply.

Fig. 6. Ripple voltage (upper trace 1V/div) and the ac drive voltage to  $C_1$  (lower trace 10V/div) with a 5A load. Time base is 5µs/div. The ringing was traced to the driver. Adding gate damper resistors of 47Ω eliminates this ringing.



Due to the dead time, the ripple is increased by 50%. Increasing the frequency fails to reduce ripple because the dead time component remains constant. Adding a small 1µH inductor to form a low-pass filter between the load and output with a shunt capacitor across the load can reduce ripple to low levels if required.

The inductor used was removed from a 10A switching power supply output and measures 6mm dia. and 15mm long with five turns of 1.5mm wire. With a 220µF 200mΩ esr electrolytic the ripple was reduced by a factor of five with a 70kHz operating frequency. If the dead time could be reduced and the frequency increased to 150kHz the ripple would fall to around 10mV rms with this filter.

With 5A load, the tantalums ran at about 50°C, or about 35°C above ambient. Operating the converter at higher ambient temperatures, of say 50°C, the current would need to be halved. This means that ripple voltage would also be halved.

Another method for reducing ripple is by running two converters in parallel and clocking them 90° out of phase. This can reduce ripple by a factor of two – more with an LC filter – while also doubling the output current. This technique can also be applied when cascading two converters for higher step down ratios.

At about 1A per capacitor, this is a remarkably high power density. The chip inside measures only 3mm diameter and 3mm long, or 1/25th the volume of an aluminium capacitor of similar rating. These capacitors were removed from a computer pcb some time ago and I don't know where they can be sourced. However, similarly rated special polypyrrole ECG series electrolytics by Panasonic are readily available.

Later tests on an ECG 6.8µF/16V electrolytic revealed an esr of only 40mΩ – the data sheet quotes 0.4Ω maximum at 400kHz – and a minimum impedance at 2MHz. It appears some manufacturers are very conservative when it comes to esr values, possibly because there is a large spread in values. These ECG capacitors are rated at 1A at 105°C, but if they are sorted, most will run at higher currents. Although to make use of this capacity, the frequency needs to be closer to 1MHz.

I also tested a 4.7µF/16V multilayer ceramic in a 1206 package. Its capacitance measured on a dmm was only 3µF at 25°C and only 1µF at 1MHz. Minimum impedance occurred at 8MHz with an esr of 130mΩ. It uses Y5V dielectric and has a temperature coefficient of 1%/°C from 25°C which means the capacitance falls to 1/5th of its room temperature value when heated to 80°C. These Y5V capacitors are not practicable for converters that operate above 40°C.

**Comparison with buck**

Comparison with a conventional buck converter is a useful exercise. The L296 application note gives complete design details for a buck converter<sup>7</sup>. Equations for the value of the inductor and output ripple voltage are given below assuming the inductor ripple current is the usual 30% of the peak inductor current,

$$L = \frac{(V_i - V_o)V_o}{0.3 I_o f}$$

$$\Delta V_C = \frac{(V_i - V_o)V_o}{8V_i f^2 LC_o}$$

$$\Delta V_R = 0.3 I_o ESR_{C_o}$$

Note that the capacitor ripple voltage is made up of two parts. Since these components are in quadrature they should not be added algebraically, although, if one component dominates by more than three times, the other can be neglected, due to the nature of quadrature addition. For a 2:1 buck configura-

tion and  $V_i = 2V_o$  the inductance required and ripple voltages are,

$$L = \frac{V_o}{0.6 f I_o}$$

$$V_C = \frac{I_o}{24 f C_o}$$

$$\Delta V_R = 0.3 I_o ESR_{C_o}$$

Using the L296 as described in the application, the frequency is 100kHz and two 100µF and 150mΩ esr output capacitors are paralleled. When loaded at 4A the ripple voltage is calculated to be 90mV pk-pk and esr ripple dominates.

For the switching capacitor converter of Fig. 3 the ripple voltage is approximately,

$$\Delta V \approx \frac{I_o}{4C_1 f} \approx \frac{I_o}{3C_o f}$$

where  $C_2$  is  $2/3 C_o$  and  $C_1$  is  $1/3 C_o$ . The input capacitor is assumed to be the same in both cases. This equation comes from the equation  $I_C = C \Delta V / \Delta t$ , where the capacitor current pulse rate is  $2f$  and current and the ripple voltage across  $C_1$  is divided by two at the output and verified by measurements. It was also verified that there is no esr ripple component present – unlike the buck converter.

Using the same value of output capacitance as used in the L296 example, the output ripple at 4A is 60mV pk-pk compared to 90mV. However, since the capacitors used in this example are only carrying 1.2A of ripple current (0.3×4A) the capacitance required for the same temperature and same life must be three times higher for a third the esr. A plus for the switching capacitor converter is lower electromagnetic radiation, lighter and more compact. The buck scores high on being able to vary the ratio over a wide range efficiently and requires less components.

**Silicon utilisation**

The buck converter requires one transistor, minimally rated at  $V_{in}$  and  $I_o$  (average) plus a diode for the same  $V_{in}$  and  $I_o$ . A switching capacitor converter such as Fig. 3 requires two transistors, each minimally rated at  $1/2 V_{in}$  and  $I_o$ , plus two diodes each rated at  $1/2 V_{in}$  and  $I_o$ . This is twice the number of devices although the total switching capacity ( $V \times I$ ) is the same.

With more parts there is a cost penalty but it also helps to distribute heat and improves reliability. Distributing heat makes natural cooling easier which improves reliability. In many cases a fan can be avoided which is often the most unreliable component.

**Single converter divide-by-n**

A circuit for a 4:1 step down, Fig. 7, has appeared in this magazine<sup>9</sup> and more recently in another magazine<sup>10</sup>. In this arrangement four capacitors, labelled  $C_{1-4}$  on the circuit, are charged in series and later discharged in parallel. They operate as a Mosmarx<sup>11</sup> step down converter.

With this technique a 60V peak-to-peak input voltage can be stepped down to around 12V with an efficiency of around 75% using conventional diodes or around 90% with schottky diodes. Adding each extra stage in this circuit involves three additional diodes and one capacitor.

Figure 8 shows a modification that allows the step down ratio to be varied from 4:1 to 1:1 in 4 steps which is useful for regulation or power factor correction for off-line converters. A ratio of three for example is obtained when  $Tr_1$  is held on for both phases, bypassing  $C_1$  during the charge phase and therefore charging three capacitors in series rather than four.

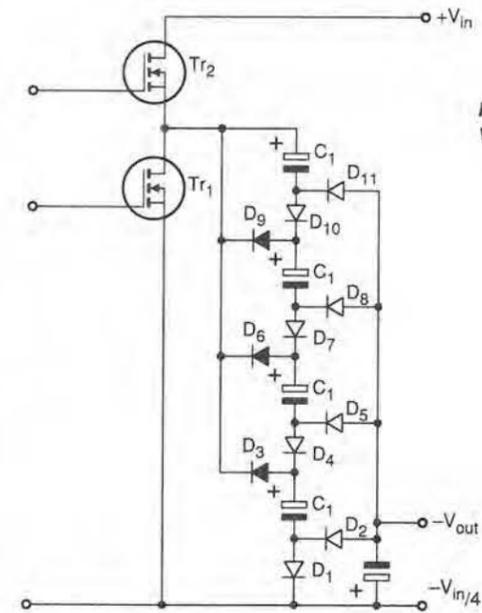


Fig. 7. This network converts  $V_{in}$  to negative  $1/4 V_{in}$ .

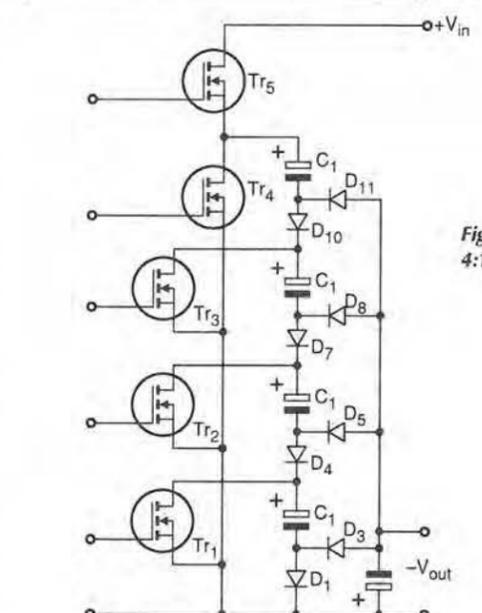


Fig. 8. Allows variable ratios of 4:1 to 1:1 in 4 steps.

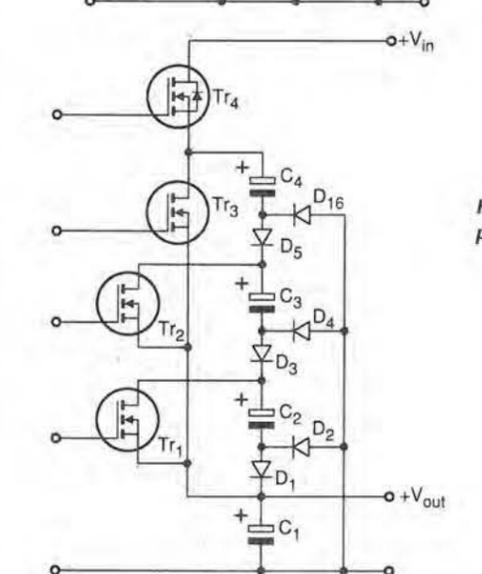


Fig. 9. Converts  $V_{in}$  to positive  $1/4 V_{in}$  with 4 steps.

If a low drop series regulator is added after the converter, the ripple can be removed and regulation over a wide range of input voltages is possible with high efficiency.

Figure 9 shows a non-inverting version. It uses two fewer diodes, one fewer transistor and one fewer capacitor. This makes it slightly more efficient. However, the transistors in a selectable ratio converter requires individual high side drive making driving more difficult.

So can the Cockcroft Walton multiplier be reversed for step down to give ratios higher than 2:1? Figure 10 shows how it can using mosfets on the improved version.<sup>12</sup> This allows the number of diodes to be reduced, improving efficiency.

Paralleling two dividers as in Fig. 11 reduces the ripple in the input current and allows much smaller input and output capacitors. Minimal dead time is required for best results.

### Equations for switching converters

Neglecting ac ripple component on  $C_1$  and the effect of energy loss from capacitor charge redistribution, the equations for steady state output are as follows. In all cases the output voltage is slightly lower due to charge redistribution losses<sup>4</sup> but appears to contribute only a few percent of losses since ripple is usually less than 10% of the dc voltage.

**Synchronous converter**, Fig. 2. All switches are mosfets with equal  $R_{DS(on)}$  since they carry the same peak current.

Charge phase,  

$$V_C = V_{in} - I_O(ESR + 2R_{DS(on)}) - V_{out} \quad (1)$$

Discharge phase,  

$$V_{out} = V_C - (ESR + 2R_{DS(on)})I_O \quad (2)$$

Substituting (2) into (1),  

$$V_C = V_{in} - I_O(ESR + 2R_{DS(on)}) - V_C - (ESR + 2R_{DS(on)})I_O$$

So,  

$$V_C = \frac{V_{in}}{2}$$

giving,  

$$V_{out} = \frac{V_{in}}{2} - (ESR + 2R_{DS(on)})I_O$$

**Single ended converter using diodes**, Fig. 3. Each diode has a forward drop  $V_D$  and ohmic resistance  $R_D$ .

Charge phase,  

$$V_C = V_{in} - I_O(ESR + R_{DS(on)} + R_D) - V_D - V_{out} \quad (3)$$

Discharge phase,  

$$V_{out} = V_C - I_O(ESR + R_{DS(on)} + R_D) - V_D \quad (4)$$

Substituting (4) into (3) also gives,  

$$V_C = \frac{V_{in}}{2}$$

hence,  

$$V_{out} = \frac{V_{in}}{2} - V_D - (ESR + R_{DS(on)})I_O$$

From this, the equivalent circuit of Fig. 4 can be drawn.

**Parallel converter**, Fig. 11. This circuit shares the output current with  $I_O/2$  through each stage giving,

$$V_{out} = \frac{V_{in}}{2} - \left(\frac{1}{2}ESR + R_{DS(on)}\right)I_O$$

### Converting from 30V down to 3V

This 30V to 15V converter gives valuable insights into the operation of a divide-by-two converter. At the time of writing, I had not tested the 30V to 3V converter, although a 24V to 12V synchronous rectifier version, as in Fig. 2, has been run, giving the target of 95% efficiency. To get this efficiency the output current is only a fraction of the mosfets current rating. The latest mosfets will improve this.

Philips now offers a 55V device in a TO220 package with an 8mΩ on resistance. Even lower resistance devices in smaller packages are likely soon.

Conversion from 30V to 3V requires a ratio of 10:1. This can be achieved a number of ways with dividers, either two divide-by-threes or three divide by twos. It appears that the  $V \times I$  capacity is about the same in both cases.

A practical converter requires regulation of the output voltage. If the input varies over a wide range it is not practical to use pulse modulation as mentioned.

Recent tests using a small inductor within a divider demonstrated efficient regulation over a 2:1 input voltage range. This allows the 30V input on the low voltage converter to

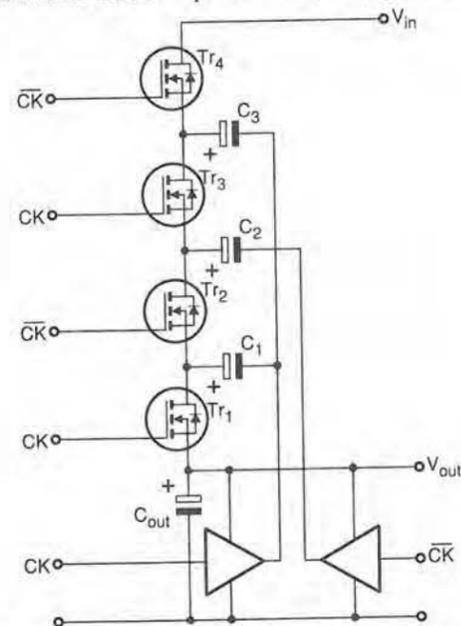


Fig. 10. Improved Cockcroft Walton multiplier can be reversed if diodes are swapped for mosfets.

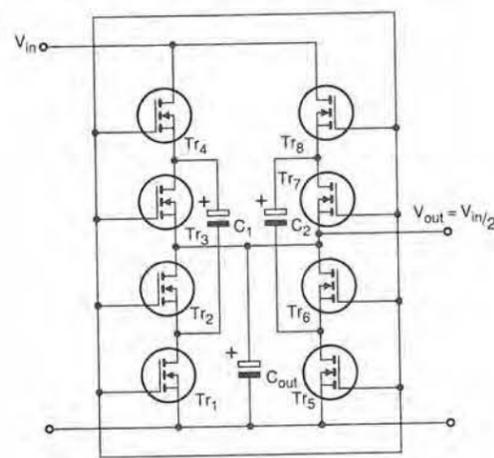


Fig. 11. Paralleling two dividers reduces the ripple in the input current and allows much smaller input and output capacitors. Minimal dead time is required for best results.

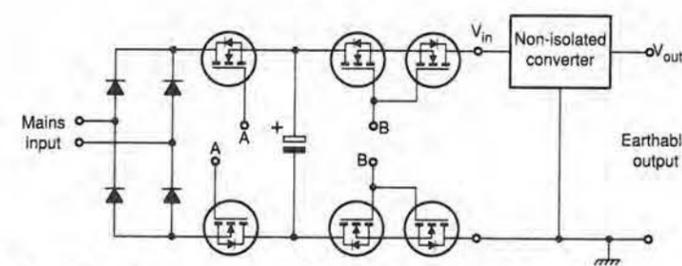


Fig. 12. The flying capacitor technique allows the normally floating output of a bridge rectifier to be connected to earth without damaging the circuit.

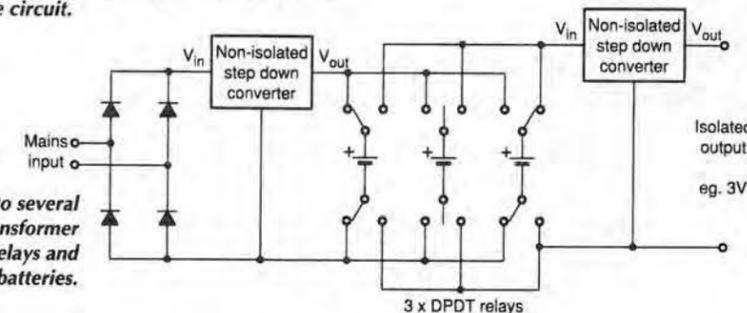


Fig. 13. Isolation to several kilovolts without a transformer is possible using three relays and switching batteries.

### \*Safety warning

When Ian speaks of mains isolation, this does not mean safety isolation. Device failure could result in a direct path between the mains live side and the converter's output. As a result, all parts of any such converter should be considered to be lethal, and never touched. Wiring regulations in your country should also be consulted before such a circuit is connected - Ed.

rise to 60V plus ripple filtering of the reservoir capacitor on this bus. I hope to present design details in a later article.

### Mains to 50V conversion

The preferred arrangement for the mains converter is the circuit in Fig. 9, but with eight stages.

This arrangement uses fewer components and it allows the ratio to be varied in small increments for voltage pre-regulation and power factor improvement. It does this by varying the ratio over the mains half cycle. Current flows over most of the cycle in a sinewave like fashion.

At 50V output, this converter can use standard diodes giving about 2V in 50V loss and an efficiency above 95%. This is well above the target of 85% for the mains converter discussed earlier. It should be possible to get 80% overall for mains to 3V without using unrealistic amounts of silicon.

### Isolating the output

The flying capacitor technique has been proposed as a way of 'isolating' the converter common from the mains<sup>13</sup>. Although this does not provide the same degree of isolation from the mains as a transformer it does allow the converter's low-voltage output common to be connected to an earth and it allows the mains to be rectified using a full-wave bridge rectifier.

Normally, the output of a bridge rectifier must be floating relative to the ac input terminals. The flying capacitor technique, Fig. 12, can be implemented with six mosfets or igbts switched at a high frequency.

Although this technique may be acceptable in some installations, it has safety limitations where people can touch the equipment being supplied. Even with a reliable earth leakage relay and the usual output over-voltage crowbar there are some people such as those with a pre-existing heart problem are at risk if exposed to a short duration mains shock while the earth leakage relay trips.

Using three batteries and three relays, Fig. 13, the output can be isolated to several kilovolts without a transformer,\* with uninterruptible power supply as a bonus. With a 30V intermediate bus, three 30V batteries can be rotated in sequence, one being charged from the mains converter while the second supplies the load. The third ensures no-break changeover. A cycle life of around a second allows small batteries to be used, while giving an acceptable relay life.

This can match transformer isolation given suitable relays and sufficient tracking clearance of circuit board tracks. The

batteries and their connections need to be suitably isolated from each other and the output side. Where the relays are exposed to humidity etc they must be protected or sealed.

### In summary

Hopefully I have demonstrated that it is not impracticable to use switched capacitor dividers to convert mains to 3V without a transformer - and do it efficiently without huge amounts of silicon.

Certainly the number of components is greater than a conventional switch-mode power supplies, but when power factor correction and distributed converters are added to a switch-mode psu, the component difference reduces. ■

Anyone interested in communicating with the author regarding the concepts described here can do so by contacting Electronics World's editorial offices.

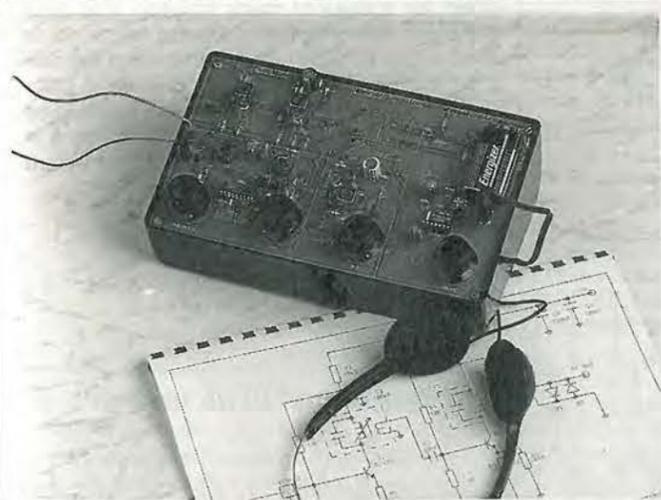
### References

- Hegglin, I, 'Stepping out', *Electronics World* October 1996, pp. 759-806.
- Small, CH, 'Distributed Power,' *EDN* April 28, 1994, pp. 54-64.
- 'Switch-mode psu technology runs at 1MHz,' *Electronics World+Wireless World*, January 1993, pp. 58-60.
- <http://www.maxim-ic.com>
- LMC7660/7669, National Semiconductor Linear Databook 1, 1988, pp. 1-271 to 1-279.
- High current inductorless switching regulator, Linear Application Handbook, 1987, p. AN3-15.
- Gattavari, G., 'Designing with the L296 monolithic power switching regulator,' AN244, SGS-Thompson Power Supply Application Manual, July 1985, pp. 93-128.
- Electrolytic capacitors solid and non-solid, Philips Data Handbook PA01, September 1988, p22.
- EDN Spotlight 'Diodes and capacitors imitate transformers' *Electronics World+Wireless World*, Sept 1991, p. 749.
- Petkov, P., 'Bridge Rectification Enhanced,' *Everyday with Practical Electronics*, July 1995, pp. 566-568.
- Donaldson, P. E. K., 'The Mosmarx Voltage Multiplier,' *Electronics & Wireless World*, August 1988, pp. 748-750.
- Ian Hickman, 'Multiplier lowers impedance,' *EDN*, 6 June 1991, p. 173.
- Novel Power Supply, *Electronics & Wireless World*, September 1988, p. 885.



# Radio Receiver Trainer

An Invaluable Learning and Design Tool for all Experimenters



The Radio Receiver Trainer contains nine receiver building blocks and a comprehensive training manual.

Simply connect the building blocks to build AM, SW, Superhet and Direct Conversion receivers. Decode SSB, CW & FM! Use proven building blocks to develop and test your own designs.

Full technical support and advice given.

Pricing: Complete £129.00  
 Kit £89.00  
 (Kit excludes case & headphones)  
 P&P is £5 (UK), £8 (EC), £12 (World)  
 Add 17.5% Vat to Total Price

Building Blocks: RF Input Tuner  
 RF Oscillator  
 Mixer  
 IF Filter  
 IF Amplifier  
 AM Detector  
 Beat Frequency Oscillator  
 Audio Filter  
 Audio Amplifier

The manual contains complete schematics and theory of operation of all the building blocks. Use this trainer to receive frequencies from 500KHz to 110MHz!

A set of proven alternate building block designs are included in the manual for you to get started with your own designs. There is no need to get your complete receiver design working all at once. Build and test each block one at a time.

Mail Order To: Pyramid Electronics Ltd.

204 Ferndale Road, Brixton, London SW9 8AG

Phone (0171) 738-4044

Fax (0171) 274-7997

Out of office ordering by answering machine.



CIRCLE NO. 121 ON REPLY CARD

## COMPONENTS & SYSTEMS FROM IOSIS



System Components from ISO9001 Source  
 Half Size Single Board Computers  
 386SX to Pentium with ISA and PC/104 Bus  
 2 Serial Ports, IDE, FDD & Printer Port  
 Flash/ROM Disc, Cache, SVGA CRT/Flat Panel Controller  
 PC/104 Modules  
 386 & 486 CPUs, Solid State Disc, Isolated RS232/485  
 VGA CRT/Flat Panel Display & SVGA Controllers  
 PCMCIA types I, II & III  
 Fast SCSI, Ethernet, Fax/Modem  
 System Enclosures with Passive Backplanes  
 System Integration and Support  
 All-In-One Standard Motherboards & Cases  
 486/586 to 200MHz Pentium

4 Somerville Rd, St Andrews  
 Bristol, BS7 9AA  
 Tel: 0117 924 9231  
 Fax: 0117 924 9233  
 Email: sales@iosis.co.uk



Details on our website . . . . . <http://www.iosis.co.uk>

CIRCLE NO. 122 ON REPLY CARD

## COLOMOR (ELECTRONICS) LTD.

Celebrating 30 years 1967 - 1997

Over 6,000 types of valves in stock. We also sell oil filled transformers, chokes, block filled capacitors, diodes, ICs, transistors, etc.

Set of RA17 Valves £29.50  
 Set of RA17L Valves £31.80  
 Set of AR88 Valves £32.25  
 AR88 and RA17L Spares—please send sae for list  
 Hewlett Packard Microwave Counter 5342A £1,292.50

**Racal Counters**  
 9904 Timer Counter 10HZ to 50MHZ £70.50  
 9913 Timer Counter 10HZ to 200MHZ £94.00  
 9914 Timer Counter 10HZ to 200MHZ £99.90  
 9915 Timer Counter 10HZ to 520MHZ £141.50  
 9916 Timer Counter 10HZ to 560MHZ £164.50  
 Philips Oscilloscope 3217, 50MHZ £352.50  
 Vartra Nicad Charger Type CC 306C, 14 hour timer, charge current 0-600mA £47.00

**Tubes**  
 DG732 - Mullard £11.75  
 DBM911 - GEC £23.50  
 Hewlett Packard CRT Stock No. 5083-1952, 4" x 5" rectangle £235  
 Magnetron M5028 £POA  
 Litton T.W.T. Type L3769 £POA  
 Oscilloscope Probe Kit X1 X10 switchable 15 & 60MHZ £14.10

All prices include VAT. Carriage extra - on application

170 Goldhawk Rd., London W12 8HJ  
 Tel: 0181 743 0899 Fax: 0181 749 3934  
 Email - giacomelli@colomor.demon.co.uk

CIRCLE NO. 123 ON REPLY CARD

ELECTRONICS WORLD September 1997

# ELECTRONICS WORLD

INCORPORATING WIRELESS WORLD

### Money back Guarantee.

Receive a full refund on your subscription within the first 90 days if you are not completely satisfied. Thereafter, we'll refund the unused portion of your subscription should you wish to cancel.

Electronics World incorporating Wireless World is applied electronic design. We'll show you how to use the latest silicon technology plus...

- ✓ CAE software
- ✓ New product reviews
- ✓ Technology reports
- ✓ Detailed circuit diagrams
- ✓ Innovations
- ✓ Explanations of complex technology
- ✓ Comment and much more in your issue.

So whether you are designing your own system or you're curious about your competitors, *Electronics World* will help you keep the leading edge.



# SAVE UP TO 10%

Guarantee your own personal copy each month

## Save on a 2 year subscription

ELECTRONICS WORLD  
INCORPORATING WIRELESS WORLD

Guarantee your own personal copy each month

## Save on a 2 year subscription

ELECTRONICS WORLD  
INCORPORATING WIRELESS WORLD

## ent order form

form to your newsagent to miss the next issue of EW.

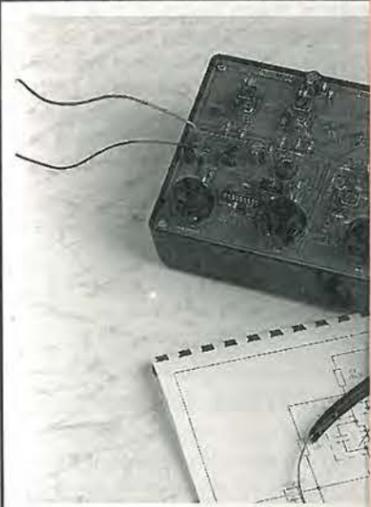
ne of Newsagent)

serve me the October *Electronics World*- on sale nber - and continue to y month's issue until rther notice

Thank you

# scribe day!

**NEW** **Ra**  
An Invaluable



The manual contains complete schematics of the building blocks. Use this trainer to get started with your complete receiver design work each block one at a time.

Mail Order To: Pyram  
204 Ferndale  
Phone (017

**COMPONENTS & FROM 10**



System Components from ISO9001 Source  
Half Size Single Board Computers  
386SX to Pentium with ISA and PC/104 Bus  
2 Serial Ports, IDE, FDD & Printer Port  
Flash/ROM Disc, Cache, SVGA CRT/Flat Panel Controller  
PC/104 Modules  
386 & 486 CPUs, Solid State Disc, Isolated RS232/485  
VGA CRT/Flat Panel Display & SVGA Controllers  
PCMCIA types I, II & III  
Fast SCSI, Ethernet, Fax/Modem  
System Enclosures with Passive Backplanes  
System Integration and Support  
All-In-One Standard Motherboards & Cases  
486/586 to 200MHz Pentium

1 Sommersville Rd., St Andrews  
Bristol, BS7 9AA  
Tel 0117 924 9231  
Fax 0117 924 9233  
Email: sales@iosis.co.uk



Details on our website . . . . . <http://www.iosis.co.uk>

EW97A

**Yes, I would like to subscribe to Electronics World incorporating Wireless World.**

1 Year  UK £32  Europe £46  Rest of world £56  
2 Years  UK £58 **SAVE 10%**  Europe £83 **SAVE 10%**  Rest of world £101 **SAVE 10%**

Name \_\_\_\_\_  
Job Title \_\_\_\_\_  
Company \_\_\_\_\_  
Address \_\_\_\_\_  
Post Code \_\_\_\_\_ Country \_\_\_\_\_ Internet Address \_\_\_\_\_  
Telephone \_\_\_\_\_ Fax \_\_\_\_\_

**THREE WAYS TO PAY**

1  I enclose a cheque made payable to **Electronics World incorporating Wireless World** for £ \_\_\_\_\_  
2  Please charge my Mastercard/Access/Visa/Diners Club/American Express (please delete appropriate card) with the sum of £ \_\_\_\_\_  
Card number \_\_\_\_\_ Expiry Date \_\_\_\_\_  
Signed \_\_\_\_\_ Date \_\_\_\_\_  
3  Please invoice me/my company. Purchase order number \_\_\_\_\_  
Company VAT registration number \_\_\_\_\_

Please allow 28 days for delivery of your first issue.  Please tick here if you do not wish to receive direct marketing promotions from other companies.

Post in the UK to Electronics World Subscriptions, FREEPOST RCC 2619, PO Box 302, Haywards Heath, RH16 3BR. Telephone 01444 445566  
Post from elsewhere to Electronics World Subscriptions, PHQ-D/1700/RH, PO Box 302, Haywards Heath, RH16 3BR, UK. Telephone +44 1444 445566

**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	151	152	153	154
155	156	157	158	159	160	161	162	163
164	165	166	167	168	169	170	171	172
173	174	175	176	177	178	179	180	181

Name \_\_\_\_\_  
Job title \_\_\_\_\_  
Company Address \_\_\_\_\_  
Telephone \_\_\_\_\_ **SEPTEMBER 1997**  
Only tick here if you do not wish to receive direct marketing promotions from other companies.

**Subscribe today!**

Guarantee your own personal copy each month

**Save on a 2 year subscription**

**ELECTRONICS WORLD**  
INCORPORATING WIRELESS WORLD

**Subscribe today!**

Guarantee your own personal copy each month

**Save on a 2 year subscription**

**ELECTRONICS WORLD**  
INCORPORATING WIRELESS WORLD

**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 October issue of *Electronics World* - on sale 4th September - and continue to order every month's issue until further notice

Name \_\_\_\_\_  
Address \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

Thank you



# CIRCUIT IDEAS

## Over £600 for a circuit idea?

### New awards scheme for circuit ideas

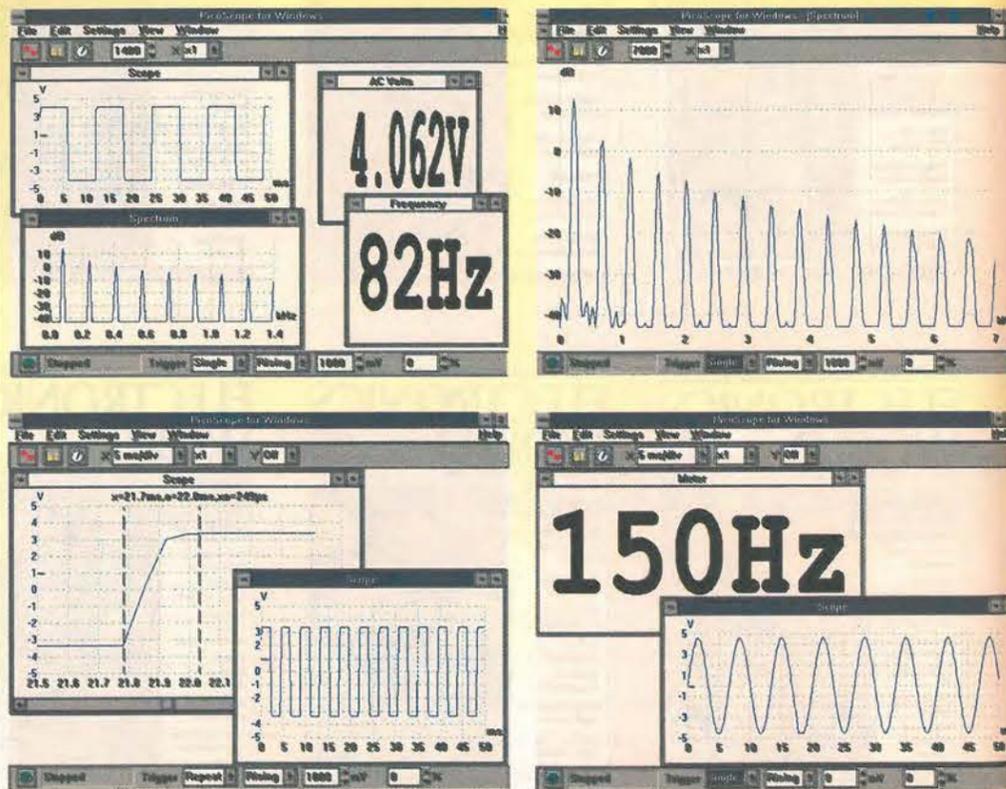
- Every circuit idea published in *Electronics World* receives £35.
- The pick of the month circuit idea receives a Pico Technology ADC42 – worth over £90 – in addition to £35.
- Once every six months, Pico Technology and *Electronics World* will select the best circuit idea published during the period and award the winner a Pico Technology ADC200-50 – worth £586.

### How to submit your ideas

The best ideas are the ones that save readers time or money, or that solve a problem in a better or more elegant way than existing circuits. We will also consider the odd solution looking for a problem – if it has a degree of ingenuity.

Your submission will be judged on its originality. This means that the idea should certainly not have been published before. Useful modifications to existing circuits will be considered though – provided that they are original.

Don't forget to say why you think your idea is worthy. We can accept anything from clear hand writing and hand-draw circuits on the back of an envelope. Type written text is better. But it helps us if the idea is on disk in a popular pc or Mac format. Include an ascii file and hard-copy drawing as a safety net and please label the disk with as much information as you can.



### Turn your PC into a high-performance virtual instrument in return for a circuit idea.

The ADC200-50 is a dual-channel 50MHz digital storage oscilloscope, a 25MHz spectrum analyser and a multimeter. Interfacing to a pc via its parallel port, ADC200-50 also offers non-volatile storage and hard-copy facilities. Windows and DOS virtual instrument software is included.

ADC42 is a low-cost, high-resolution a-to-d converter sampling to 12 bits at 20ksample/s. This single-channel converter benefits from all the instrumentation features of the ADC200-50.

## Three-phase over/under voltage detector

When the voltage of each phase of a three-phase supply is within limits set by the user, the supply is connected to the output; otherwise the output remains off. No relays or contactors are used; zero-crossing, optoisolated triac drivers control each phase.

Each phase is stepped down by an ordinary 12V, 100mA transformer, whose output is rectified, filtered and passed to a BB4115 window detector via the 5kΩ adjustment trimmer. Upper and lower limits  $V_{ut}$  and  $V_{lt}$  are set by the two trimmers on the output of the 7812 regulator. Depending on the outputs of the three window detectors and the following MOC 3012 optocouplers, the MOC3083 zero-crossing, optoisolated, triac drivers, the leds of which are in series, remain off or switch on. Switching logic is shown in the table.

The power circuit consists of three power triacs with optional snubbers, each driven by one of the MOC3083s.

At start-up, the two triac drivers that see zero voltage difference between two of the

phases switch on, followed by the third when its voltage approaches the sum of that in the phases already on. This ensures zero-current turn-on of all three load branches, whether arranged as star, Y or delta.

When all leds in the 3083 switch off, all three phases switch off when current in two of them falls below triac holding current, creating zero current; the third phase then switches off. Switch  $S_1$  controls the power circuit and an additional switch at the three-phase input might also be used. It might be useful to replace  $S_1$  by an optocoupler, driven by an external circuit such as a temperature controller.

Triacs used in this circuit are MAC223 10FP, rated for an off-state voltage of 800V, rms current 25A and peak surge 250A.

Fuse indicators shown illuminate red to show a blown fuse and green to indicate an intact one.

Porus M Mehta  
Maharashtra  
India

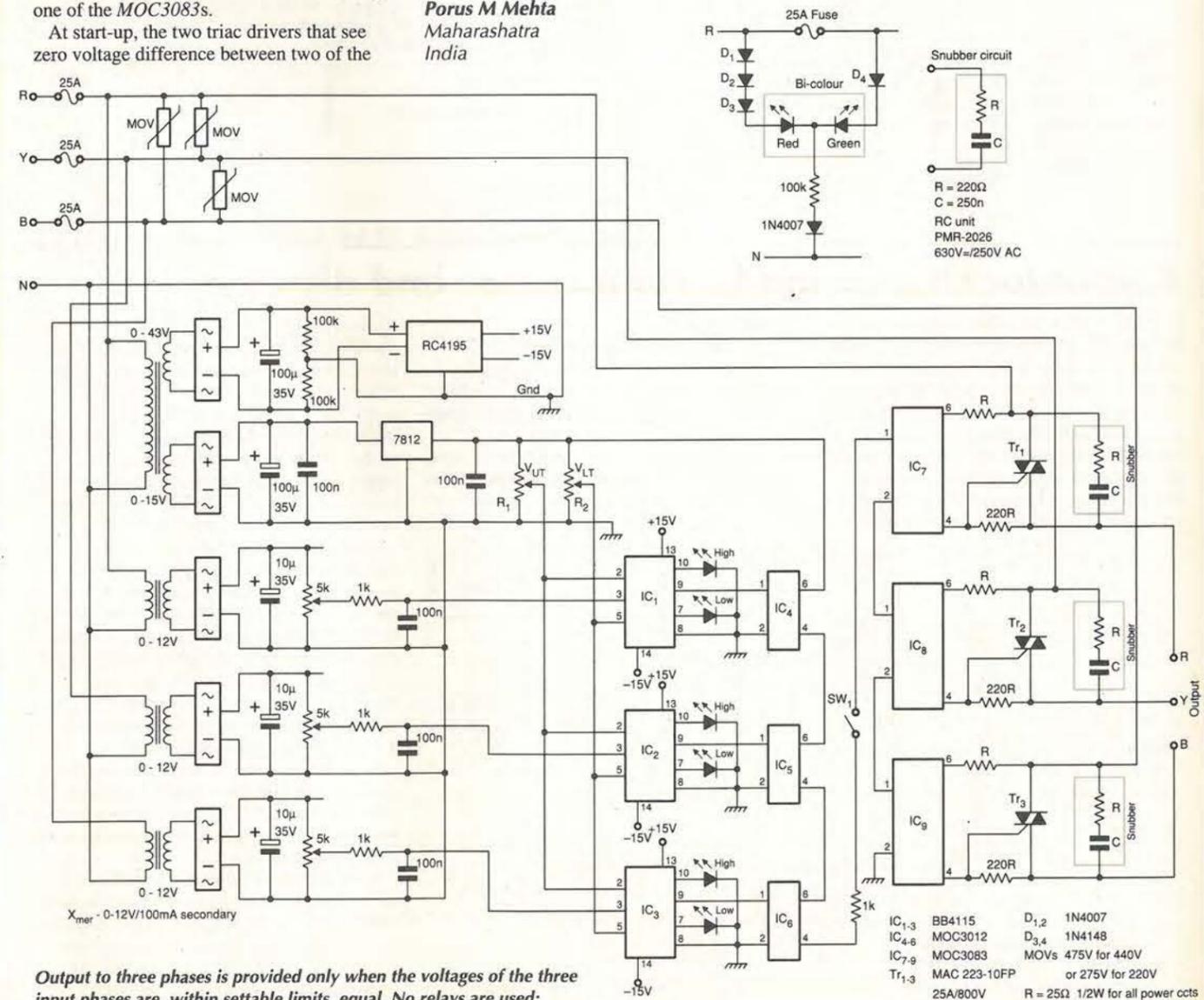
Logic table for the window comparator.

	$V_{in} > V_{ut}$	$V_{lt} < V_{in} < V_{ut}$	$V_{in} < V_{lt}$
High (red led)	on	off	off
Opto drive	off	on	on
Low (green)	off	off	on

$V_{ut}$ =upper threshold,  $V_{lt}$ =lower threshold.

### BB4115 is obsolete

Please note that although the idea is expressed here is sound, the Burr Brown BB4115 is obsolete. I could find a direct equivalent, but the AD1317 window comparator might be suitable, with circuit modifications. Alternatively, it may be possible to duplicate the function using two AD790 comparators. If any of you know of a more direct replacement, would you mind letting us know please? Ed.



Output to three phases is provided only when the voltages of the three input phases are, within settable limits, equal. No relays are used; instead, three triacs are driven by optoisolated zero-crossing detectors

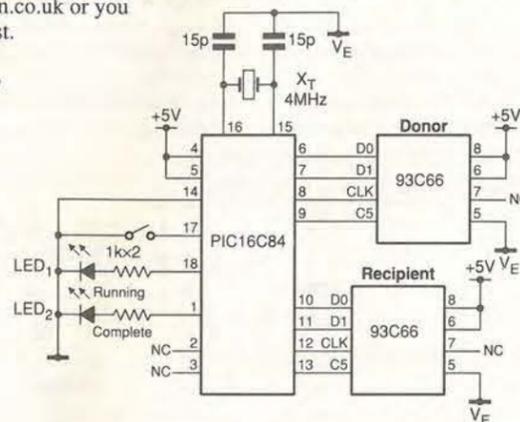
- IC<sub>1-3</sub> BB4115
- IC<sub>4-6</sub> MOC3012
- IC<sub>7-9</sub> MOC3083
- Tr<sub>1-3</sub> MAC 223-10FP
- D<sub>1,2</sub> 1N4007
- D<sub>3,4</sub> 1N4148
- MOVs 475V for 440V or 275V for 220V
- R = 25Ω 1/2W for all power ccts

## Eprom programmer/copier

Having previously used a pc-based method of programming eeproms, I produced this device to free the pc for other work. A donor microwire memory device is read by the circuit one byte at a time, the information then being programmed into a recipient, which is automatically erased when the process starts; all locations are written. Furthermore, instead of the manual input needed by the pc programmer, this only needs one four-second switch operation. You do, of course, have to make one donor using the pc or some other method; donors can be kept to guard against hiccups of the hard disk. Pressing the switch starts the programming operation, which halts on completion; led 1 flashes while programming is in operation and led 2 glows on completion; opening the switch primes the PIC16C84 for another run, but switch the power off when changing the recipient chip.

Opcode is shown here, but I can supply a 3.5in disk; my e-mail address is brian@briano.demon.co.uk or you can use ordinary post.  
**Brian Olliver**  
 12, Fountain Drive  
 St Georges  
 Telford TF2 9DP

Instead of tying up a pc, use this programmer with donor and recipient devices to program eeproms.



```

:100000004A280028861086110611000086158614DD
:10001000000006150000000061100348612861349
:100020000613000086178616000006170000000061
:10003000061300348A1406150000061C8A100611E7
:1000400000348D010830910003108D0D1A200D1021
:100050008A180D14910B252800348A1E3128861623
:100060003228861206170000061300341208910089
:100070008A12901B8A162D20900D910B382800347F
:10008000120891000A10901B0A142D20900D910B5C
:100090004228003401306500850111306600860178
:1000A0000518502885140E20023092000030900070
:1000B000362008309200C0309000362086130000B1
:1000C000B52000308C000220023092008030900079
:1000D0004020083092000C089000402021200D089C
:1000E000970021200D089800861183286E30960015
:1000F000000000000000000000000000960B7828BF
:10010000950B762800340E2002309200403090008B
:100110003620083092000C08900036201708900016
:10012000362018089000362086130A309500762075
:100130008C0F6328A728851005156430950076205C
:100140000511643095007620051850289C280E2053
:1001500002309200003090003620083092000030CB
:1001600090003620861300009B280E20023092005B
:100170000030900036200830920080309000362009
:0C018000861300003C309500762008003B
:00000001FF
    
```

## Calculator chip as maths coprocessor and display

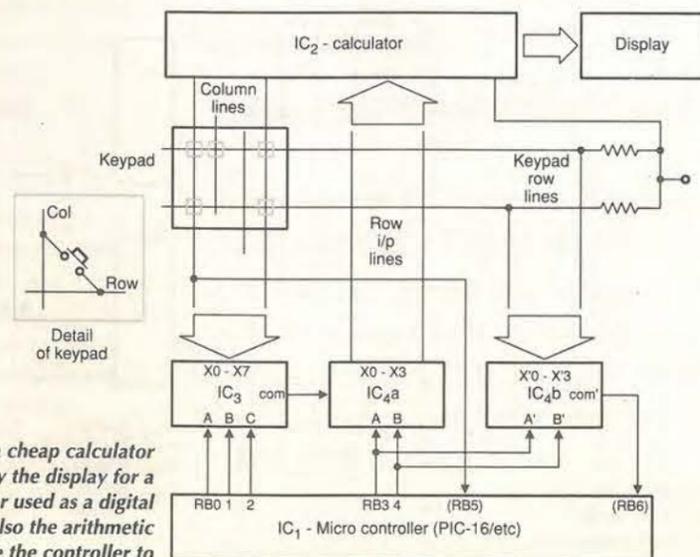
Using a cheap microcontroller can make digital instruments cost-effective in small numbers, but the cost of displays and their demands on the processor pose a problem. One solution to both problems is to use the ic and display from a cheap calculator as a combined coprocessor and display controller, all calculation and display functions then being carried out by this purpose-designed processor; the main microcontroller is then

left to pursue its own affairs. Calculator keypads are normally multiplexed and may be emulated from the microcontroller by monitoring column outputs and pulling the appropriate row input line high or low, depending on the calculator used. The diagram shows an alternative: two cmos analogue multiplexers, IC<sub>3,4</sub>, will simulate the keypad directly, simplifying the software interface and reducing the number of port

lines used. Only five lines, RB<sub>0-4</sub>, are needed for calculators using the 6 by 4 or 7 by 4 matrix. Since these lines are only used when writing to the coprocessor, they can be multiplexed for other purposes – possibly using the enable pin on IC<sub>3</sub> to disable display writes. An unused column address in IC<sub>3</sub> is otherwise used as a No-op command and each digit or operand entry is achieved by writing one five-byte to the display controller. As you can see from the diagram, the calculator keypad can be kept as a free control panel by using the spare 4:1 multiplexer in IC<sub>4</sub> and the extra port lines RB<sub>5,6</sub>. Selecting No-op on RB<sub>0,2</sub> and the row address on RB<sub>3,4</sub> allows RB<sub>6</sub> to be monitored for a pulse. If columns rise in sequence, the active key column can be determined from the time delay from the first column at RB<sub>5</sub>, or a priority encoder could be used to indicate a keystroke directly.

A variety of arithmetic functions is possible with eight-digit precision, even from cheap calculators; not only the basic functions, but with a little ingenuity, accumulation, average, delta and many others. You can measure the mains frequency accurately without long gate times by using a PIC16X in timer mode and the calculator to find the reciprocal. Functions not normally found in commercial counter-timers are percentage or frequency change; these can be performed easily using this method.

**Anthony New Bristol**



Innards of a cheap calculator provide not only the display for a microcontroller used as a digital instrument, but also the arithmetic functions to free the controller to

## High-current variable lipstick

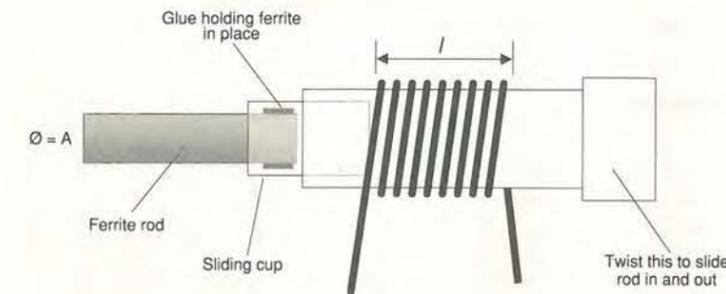
If you remove all the metallic parts – and the red part – of a lipstick applicator and substitute a ferrite rod for the lipstick, the result is the core of a variable inductor capable of carrying an alternating current of several amps. Maximum inductance is given by the standard formula:

$$L = \frac{n^2 A \mu_0 \mu_r}{l} \text{ henries}$$

and the minimum inductance approaches the value given when the relative permeability  $\mu_r=1$ .

Using the layout shown in the diagram with about 20 turns, inductance ranged from 4-20µH with my prototype.

**Name not supplied**  
 Edinburgh



Mechanics of a lipstick make a low-value variable inductor.

## Monitor RS-232 activity

Using only a moving-coil voltmeter, you can observe the average activity on an RS-232 link and easily detect oddities.

A centre-zero meter in voltmeter configuration with a suitable series resistor is simply connected between common and the line to be watched.

Since RS-232 transmission is in the form of two voltages with opposite polarity to indicate binary 0 or 1. If you assume one start and one stop bit, maximum usage will show on the meter, scaled for ±100%, as zero. Idling shows up as -50% to -100%, fairly busy as -20% to -20% and flat out as -20% to +20%. The region +20% to +50% means that something is not quite right. Anything over +50% indicates a probable fault.

Trim the series resistor to obtain a -100% reading for zero traffic.  
**Keith Wootten**  
 Reading

## Transconductance square rooter

In the simple circuit of Fig. 1, output signal  $V_o$  is the square root of input voltage  $V_i$ . The circuit is based on the quadratic law connecting  $I_D$  and  $V_{GS}$  in an enhancement mode mosfet,  $I_D=K(V_{GS}-V_T)^2$ . This may also be written  $V_{GS}=V_T+\sqrt{I_D/K}$ , where  $V_T$  is the threshold voltage and K is a constant depending on the physical parameters of the mosfet.

Together with  $Tr_1$ , op-amp  $A_1$  forms a voltage follower, so  $V_{R2}=V_i$ ,  $I_D=V_i/R_2$  and  $V_{GS}$ , which is buffered and referred to ground by a difference amplifier, is then  $V_T+\sqrt{(V_i/KR_2)}$ .

The second stage allows  $V_T$  to be subtracted, through  $RV_1$ , and it allows total gain to be adjusted through  $RV_2$ , in order to obtain  $V_o=\sqrt{V_i}$ .

To avoid thermal drift problems, the mosfet works close to the threshold voltage, with low values of  $I_D$ , where  $I_D=f(V_{GS})$  is exponential rather than quadratic. However, a good adherence to the root law can be obtained by iteratively adjusting  $RV_1$  and  $RV_2$ .

Figure 2 shows  $V_o$  versus  $V_i$  with an input range of 0 to 1V with a root function.

**Giorgio Delfitto**  
 University of Padova  
 Department of Physics  
 Istituto Nazionale per la Fisica  
 della Materia  
 Italy

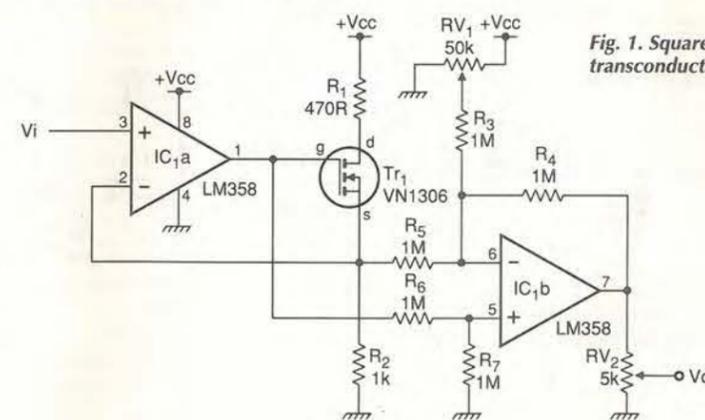


Fig. 1. Square rooting circuit based on transconductance.

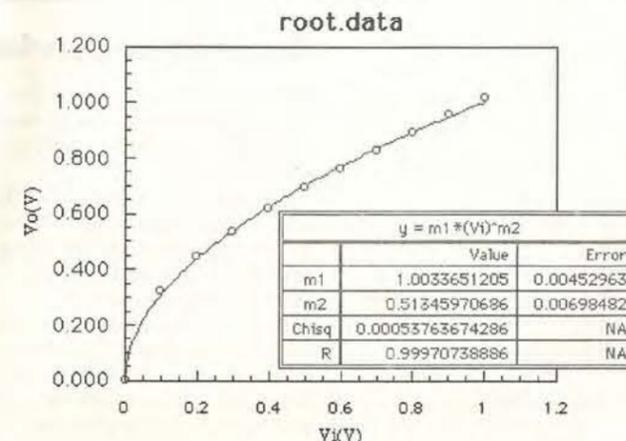


Fig. 2. Graph showing how voltage  $V_o$  closely approximates the square root of  $V_i$ .

# Higher-order elliptic filter design

High-speed, current-feedback op-amps such as the Burr-Brown OPA603 make it possible to design active filters working in the megahertz range of frequencies. Presented here is a quick method of calculating elliptic filters of any order, the example shown being a fifth-order type which is considered as being in two sections, as shown in Fig. 1.

Assume the poles  $s = \alpha + j\beta$  and zeros  $\Omega$  are given for a filter having the reflection factor of  $\rho$  and modulus  $\alpha_0$ .

Design can proceed in three steps. Assume  $\rho = 20\%$  and  $\alpha_0 = 20^\circ$ :

$$\begin{aligned} \Omega_2 &= 3.0653 & s_{1,2} &= 0.382271 \pm j0.67123 \\ \Omega_4 &= 4.8753 & s_3 &= \gamma = 0.49308 \\ & & s_{4,5} &= 0.13647 \pm j1.05129 \end{aligned}$$

1. If you calculate the constants  $A_1$  and  $A_2$  using the expressions,

$$A_1 = 2\alpha A_2 \text{ and } A_2 = 1/(\alpha^2 + \beta^2), \text{ then for a third-order filter,}$$

$$A_2 = 1.6759379 \text{ and } A_1 = 1.2813249$$

and for a second-order filter,

$$A_2 = 0.88918 \text{ and } A_1 = 0.242865.$$

2. Calculate normalised capacitances using the expressions in Fig. 1.

3rd-order

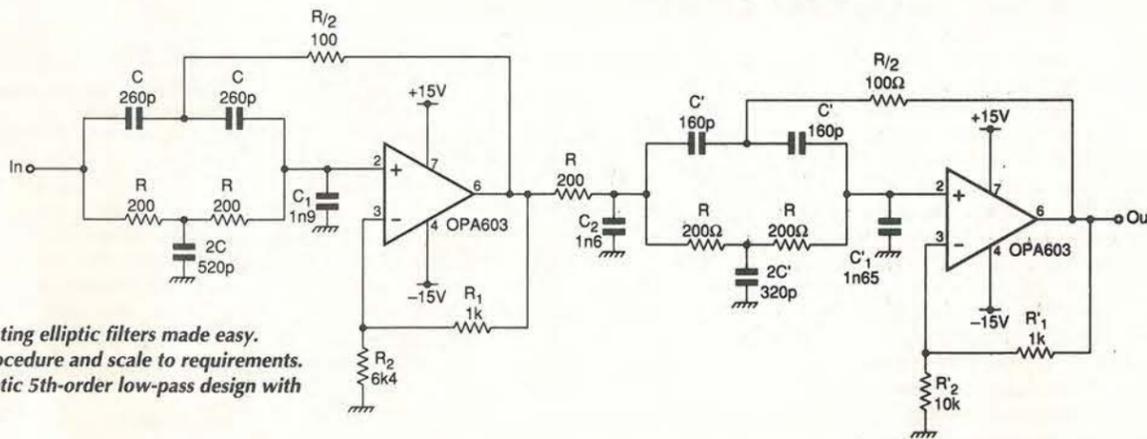


Fig. 2. Calculating elliptic filters made easy. Follow the procedure and scale to requirements. This is an elliptic 5th-order low-pass design with 1MHz cut-off.

$$\begin{aligned} c &= 1/\Omega_2 = 0.326232 \\ c_1 &= 2.40551 \\ c_2 &= 2.02807 \\ k &= 0.134956 \end{aligned}$$

and for a second-order filter,

$$\begin{aligned} c' &= 1/\Omega_4 = 0.205116 \\ c'_1 &= 2.06648 \\ k' &= 0.087087. \end{aligned}$$

3. For physical capacitance values, multiply the above  $c$  values by a factor of  $1/2\pi f_0 R$ , where  $f_0$  is the cut-off frequency and  $R$  the reference resistance. In the case shown here,  $f_0 = 1\text{MHz}$  and  $R = 200\Omega$ .

**Kamil Kraus**  
Rokycany  
Czech Republic

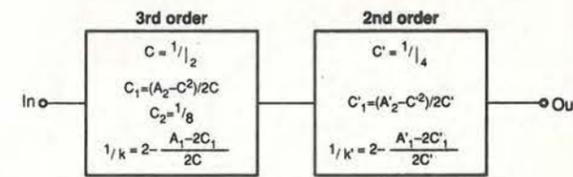
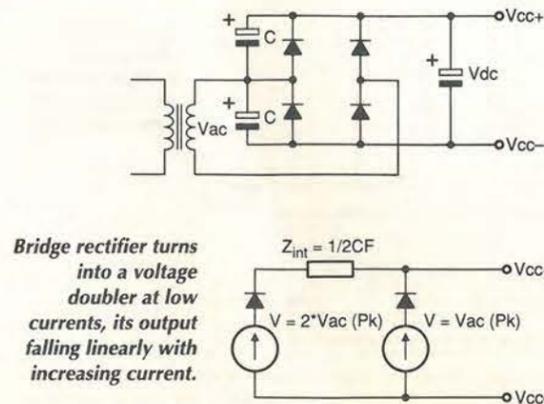


Fig. 1. Decomposition into third and second-order sections and formulas.



Bridge rectifier turns into a voltage doubler at low currents, its output falling linearly with increasing current.

## Current-dependent rectifier or doubler

This bridge rectifier becomes a voltage doubler at low currents, reverting to normality when current drain increases.

It is essentially a bridge rectifier with the extra capacitors  $C$ . When no current is taken, output voltage is twice that at the input and, as current increases, internal impedance causes the output to fall linearly according to  $Z_{int} = 1/(2Cf)$ , assuming ideal components, until the output voltage equals the peak ac, when the circuit becomes an

ordinary bridge rectifier.

An application is as a rectifier for lead-acid battery charging, in which a high voltage (25-30V) is needed to drive a small current into a 12V battery that has been discharged for a period and has an isolating layer on the electrodes. As current increases, a lower output from the rectifier reduces dissipation in the charger's output transistor.

**Albert Pijuan**  
Girona  
Catalonia

# Frugal buzzer

Four components make this very simple buzzer. Some n-p-n transistors oscillate at audio and low ultrasonic frequencies when polarity is reversed. Lowest working voltage depends on power rating, but it is about 7-8V for devices such as the BC109, BC337 and BC238, 12V for the BD139 and around 16V for power transistors 2N6543 and BUX22.

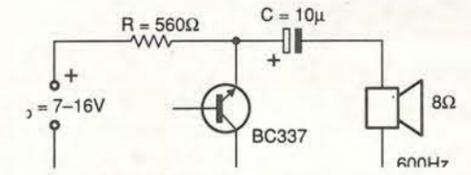
Oscillation frequency for the circuit shown is given by the empirical

equation

$$f = (V_b - 5.5)/RC$$

and is constant for devices of the same type. Power requirements are 5mA at 9V, 10mA at 12V; increasing  $R$  and decreasing  $C$  reduces power drain and also sound output. Higher voltage supplies can be used with increased values of  $R$ .

**D Di Mario**  
Milan  
Italy



Buzzer using reversed-polarity transistor as oscillator. Since the base is left open, it could be used to gate the buzzer.

# 10pF-10μF capacitance meter

A very simple circuit using a 555 timer and a few passive components forms a capacitance meter measuring full-scale ranges of 100pF-10μF.

Figure 1 shows the meter circuit, in which the 555 is connected as a free-running multivibrator, the frequency of the output rectangular wave being determined by

$$f = 1/T = 1.44/(R_A + 2R_B)C,$$

and

$$D = R_B/R_A + 2R_B,$$

$T$  being the period and  $D$  the duty cycle, which is made asymmetrical by setting  $R_A = R_B$ , since charging through the meter takes longer than discharging via the diode.

Unknown capacitors connect points A and B and C takes the form of six components selected by the switch in Fig. 2. If  $V$  is the amplitude of the 555 output, current through the meter is  $I = VCf$ , capacitance being therefore proportional to current for a constant

frequency. The table shows the ranges and frequencies for a 10V supply. Without the damping components  $R_{1,2}, C_1$ , the meter bounces a little on the highest range, since the frequency is 1Hz; at higher frequencies it is steady.

The charge-pump power supply shown in Fig. 3 also uses a 555 to double the input voltage and produce a 10V output, filtered sufficiently by  $C_3$ . A regulated supply would give better stability.

Calibration in the original was by the use of known capacitors, adjustment being by the trimmer for one range.

**Raj K Gorkhali**  
Kathmandu  
Nepal

Fig. 3. Another 555 forms the power supply, a charge-pump voltage doubler to give 10V from the 6V supply.

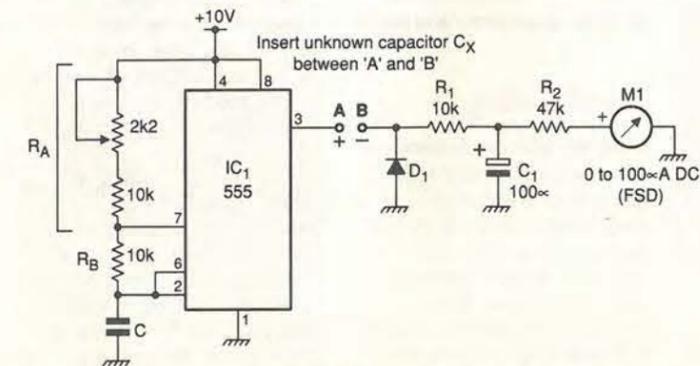


Fig. 1. Linear, direct-reading capacitance meter for values of 10pF-10μF.

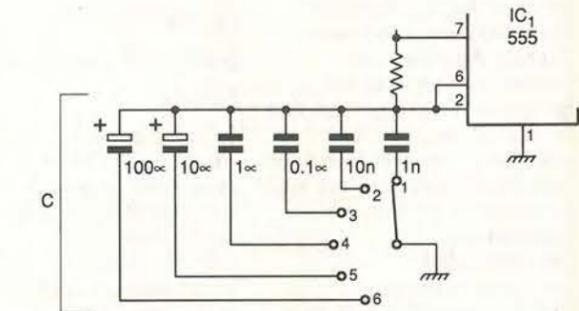
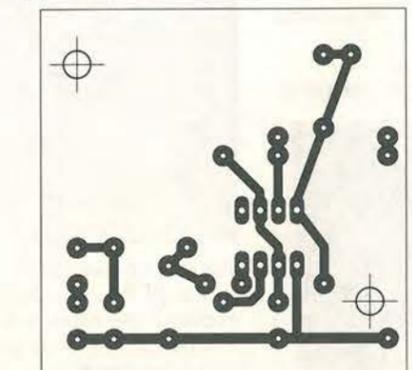
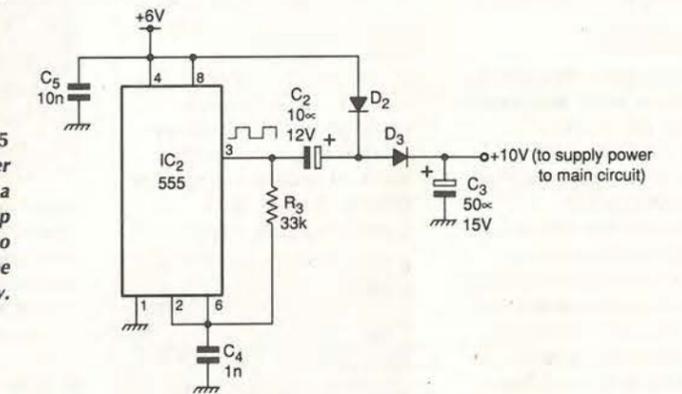
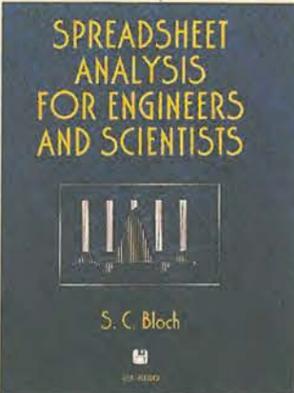


Fig. 2. Range-selection switch.

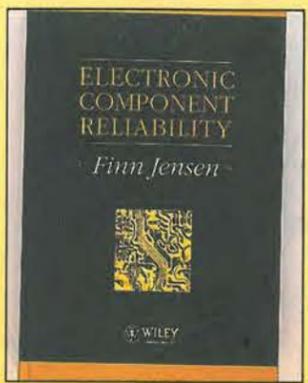


BOOKS TO BUY BOOKS TO BUY BOOKS TO BUY



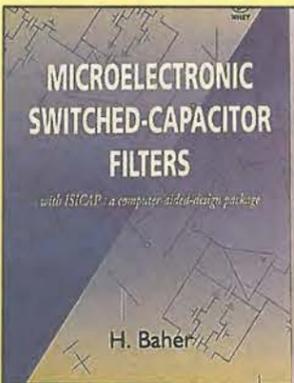
**Spreadsheet Analysis for Engineers and Scientists**  
 With this practical, hands-on guide, engineers and researchers learn, quickly and easily, the latest and most useful electronic spreadsheet methods. Using a variety of interactive techniques, including worksheets, self-test and practical programs on the included disk, *Spreadsheet Analysis for Engineers and Scientists* show you how to harness the power and versatility of spreadsheet programs, including those that contain the fast Fourier transform, complex operations and Bessel functions, and how to customise your own applications.  
**Includes disk**  
 0471 126837, 336pp  
 UK £37.50, Europe £39.50, ROW £49.50

**Electronic Component Reliability**  
*Fundamentals, Modelling, Evaluation and Assurance*  
 This text approaches the quality and reliability of electronic components from a unique standpoint. Traditionally the twin subjects of reliability physics and reliability statistics have been treated as separate entities. Here, the author examines both areas and reveals how components fail and how failures develop over a period of time.  
 0471 952966, 374pp  
 UK £50.50, Europe £53.50, ROW £66.50



**Fuzzy Logic Implementations and Applications**  
 Offering a new perspective on a growing field, this text explores the many hardware implications of fuzzy logic based circuits. As use of AI increases, so the VLSI area of circuits is becoming a growth subject. Opening with an overview of fuzzy sets and fuzzy logic the book moves on to cover a range of non-standard solutions for fuzzy logic VLSI circuits. Future trends, new concepts and ideas are all examined and supported with practical examples from the author's research.  
 ISBN 0471 950599, approx 346pp,  
 UK £50.50, Europe £53.50, ROW £66.50

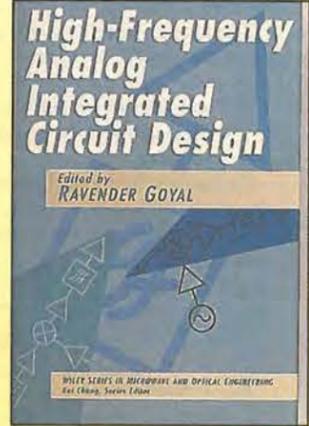
**Microelectronic Switched-Capacitor Filters**  
 Switched-capacitor filters and associated MOS integrated circuits are now an established technology finding applications in the telecommunications and instrumentation fields. With unrivalled breadth of coverage, this book surveys the design techniques of an important class of analogue signal processing systems. An accompanying diskette containing a comprehensive computer-aided design package (ISICAP) enables readers to gain a greater depth of understanding of the described techniques. Containing both source code



files and an executable version of the main design package, this alone will be an indispensable tool for many circuit designers.  
**Includes disk**  
 0471 954047 384pp  
 UK £75.50, Europe £79.00, ROW £92.00

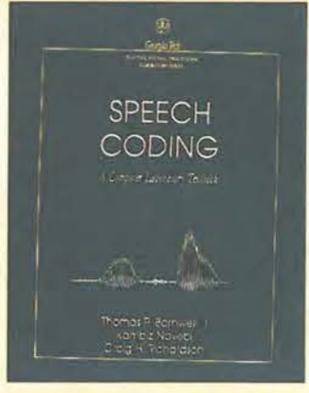
**The I<sup>2</sup>C Bus From theory to Practice**  
 With a special emphasis on the I<sup>2</sup>C Bus, this guidebook through the world of micro controller-managed serial buses presents comprehensive coverage of the theory necessary to design the best possible communications bus for any particular application. The book examines typical industrial and consumer applications and enables the reader to design effectively in a real-world environment. A disk containing software for the I<sup>2</sup>C bus is also included.  
**Includes disk**  
 0471 96268 6, 314pp  
 UK £54.50, Europe £56.50, ROW £65.00

**High Frequency Analog Integrated Circuits**  
 As one of the first textbooks to discuss integrated circuit design considerations and



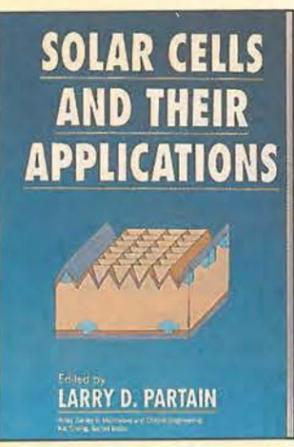
actual designs from the basic concepts, this title provides a solid background in designing basic circuits, advanced circuits and synthesis techniques.  
 0471 530433 424pp  
 UK £80.00, Europe £83.00, ROW £95.00

**Speech Coding A Computing Laboratory Textbook**  
 This is one of the first lab manuals with software dedicated exclusively to speech processing and coding. It takes advantage of the development of the personal computer by making this technology accessible to a wider audience. The manual and Dos based software together create a user-friendly digital signal processing lab which allows the user to



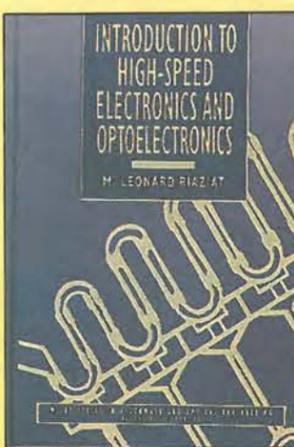
perform a wide variety of speech coding and speech processing experiments. The text presents and explains a set of basic speech coders analytically and in terms of the specific parameters controlling each coder. The manual leads the student through the experimental process of understanding how speech coders work and sound via over 70 exercises and projects. The class-tested menu-driven, Dos-based software can be operated by students with little or no training.  
**Includes disks**  
 0471 516929, 194pp,  
 UK £28.95, Europe £30.95, ROW £36.95

**Solar Cells and their Applications**  
 The past decade has witnessed numerous important breakthroughs in solar cell technology, many of which have occurred in just the past few years. Far cheaper to produce and maintain, exhibiting a longer lifetime, and considerably more efficient than ever before, solar cells are, at last, in a position to compete with traditional technologies for both small and large-scale energy conversion applications. Including contributions from some of the world's leading experts in the field, this book reports the most important recent advances in solar cell technology. From in-depth discussions of breakthroughs in cell, module, and system technologies to a probing look at important environmental, health, and safety issues in the photovoltaic industry, it covers a broad range of topics of vital interest to solar cell researchers, power systems designers, and all those with professional interest in current and future capabilities of this important technology. Offers a detailed look at cutting-edge solar technology from an international team



of researchers. Covers silicon, GaAs, InP, CdTe, a-Si:H, CuInSe<sub>2</sub> and GaSb solar cells, cells, concentrators, multijunction cell configurations, space cells, and more. Describes a wide range of applications - from space cells to terrestrial systems. Provides an informal look ahead at the future of solar cell technology.  
 0471 574201, 596pp,  
 UK £71.50, Europe £75.00, ROW £92.00

**Introduction to High-Speed Electronics and Optoelectronics**  
 Lasers, fibre optics, and high-speed optical systems share many concepts with microwave devices. Furthermore, semiconductor-based optoelectronics and microwave integrated circuits share evolving process technologies. It is only natural, therefore, that students of optoelectronics be introduced to high-speed concepts in a unified manner. This highly practical intensive introduction enables electrical engineers, applied physicists, and students to develop and identify tools for understanding, analysis, design, and characterisation of high speed components. Broad in scope, this unique



text/reference examines the complementary nature of electronics and optics and emphasizes high-speed technology in which the two fields are less differentiated. Beginning with an overview that develops a perspective and appreciation of analog high-speed technology in general, the book goes on to cover devices and circuits used at microwave and millimeter-wave frequencies, optical components, and optoelectronic integrated circuits and subsystems. Particular attention is paid to applications in the area of high levels of interest in this area and because many of the concepts are applicable in other fields. The book concludes with important coverage of the often-overlooked area of measurement and characterization of high-speed devices. Fully referenced and supplemented with hundreds of helpful illustrations, *Introduction to High-Speed Electronics and Optoelectronics* is equally useful as a professional reference or a textbook for senior undergraduate and first-year graduate courses.  
 0471 015822, 312pp,  
 UK £65.00, Europe £67.00, ROW £77.00

**Risc Systems and Applications**  
 Professor Daniel Tabak has completely revised and updated his two previous books on Reduced Instruction Set Computer architecture to produce this new book, RISC Systems and Applications. The text is a unique, concentrated, detailed description of the architecture and implementation of most recent high-performance RISC systems, such as DEC Alpha AXP21164, IBM/Motorola/Apple PowerPC 620, Sun Microsystems and Texas Instruments UltraSPARC and SuperSPARC, MIPS technologies R10000, Intel i860 XP, Motorola MC88110, Hewlett-Packard PA-7100/8000 and the transputer. It also includes details of pioneering devices such as Berkeley's RISC II and Stanford's MIPS and multiprocessor, real-time and workstation systems.  
 ISBN 0863 801889, 452pp,  
 UK £50.50, Europe £54.00, ROW £67.00

**All prices are fully inclusive of packing and delivery**

**Return to Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS**

Please supply the following titles:

Qty	Title or ISBN	Price

\*\* All prices on these pages include delivery and package \*\*

Total \_\_\_\_\_

Name \_\_\_\_\_

Address \_\_\_\_\_

Postcode \_\_\_\_\_ Telephone \_\_\_\_\_

Method of payment (please circle)

Access/Mastercard/Visa/Cheque/PO

**Cheques should be made payable to Reed Business Publishing**

Credit card no \_\_\_\_\_

Card expiry date \_\_\_\_\_

Signed \_\_\_\_\_

**Please allow up to 28 days for delivery**



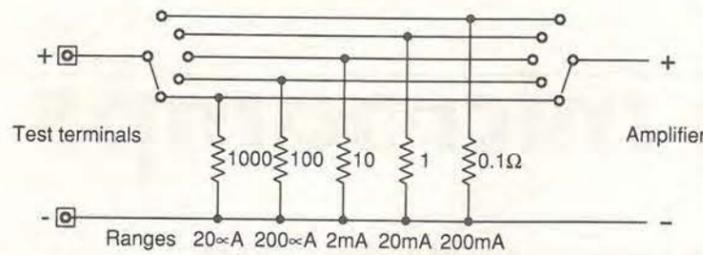


Fig. 2. Millimeter shunt switching involves doubling up on the contacts to minimise effects of contact resistance.

pushed beyond its maximum input limits by the unwanted alternating signal. This is an important reason for including some signal amplitude limitation. The 100nF capacitors provide useful rejection of higher frequencies.

In Fig. 1, there appears to be no circuitry defining the vital 'common' rail potential for the amplifier input circuit. Since the panel meter section is completely inside the same box as the amplifier and uses the same battery supply, the meter must be allowed to set the level of its own input reference potential. This then becomes the common reference potential for the amplifier and the whole instrument. The reference potential is about 60% of the meter's positive supply voltage - a little too high to allow the very best performance from the op-amp. So although not absolutely necessary, the addition of one cheap AA dry cell, to raise the amplifier supply voltage above that for the meter, is a refinement worth the extra inconvenience.

**Details and options**

If the amplifier circuit is used to drive the 200mV range of a separate multimeter with its own battery, instead of the built in panel meter, then some changes should be made. The 1.5V cell is no longer necessary, but the remaining 9V supply for the amplifier requires splitting in half to provide a reference potential. Use two equal resistors, 47kΩ, one across each of the 47µF capacitors for example.

Also, some existing multimeters have an input resistance as low as 100kΩ on the 200mV range. If such an external instrument is used instead of the internal panel meter, the protection circuit between the amplifier output and the multimeter would cause an unacceptable loss in output voltage. As a result, the protection circuitry should be omitted.

Shunt switching for the five current ranges: 20µA, 200µA, 2mA, 20mA, 200mA, involves two switch wafers, each an 11-way make-before-break rotary switch. The six spare positions are wired with a short circuit in place of a shunt. This option of 11, rather than 5 switch positions is not shown in Fig. 2 but is strongly recommended. It conveniently enables the meter to be switched safely and quickly away from any sudden or unexpected large current, without interrupting the circuit under test.

A third switch wafer can be added to select the decimal point display of the internal panel meter. This merely completes a connection to one of three points, labelled P1, P2, P3. Note that in the samples I tried, these were in the

opposite sequence to that suggested in the accompanying leaflet.

If the 11-way option is chosen then this third switch wafer can also be of the same kind as the others, but if only a 5-way switch is used, the decimal point wafer alone, should be break-before-make.

Useful additional protection would be a further pair of back-to-back diodes, wired across the feedback resistor  $R_2$ . I tried this, but rejected it because in a very warm room, the diode forward current was just beginning to upset indications near full scale. To make such a scheme satisfactory would need four diodes, two in series in each direction.

To keep the overall cost very low, all resistors used were metal film types with 1% tolerance. Thus the overall uncertainty limit could, at worst, reach just over 3% plus 0.5% for the meter. The shunts contribute only 1% to the overall uncertainty limit and are cheap enough to be expendable in an accident.

A further 2% depends upon the resistors  $R_1$  to  $R_4$ . If these four resistors are upgraded to 0.1% tolerance, their overall contribution to uncertainty will fall to 0.2% and this is certainly worth considering.

**Digital panel meter for just £8.95**

Incorporating the ICL7106 a-to-d converter, the PM128 digital panel meter has a full-scale input sensitivity of 200mV and a high input impedance of >100MΩ.

Its normal selling price is £12.95 - excluding VAT and postage. Vann Draper has decided to repeat the special offer price for this meter of £8.95 - fully inclusive of postage, packing and VAT - or even less in quantities above four off until 28 November (see January 1997 issue for full details of the meter).

Simply send the coupon below from Vann Draper Electronics at Unit 5, Premier Works, Canal Street, South Wigston, Leicester LE18 2PL, fax 0116 2773945 or tel. 0116 2771400.

=====

Please send me

..... PM-128 digital panel meter(s)

at the fully inclusive special offer price of £8.95 each for quantities up to 4 off £8.65 each for quantities of 5 or more or £8.35 each for 10 or more quantities

for which I enclose a total of £.....

Name

Company (if any)

Address

Phone number/fax

Make cheques payable to Vann Draper Electronics Ltd Or, please debit my Master, Visa or Access card.

Card type (Access/Visa)

Card No

Expiry date

Please mail this coupon to Vann Draper Electronics, together with payment. Alternatively fax credit card details with order on 0116 2773945 or telephone on 0116 2771400. Address orders and all correspondence relating to this order to Vann Draper Electronics at Unit 5, Premier Works, Canal Street, South Wigston, Leicester LE18 2PL. Overseas readers can also obtain this discount but details vary according to country. Please ring, write or fax to Vann Draper Electronics.

**SMALL SELECTION ONLY LISTED - EXPORT TRADE AND QUANTITY DISCOUNTS - RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK**

- HP New Colour Spectrum Analysers
- HP141T + 8552B IF + 8553B RF - 1KHz-110Mc/s - £700.
- HP141T + 8552B IF + 8554B RF - 100KHz-1250Mc/s - £900.
- HP141T + 8552B IF + 8556A RF - 20Hz-300KHz - £700.
- Special Offer just in from MOD Qty 40 HP8555A RF Units 10Mc/s - 18GHz.S.
- HP141T + 8552B IF + 8555A 10Mc/s-18GHz.S - £1200.
- HP ANZ Units Available separately - New Colours - Tested
- HP141T Mainframe - £350.
- HP8552B IF - £300.
- HP8553B RF 1KHz to 110Mc/s - £200.
- HP8554B RF 100KHz to 1250Mc/s - £500.
- HP8555A RF 10Mc/s to 18GHz.S - £800.
- HP8556A RF 20Hz to 300KHz.S - £250.
- HP8443A Tracking Generator Counter 100KHz-110Mc/s - £300.
- HP8445B Tracking Preselector DC to 18GHz - £350.
- HP3580A 5Hz - 50KHz ANZ - £750 - £1000.
- HP3582A 0.2Hz to 25.6KHz - £2k.
- HP8580A 100Hz-1500Mc/s ANZ - £6k.
- HP8589B 10Mc/s-22GHz ANZ - £6k.
- HP Mixers are available for the above ANZ's to 40GHz
- TEK 492 - 50KHz - 18GHz Opt 1+2 - £4k-£4.2k.
- TEK 492 - 50KHz - 18GHz Opt 1+2+3 - £4.5k.
- TEK 492P - 50KHz - 21 GHz Opt 1+2+3 - £5k.
- TEK 494AP 1KC/s - 21GHz - £7k.
- TEK 496P 1KHz-1.8GHz - £4k.
- TEK 5L4N 0-100KHz - £400.
- TEK 7L5 + L1 - 20Hz-5Mc/s - £700.
- TEK 7L5 + L3 - Opt 25 Tracking Gen - £900.
- TEK 7L12 - 100KHz - 1800Mc/s - £1000.
- TEK 7L18 - 1.5-60GHz - £1500.
- TEK 491 10Mc/s-12.4GHz-40GHz - £750. 12.4GHz-40GHz with Mixers.
- Tektronix Mixers are available for above ANZ to 60GHz
- Syston Donner 763 Spectrum ANZ + 4745B Preselector .01-18GHz + Two Mixers 18-40GHz in Transit Case - £3k.
- HP8673D Signal Generator .05-26.5GHz - £20k.
- Syston Donner 1618B Microwave AM FM Synthesizer 50Mc/s 2-18GHz
- R&S SWP Sweep Generator Synthesizer AM FM 4-2500Mc/s - £3.5k.
- ADRET 3310A FX Synthesizer 30Hz-50Mc/s - £500.
- HP8640A Signal Generator 1024Mc/s - AM FM - £800.
- HP3717A Modulator - Demodulator - £500.
- HP8551A RF Oscillator 22KC/s - 22Mc/s.
- HP5316B Universal Counter A+B.
- HP6002A Power Unit 0-5V 0-10A 200W.
- HP6825A Bipolar Power Supply Amplifier.
- HP461A-465A-467A Amplifiers.
- HP81519A Optical Receiver DC-400Mc/s.
- HP Plotters 7470A-7475A.
- HP3770A Amplitude Delay Distortion ANZ.
- HP3708B Telephone Line Analyser.
- HP8182A Data Analyser.
- HP59401A Bus System Analyser.
- HP6250B Power Unit 0-10V 0-100 Amps.
- HP3782A Error Detector.
- HP3781A Pattern Generator.
- HP3730A + 3737A Down Converter Oscillator 3.5-6.5GHz.
- HP Microwave Amps 491-492-493-494-495-16GHz - £250.
- HP105B Quartz Oscillator - £400.
- HP5087A Distribution Amplifier.
- HP6034A System Power Supply 0-60V 0-10A-200W - £500.
- HP131C Digital Voltage Source - 100V 1/2 Amp.
- HP4275A Multi Frequency L.C.R. Meter.
- HP3779A Primary Multiplex Analyser.
- HP3779C Primary Multiplex Analyser.
- HP8150A Optical Signal Source.
- HP1630G Logic Analyser.
- HP5316A Universal Counter A+B.
- HP5335A Universal Counter A+B+C.
- HP59501B Isolated Power Supply Programmer.
- HP8901A Modulation Meter AM - FM - also 8901B.
- HP5370A Universal Time Interval Counter.
- Marconi TF2370 - 30Hz - 110Mc/s 750HM Output (2 BNC Sockets + Resistor for 500HM MOD with Marconi MOD Sheet supplied - £650).
- Marconi TF2370 30Hz-110Mc/s 50 ohm Output - £750.
- Marconi TF2370 as above but late type - £850.
- Marconi TF2370 as above but late type Brown Case - £1000.
- Marconi TF2374 Zero Loss Probe - £200.
- Marconi TF2440 Microwave Counter - 20GHz - £1500.
- Marconi TF2442 Microwave Counter - 26.5GHz - £2k.
- Marconi TF2305 Modulation Meter - £2.3k.
- Racal/Dana 2101 Microwave Counter - 10Hz-20GHz - £2k.
- Racal/Dana 1255-1261 Universal Switch Controller + 200Mc/s PI Cards.
- Racal/Dana 9303 True RMS Levelmeter + Head - £450. IFFE - £500.
- TEKA6902A also A6902B Isolator - £300-£400.
- TEK 1240 Logic Analyser - £400.
- TEK FG5010 Programmable Function Generator 20Mc/s - £600.
- TEK2465A 350Mc/s Oscilloscope - £2.5k + probes - £150 each.
- TEK CT-5 High Current Transformer Probe - £250.
- TEK J16 Digital Photometer + J6523-2 Luminance Probe - £300.
- TEK J16 Digital Photometer + J6503 Luminance Probe - £250.
- ROTEK 320 Calibrator + 350 High Current Adaptor AC-DC - £500.
- FLUKE 5102B AC-DC Calibrator - £4k.
- FLUKE 1120A IEEE - 488 Transistor - £250.
- Tinsley Standard Cell Battery 5644B - £500.
- Tinsley Transportable Voltage Reference - £500.
- FLUKE Y5020 Current Shunt - £150.
- HP745A + 746A AC Calibrator - £600.
- HP8080A MF + 8091A 1GHz Rate Generator + 8092A Delay Generator + Two 8093A 1GHz Amps + 15400A - £800.
- HP54200A Digitizing Oscilloscope.
- HP11729B Carrier Noise Test Set .01-18GHz - LEF - £2000.
- HP3311A Function Generator - £300.
- Marconi TF2008 - AM-FM signal generator - also sweeper - 10Kc/s - 510Mc/s - from £250 - tested to £400 as new with manual - probe kit in wooden carrying box.
- HP Frequency comb generator type 8406 - £400.
- HP Vector Voltmeter type 8405A - £400 new colour.
- HP Sweep Oscillators type 8690 A & B + plug-ins from 10Mc/s to 18GHz also 18-40GHz. P.O.R.
- HP Network Analyzer type 8407A + 8412A + 8501A - 100Kc/s - 110Mc/s - £500 - £1000.
- HP Amplifier type 8447A - 1-400Mc/s £200 - HP8447A Dual - £300.
- HP Frequency Counter type 5340A - 18GHz £1000 - rear output £800.
- HP 8410 - A - B - C Network Analyzer 110Mc/s to 12GHz or 18GHz - plus most other units and displays used in this set-up - 8411a - 8412 - 8413 - 8414 - 18Hz - 8740 - 8741 - 8742 - 8743 - 8746 - 8650. From £1000.
- Racal/Dana 9301A - 9302 RF Millivoltmeter - 1.5-2GHz - £250-£400.
- Racal/Dana Modulation Meter type 9009 - 8Mc/s - 1.5GHz - £250.
- Marconi RCL Bridge type TF2700 - £150.
- Marconi/Saunders Signal Sources type - 6058B - 6070A - 6055A - 6059A - 6057A - 6056 - £250-£350. 400Mc/s to 18GHz.
- Marconi TF1245 Circuit Magnification meter + 1246 & 1247 Oscillators - £100-£300.
- Marconi microwave 6600A sweep osc. mainframe with 6650 PI - 18-26.5GHz or 6651 PI - 26.5-40GHz - £1000 or PI only £600. MF only £250.
- Marconi distortion meter type TF2331 - £150. TF2331A - £200.
- Tektronix Plug-Ins 7A13 - 7A14 - 7A18 - 7A24 - 7A26 - 7A11 - 7M11 - 7S11 - 7D10 - 7S12 - S1 - S2 - S6 - S52 - PG506 - SC504 - SG502 - SG503 - SG504 - DC503 - DC508 - DD501 - WR501 - DM501A - FG501A - TG501 - PG502 - DC505A - FG504 - 7B80 - 85-7B92A
- Gould J3B test oscillator + manual - £150.
- Tektronix Mainframes - 7603 - 7623A - 7613 - 7704A - 7844 - 7904 - TM501 - TM503 - TM506 - 7904A - 7834 - 7623 - 7633.
- Marconi 6155A Signal Source - 1 to 2GHz - LED readout - £400.
- Bar & Stroud Variable Filter EF3.0.1Hz - 100kc/s + high pass + low pass - £150.
- Marconi TF2163S attenuator - 1GHz. £200.
- Farnell power unit H60/50 - £400 tested. H60/25 - £250.
- Racal/Dana 9300 RMS voltmeter - £250.
- HP 8750A storage normalizer - £400 with lead + S.A. or N.A. Interface.
- Marconi TF2330 - or TF2330A wave analyser - £100-£150.
- Tektronix - 7S14 - 7T11 - 7S11 - 7S12 - S1 - S2 - S39 - S47 - S51 - S52 - S53 - 7M11.
- Marconi mod meters type TF2304 - £250.
- HP 5065A rubidium vapour FX standard - £1.5k.
- Syston Donner counter type 6054B - 20Mc/s - 24GHz - LED readout - £1k.
- Racal/Dana 9083 signal source - two tone - £250.
- Syston Donner - signal generator 1702 - synthesized to 1GHz - AM/FM - £600.
- Tektronix TMS15 mainframe + TM5006 mainframes - £450 - £850.
- Farnell electronic load type RB1030-35 - £350.
- Racal/Dana counters - 9904 - 9905 - 9906 - 9915 - 9916 - 9917 - 9921 - 50Mc/s - 3GHz - £100 - £450 - all fitted with FX standards.
- HP4815A RF vector impedance meter c/w probe - £500-£600.
- Marconi TF2092 noise receiver. A, B or C plus filters - £100-£350.
- Marconi TF2091 noise generator. A, B or C plus filters - £100-£350.
- Marconi 2017 S/G 10KHz - 1024MHz.
- HP 8627R, HP 8627 mainframes - £300-£500.
- Philips panoramic receiver type PM7900 - 1 to 20GHz - £400.
- Marconi 6700A sweep oscillator + 18GHz PI's available.
- HP8505A network ANZ + 8503A S parameter test set + 8501A normalizer - £4k.
- HP8505 network ANZ 8505 + 8501A + 8503A.
- Racal/Dana VLF frequency standard equipment. Tracer receiver type 900A + difference meter type 527E + rubidium standard type 9475 - £2750.
- HP signal generators type 626 - 628 - frequency 10GHz - 21GHz.
- HP 432A - 435A or B - 436A - power meters + powerheads - Mc/s - 40GHz - £200-£1000.
- Bradley oscilloscope calibrator type 192 - £600.
- HP8614A signal generator 800Mc/s - 2.4GHz - new colour £400.
- HP8615A signal gen 1.8GHz - 4.5GHz - new colour £400.
- HP 3325A syn function gen 20Mc/s - £1500.
- HP 3336A or B syn level generator - £500-£600.
- HP 3586B or C selective level meter - £750-£1000.
- HP 3575A gain phase meter 1Hz - 13Mc/s - £400.
- HP 8683D S/G microwave 2.3 - 13GHz - opt 001 - 003 - £4.5k.
- HP 8680 A-B-C syn S/G. AM + FM + 10Kc/s to 110Mc/s PI - 1Mc/s to 1300Mc/s - 1Mc/s to 2600Mc/s - £500-£2000.
- HP 8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 - £800-£1250.
- HP 86222B Sweep PI - 01 - 2.4GHz + ATT - £1750.
- HP 8629A Sweep PI - 2 - 18GHz - £1000.
- HP 86290B Sweep PI - 2 - 18GHz - £1250.
- HP 86 Series PI's in stock - splitband from 10Mc/s - 18.6GHz - £250-£1k.
- HP 8620C Mainframe - £250. IEEE - £500.
- HP 8615A Programmable signal source - 1MHz - 50Mc/s - opt 002 - £1k.
- HP 8601A Sweep generator .1 - 110Mc/s - £300.
- HP 3488A HP - IB switch control unit - £500 + control modules various - £175 each.
- HP 8160A 50Mc/s programmable pulse generator - £1000.
- HP 853A MF ANZ - £1.5k.
- HP 8349A Microwave Amp 2 - 20GHz Solid state - £1500
- HP 3585A Analyser 20Hz - 40Mc/s - £4k.
- HP 8589B Analyser .01 - 22GHz - £5k.
- HP 3580A Analyser 5Hz - 50KHz - £1k.
- HP 1980B Oscilloscope measurement system - £600.
- HP 3455A Digital voltmeter - £500.
- HP 3437A System voltmeter - £300.
- HP 3581C Selective voltmeter - £250.
- HP 5370A Universal time interval counter - £450.
- HP 5335A Universal counter - 200Mc/s - £500.
- HP 5328A Universal counter - 500Mc/s - £250.
- HP 5150A Thermal printer - £250.
- HP 1645A Data error analyser - £150.
- HP 4437A Attenuator - £150.
- HP 3717A 70Mc/s modulator - £400.
- HP 3710A - 3715A - 3716A - 3702B - 3703B - 3705A - 3711A - 3791B - 3712A - 3793B microwave link analyser - P.O.R.
- HP 3730A - B RF down converter - P.O.R.
- HP 3552A Transmission test set - £400.
- HP 3763A Error detector - £500.
- HP 3764A Digital transmission analyser - £600.
- HP 3770A Amp delay distortion analyser - £400.
- HP 3780A Pattern generator detector - £400.
- HP 3781A Pattern generator - £400.
- HP 3781B Pattern generator (bell) - £300.
- HP 3782A Error detector - £400.
- HP 3782B Error detector (bell) - £300.
- HP 3785A Jitter generator + receiver - £750-£1k.
- HP 8006A Word generator - £100-£150.
- HP 8016A Word generator - £250.
- HP 8170A Logic pattern generator - £500.
- HP 59401A Bus system analyser - £350.
- HP 59500A Multiprogrammer HP - IB - £300.
- Philips PMS390 RF syn - 0.1 - 1GHz - AM + FM - £1000.
- S.A. Spectral Dynamics SD345 spectrascope 111 - LF ANZ - £1500.
- Tektronix R7912 Transient waveform digitizer - programmable - £400.
- Tektronix TR503 + TM503 tracking generator 0.1 - 1.8GHz - £1k - or TR502.
- Tektronix 576 Curve tracer + adaptors - £900.
- Tektronix 577 Curve tracer + adaptors - £900.
- Tektronix 1502/1503 TDR cable test set - £1000.
- Tektronix AM503 Current probe + TM501 m/frame - £1000.
- Tektronix SC501 - SC502 - SC503 - SC504 oscilloscopes - £75-£350.
- Tektronix 465 - 465B - 475 - 2213A - 2215 - 2225 - 2235 - 2245 - 2246 - £250-£1000.
- Kikusui 100Mc/s Oscilloscope COS100M - £350.
- Nicolet 3091 LF oscilloscope - £400.
- Racal 1991 - 1992 - 1988 - 1300Mc/s counters - £500-£900.
- Fluke 80K-40 High voltage probe in case - BN - £100.
- Racal Recorders - Store 4 - 4D - 7 - 14 channels in stock - £250 - £500.
- Racal Store Horse Recorder & control - £400-£750 Tested.
- EIP 545 microwave 18GHz counter - £1200.
- Fluke 510A AC ref standard - 400Hz - £200.
- Fluke 355A DC voltage standard - £300.
- Whitron 610D Sweep Generator + 6124C PI - 4 - 8GHz - £400.
- Whitron 610D Sweep Generator + 61084D PI - 1Mc/s - 1500Mc/s - £500.
- Time Electronics 9814 Voltage calibrator - £750.
- Time Electronics 9811 Programmable resistance - £600.
- Time Electronics 2004 D.C. voltage standard - £1000.
- HP 8699B Sweep PI YIG oscillator .01 - 4GHz - £300. 8690B MF - £250. Both £500.
- Schlumberger 1250 Frequency response ANZ - £1500.
- Dummy Loads & power at up to 2.5 kilowatts FX up to 18GHz - microwave parts new and ex equipt - relays - attenuators - switches - waveguides - Yigs - SMA-APC7 plugs - adaptors. B&K Items in stock - ask for list. W&G Items in stock - ask for list. Power Supplies Heavy duty + bench in stock - Farnell - HP - Weir - Thurlby - Racal etc. Ask for list.

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-SYNCS-TRANSMITTING AND RECEIVING EQUIPMENT ETC.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No: (01274) 684007. Fax: 651160

**GAS HOBS** Standard domestic units, new and boxed, 3 burner, household gas, brown. Bargain at just £12.95 ref BAR316

**INFRA RED FILM** 6" square piece of flexible infra red film that will only allow IR light through. Perfect for converting ordinary torches, lights, headlights etc to infra red output using standard light bulbs. Easily cut to shape. 6" square £15 ref IRF2

**HYDROGEN FUEL CELL PLANS** Loads of information on hydrogen storage and production. Practical plans to build a Hydrogen fuel cell (good workshop facilities required) £8 set ref FCP1

**STIRLING ENGINE PLANS** Interesting information pack covering all aspects of Stirling engines, pictures of home made engines made from an aerosol can running on a candle! £12 ref STIR2

**12V OPERATED SMOKE BOMBS** Type 3 is a 12v trigger and 3 smoke cannisters, each cannister will fill a room in a very short space of time! £14.99 ref SB3. Type 2 is 20 smaller cannisters (suitable for simulated equipment fires etc) and 1 trigger module for £29 ref SB2

Type 1 is a 12v trigger and 20 large cannisters £49 ref SB1

**HI POWER ZENON VARIABLE STROBES** Useful 12v PCB fitted with hi power strobe tube and control electronics and speed control potentiometer. Perfect for interesting projects etc 70x55mm 12vdc operation. £6 ea ref FLS1, pack of 10 £49 ref FLS2

**NEW GEIGER COUNTERS IN STOCK** Hand held unit with LCD screen, auto ranging, low battery alarm, audible 'click' output. New and guaranteed. £129 ref GE1

**RUSSIAN BORDER GUARD BINOCULARS £1799**

Probably the best binoculars in the world! ring for colour brochure.

**RUSSIAN MULTIBAND WORLD COMMUNICATIONS RECEIVER** Exceptional coverage of 9 wave bands, (5 short, 1 LW, 1FM, 1MW) internal ferrite and external telescopic aerials, mains/battery. £45 ref VEGA

**NEW LASER POINTERS** 4.5mw, 75 metre range, hand held unit runs on two AA batteries (supplied) 670nm. £29 ref DEC49

**HOW TO PRODUCE 35 BOTTLES OF WHISKY FROM A SACK OF POTATOES** Comprehensive 270 page book covers all aspects of spirit production from everyday materials. Includes construction details of simple stills etc. £12 ref MS3

**NEW HIGH POWER MINI BUG** With a range of up to 800 metres and a 3 days use from a PP3 this is our top selling bug! less than 1" square and a 10m voice pickup range. £28 ref LOT102

**BUILD YOUR OWN WINDFARM FROM SCRAP** New publication gives step by step guide to building wind generators and propellers. Armed with this publication and a good local scrap yard could make you self sufficient in electricity! £12 ref LOT81

**PC KEYBOARDS PS2 connector**, top quality suitable for all 286/386/486 etc £10 ref PCKB. 10 for £85.

**NEW LOW COST VEHICLE TRACKING TRANSMITTER KIT £29** range 1.5-5 miles, 5,000 hours on AA batteries, transmits info on car direction, left and right turns, start and stop information. Works with any good FM radio. £29 ref LOT101a

**HIGH SECURITY ELECTRIC DOOR LOCKS** Complete brand new Italian lock and latch assembly with both Yale type lock (keys inc) and 12v operated deadlock. £10 ref LOT99

**\*NEW HIGH POWER WIRELESS VIDEO AND AUDIO BUG KIT 1/2 MILE RANGE** Transmits video and audio signals from a miniature CCTV camera (included) on any standard television! Supplied with telescopic aerial. £169

**CCTV PAN AND TILT KIT** Motorize your CCTV camera with this simple 12vdc kit. 2 hermetically sealed DC linear servo motors 5mm threaded output 5 secs stop to stop, can be stopped any where, 10mm travel, powerful. £12 ref LOT125

**CCTV CAMERA MODULES** 46X70X29mm, 30 grams, 12v 100mA, auto electronic shutter, 3.8mm F2 lens, CCIR, 512x492 pixels, video output is 1v p-p (75 ohm). Works directly into a scart or video input on a tv or video. IR sensitive. £79.95 ref EF137.

**IR LAMP KIT** Suitable for the above camera, enables the camera to be used in total darkness! £6 ref EF138

**UK SCANNING DIRECTORY** As supplied to Police, MOD, M15 and GCHQ! covers everything from secret government frequencies, eyes in the sky, prisons, military aviation etc £18.50 ref SCANB

**INFRA RED POWERBEAM** Handheld battery powered lamp, 4 inch reflector, gives out powerful pure infrared light! perfect for CCTV use, night sights etc. £29 ref PB1

**SUPER WIDEBAND RADAR DETECTOR** Detects both radar and laser. X K and KA bands, speed cameras, and all known speed detection systems. 360 degree coverage, front & rear waveguides, 1.1"x2.7"x4.6" fits on sun visor or dash £149 ref

**CHIEFTAN TANK DOUBLE LASERS**

**9 WATT+3 WATT+LASER OPTICS**

Could be adapted for laser listener, long range communications etc. Double beam units designed to fit in the gun barrel of a tank, each unit has two semi conductor lasers and motor drive units for alignment. 7 mile range, no circuit diagrams due to MOD, new price £50,000? us? £199. Each unit has two gallium Arsenide injection lasers, 1 x 9 watt, 1 x 3 watt, 900nm wavelength, 28vdc, 600Hz pulse frequency. The units also contain an electronic receiver to detect reflected signals from targets. £199 for one. Ref LOT4.

**NEW LOW PRICED COMPUTER/WORKSHOP/HI-FI RCB UNITS** Complete protection from faulty equipment for everybody! Inline unit fits in standard IEC lead (extends it by 750mm), fitted in less than 10 seconds, reset/test button, 10A rating. £6.99 each ref LOT5. Or a pack of 10 at £49.90 ref LOT6. If you want a box of 100 you can have one for £250!

**TWO CHANNEL FULL FUNCTION B-GRADE RADIO CONTROLLED CARS** From World famous manufacturer these are returns so they will need attention (usually physical damage) cheap way of buying TX and RX plus servos etc for new projects etc. £12 each sold as seen ref LOT2.

**MAGNETIC CREDIT CARD READERS AND ENCODING MANUAL** £9.95 Cased with flyleads, designed to read standard credit cards! complete with control electronics PCB and manual covering everything you could want to know about what's hidden in that magnetic strip on your card! just £9.95 ref BAR31

**WANT TO MAKE SOME MONEY? STUCK FOR AN IDEA?** We have collected 140 business manuals that give you information on setting up different businesses, you peruse these at

your leisure using the text editor on your PC. Also included is the certificate enabling you to reproduce (and sell) the manuals as much as you like! £14 ref EP74



**HIGH POWER DC MOTORS, PERMANENT MAGNET** 12 - 24v operation, probably about 1/4 horse power, body measures 100mm x 75mm with a 60mm x 5mm output shaft with a machined flat on it. Fixing is simple using the two threaded bolts protruding from the front of the motor 4mm x 12mm). These motors are perfect for model engineering etc they may even be suitable as a cycle motor? We expect high demand so if you would like one or think you may require one in the future place your order today! £22 ref MOT4. 10 pack £185 ref MOT5B

**ELECTRONIC SPEED CONTROLLER KIT** For the above motor is £19 ref MAG17. Save £5 if you buy them both together, 1 motor plus speed controller rrp is £41, offer price £36 ref MOT5A

**RUSSIAN 900X MAGNIFICATION ZOOM MICROSCOPE** metal construction, built in light, mirror etc. Russian shrimpfarm, group viewing screen, lots of accessories. £29 ref ANAYLT.

**AA NICAD PACK** Pack of 4 tagged AA nicads £2.99 ref BAR34

**RUSSIAN NIGHTSIGHTS** Model TZS4 with infra red illuminator, views up to 75 metres in full darkness in infrared mode, 150m range, 45mm lens, 13 deg angle of view, focussing range 1.5m to infinity. 2AA batteries required. 950g weight. £199 ref BAR61. 1 years warranty

**LIQUID CRYSTAL DISPLAYS BARGAIN PRICES**, 20 character 2 line, 83x19mm £3.99 ref SMC2024A

16 character 4 line, 62x25mm £5.99 ref SMC1640A

**TAL-1, 110MM NEWTONIAN REFLECTOR TELESCOPE** Russian. Superb astronomical 'scope, everything you need for some serious star gazing! up to 169x magnification. Send or fax for further information 20kg, 885x800x1650mm ref TAL-1, £249

**YOUR HOME COULD BE SELF SUFFICIENT IN ELECTRICITY** Comprehensive plans with loads of info on designing systems, panels, control electronics etc £7 ref PV1



**COLOUR CCTV VIDEO CAMERAS, BRAND NEW AND CASED, FROM £99.**

**Works with most modern video's, TV's, Composite monitors, video grabber cards etc** Pal, 1v P-P, composite, 75ohm, 1/3" CCD, 4mm F2.8, 600x582, 12vdc, mounting bracket, auto shutter, 100x50x180mm, 3 months warranty, 1 off price £118 ref XEF150, 10 or more £99 ea 100+ £89

**YUASHA SEALED LEAD ACIDS FROM £2.50** 12v 6.5Ah ex equipment batteries to clear at just £9.99 for a pack of four ref XX1

**A MAGNET THAT LIFTS 33 KILO'S!** Just in this week are these incredible magnets that lift 33 kilo's! Price is £14.99 ref MAG33

**25 SQUARE FOOT SOLAR ENERGY BANK KIT** 100 6"x6" 6v Amorphous 100mA panels, 100 diodes, connection details etc to build a 25 square foot solar cell for just £99 ref EF112.

**CONVERT YOUR TV INTO A VGA MONITOR FOR £25!** Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. Ideal for laptops or a cheap upgrade. Supplied in kit form for home assembly. SALE PRICE £25 REF SA34

**\*15 WATT FM TRANSMITTER** Already assembled but some RF knowledge will be useful for setting up. Preamp req'd, 4 stage 80-108mhz, 12-18vdc, can use ground plane, yagi or dipole £69 ref 1021

**\*4 WATT FM TRANSMITTER KIT** Small but powerful FM transmitter kit. 3 RF stages, mic & audio preamp included £24 ref 1028

**YUASHA SEALED LEAD ACID BATTERIES** 12v 15AH at £19 ref LOT8 and below spec 6v 10AH at £5 a pair

**ELECTRIC CAR WINDOW DE-ICERS** Complete with cable, plug etc SALE PRICE JUST £4.99 REF SA28

**AUTO SUNCHARGER** 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £12.99 REF AIOG10P3.

**SOLAR POWER LAB SPECIAL** You get 2 6"x6" 6v 130mA cells, 4 LED's, wire, buzzer, switch + 1 relay or motor. £7.99 REF SA27

**SOLAR NICAD CHARGERS** 4 x AA size £9.99 ref 6P476, 2 x

## BULL ELECTRICAL

250 PORTLAND ROAD, HOVE, SUSSEX.  
BN3 5QT. (ESTABLISHED 50 YEARS).

MAIL ORDER TERMS: CASH, PO OR CHEQUE  
WITH ORDER PLUS £3.50 P&P PLUS VAT.

24 HOUR SERVICE £4.50 PLUS VAT.  
OVERSEAS ORDERS AT COST PLUS £3.50

'phone orders: 01273 203500  
(ACCESS, VISA, SWITCH, AMERICAN EXPRESS)  
FAX 01273 323077  
E-mail bull@pavillon.co.uk

C size £9.99 ref 6P477

**GIANT HOT AIR BALLOON KIT** Build a 4.5m circumference, fully functioning balloon, can be launched with home made burner etc. Reusable (until you loose it!) £12.50 ref HA1

**AIR RIFLES .22** As used by the Chinese army for training purposes, so there is a lot about! £39.95 Ref EF78. 500 pellets £4.50 ref EF80.

**\*NEW MEGA POWER VIDEO AND AUDIO SENDER UNIT.** Transmits both audio and video signals from either a video camera, video recorder, TV or Computer etc to any standard TV set in a 500m range! (tune TV to channel 31) 12v DC

op. Price is £85 REF: MAG15 12v psu is £5 extra REF: MAG5P2

**\*MINIATURE RADIO TRANSCIEVERS** A pair of walkie talkies with a range up to 2 km in open country. Units measure 22x52x155mm, including cases and ear pieces. 2xPP3 req'd. £37.00 pr. REF: MAG30

**\*FM TRANSMITTER KIT** housed in a standard working 13A adapter!! the bug runs directly off the mains so lasts forever! why pay £700? or price is £18 REF: EF62 (kit) Transmits to any FM radio. Built and tested version now available at £45 ref EXM34

**\*FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

**GAT AIR PISTOL PACK** Complete with pistol, darts and pellets £14.95 Ref EF82B extra pellets (500) £4.50 ref EF80.

**HEAT PUMPS** These are mains operated air to air units that consist of a aluminium plate (cooling side) and a radiator (warming side) connected together with a compressor. The plate if inserted into water will freeze it. Probably about 3-400 watts so could produce 1kw in ideal conditions. £30 ref HP1

**3 FOOT SOLAR PANEL** Amorphous silicon, 3' x 1' housed in an aluminium frame, 13v 700mA ouput. £55 ref MAG45

**SOLAR/WIND REGULATOR** Prevents batteries from over charging. On reaching capacity the regulator diverts excess power into heat avoiding damage. Max power is 60 watts. £27.99 ref S/CA11-05

**4X28 TELESCOPIC SIGHTS** Suitable for all air rifles, ground lenses, good light gathering properties. £24.95 ref R7.

**NICAD CHARGERS AND BATTERIES** Standard universal mains operated charger, takes 4 batts + 1 PP3, £10 ref PO11D. Nicads - AA size (4 pack) £4 ref 4P44, C size (2 pack) £4 ref 4P73, D size (4 pack) £9 ref 9P12.

**PHOTOGRAPHIC RADAR TRAPS CAN COST YOU YOUR LICENCE!** The new multiband 2000 radar detector can prevent even the most responsible of drivers from losing their licence! Adjustable audible alarm with 8 flashing leds gives instant warning of radar zones. Detects X, K, and Ka bands, 3 mile range, 'over the hill' 'around bends' and 'rear trap' facilities. micro size just 4.25"x2.5"x.75". Can pay for itself in just one day! £89 ref EP3.

**STEREO MICROSCOPES BACK IN STOCK** Russian, 200x complete with lenses, lights, filters etc very comprehensive microscope that would normally be around the £700 mark, our price is just £299 (full money back guarantee) full details in catalogue.

**SECOND GENERATION NIGHT SIGHTS FROM £748** RETRON Russian night sight, 1.8x, infra red lamp, 10m-inf, standard M42 lens, 1.1kg. £349 ref RET1

**MAINS MOTORS 180 RPM** 90X70mm, 50X55mm 50x55mm output shaft, start cap included. £22 ref MGM1

**PC POWER SUPPLIES, CUSTOMER RETURNS, ALL FAN COOLED, OUR CHOICE, BARGAIN AT 8 PSU'S FOR £9.99 REF XX16**

**LOW COST CORDLESS MIC** 500' range, 90 - 105mhz, 115g, 193 x 26 x 39mm, 9v PP3 battery required. £17 ref MAG15P1

**JUMBO LED PACK** 15 10mm bicolor leds, plus 5 giant (55mm) seven segment displays all on a pcb £8 ref JUM1. Pack of 30 55mm seven seg displays on pcbs is £19 ref LED4, pack of 50 £31 ref LED50

**12VDC 40MM FANS** MADE BY PANAFLO. NEW. £4. REF FAN12



**WIND GENERATORS 380 WATT**

1.14 metre dia blades, carbon matrix blades, 3 year warranty, 12vdc output, 24v version available, control electronics included, brushless neodymium cubic core alternator, only two moving parts, maintenance free, simple roof top installation, start up speed 7mph, max output (30mph) 380w. £499 ref AIR1

Check out our WEB SITE  
full colour interactive  
1997 catalogue

<http://www.pavillon.co.uk/bull-electrical>

FREE COLOUR CATALOGUE  
WITH EVERY ORDER

SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

WE BUY SURPLUS STOCK  
FOR CASH

SURPLUS STOCK LINE 0802 660335

# NEW PRODUCTS CLASSIFIED

Please quote "Electronics World" when seeking further information

## ACTIVE

### Discrete active devices

**Power darlington's.** FMMT634 power darlington's from Zetex in the surface-mount 'SuperSOT' package cope with the current of SOT23 alternatives, replacing darlington's in SOT89, SOT223 and TO126 packages. Peak pulse current is 5A and power dissipation 625mW. At a collector current of 2A, minimum device gain is 5000, V<sub>CE(sat)</sub> at 1A being 960mV maximum. In automotive use, the collector/emitter voltage rating of 100V will help with the transients normally found. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

**Linear integrated circuits**

**G-p op-amp.** Micrel has introduced the MIC6211, which is said to be the first general-purpose op-amp in an SOT-23-5 package, whimsically known to some as an *IttyBitty*. It is similar to one of the devices in the quad LM324, the miniature package allowing four single op-amp 6211s to occupy less space than in the 324. Operating from either single 4 to 32V or ±2V to ±16V supplies, the 6211 provides high gain and is frequency compensated. Current drawn is 2mA, unity-gain bandwidth 2.5MHz and slew rate 7V/μs. Micrel Semiconductor Europe. Tel., 01635 524455; fax, 01635 524466.

**Microprocessors and controllers**

**New PICs.** New 8-bit microcontrollers from Microchip, the PIC16C66/7 feature extensive communications and a 5Mips performance. They are eeprom-based and the usart operates at up to 5Mb/s, have 35 single-cycle 200ns instructions, 8K by 14 words of program memory and 368byte of data ram. Current taken from a 33kHz 3V supply is under 15μA and 1μA in sleep mode. Of the 40 pins, 33 are for communications, which include an 8-bit asynchronous slave port, a synchronous serial port for DPI or I<sup>2</sup>C protocols, two pwm outputs at 80kHz and 8-bit resolution and a 16-bit capture/compare facility with 200ns resolution. The chips also drive leds

and triacs directly. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

### Mixed-signal ICs

**Digital video demodulator.** Siemens' TDA6180X amplifier and demodulator ic handles qpsk modulation in digital video broadcast signals, converting signals at 300-600MHz to I and Q analogue levels. Functionally, the device is a qpsk-input amplifier, an agc oscillator which generates the 0° and 90° signals for demodulation and a qpsk demodulator. Filtered if goes to a variable-gain amplifier and is then demodulated to baseband. It is the split and passed to two low-level detectors, from which it is amplified and output as Q and I. Siemens plc. Tel., 0990 550500; fax, 01344 396721.

**Optical devices**

**High-voltage isolators.** Isocom has a 300V optoisolator, the IS7000, that withstands 300V across its output transistor; it is meant for use in positions such as fax modems and power supply interfaces. Input/output isolation is to 5kV and the darlington output stage produces a current output of up to 150mA on inputs down to 1mA, or much more with pulse inputs. Turn-on and turn-off times are 50μs and 15μs and performance is held over the -30°C to 100°C range. Isocom Components Ltd. Tel., 01429 863609; fax, 01429 863581.

**DII clocks.** Dual-in-line clock oscillators from Total Frequency Control can be specified, made and delivered within seven working days. Frequency range is 4-30MHz to within ±5%, ageing rate ±1ppm/year and output is hcmos/ttl-compatible. Total Frequency Control Ltd. Tel., 01903 745513; fax, 01903 742208; e-mail, eddie@tfc.co.uk.

**Cameras**

**Conference camera.** QuartzSight, developed by Vision and Rockwell, is a digital colour camera, made to international standards, for use in pc-based videoconferencing. The camera itself is simply the lens and



cmos single-chip colour sensor, while the QuartzCapture chip set contains many of the camera dsp functions. Digitised video signals, power and control are all carried by a 9-wire cable. Colour balance and exposure control are automatic, while the user controls focus, colour saturation, contrast, brightness, frame rate and resolution. An anti-flicker mode reduces the effects of fluorescent tubes. VLSI Vision Ltd. Tel., 0131-539 7111; fax, 0131-539 7141.

**Memory**

**Compact flash.** New range of compact flash cards by Kingmax is intended to increase the number of pictures stored in digital cameras and the data available to mobile telephone users. Used with a camera, it avoids the need to download the data straight from the camera; many cards may be filled with data at high definition and interfaced to a pc. The range of capacities is 2-16Mbyte and a high-speed buffer allows transfer rates to and from memory at up to 8Mbyte/s, a speed compatible with the fastest digital cameras. Cards are compatible with PC Card services and Socket Services and, by the use of an adaptor, can be plugged into PCMCIA sockets. Premier Electronics Ltd. Tel., 01922 634652; fax, 01922 634616.

**Communications equipment**

**Ring generator.** The PowerDsine PCR-SIN01 is a 1W sine generator for telephony, putting out selectable 17, 20 and 25Hz frequencies for different countries. Current taken from 12V or 24V dc is 90mA and rf filtering is included. It is for use in single or dual line applications and an external inhibit control reduces idle power, the control also being used to generate the ringing signal intervals, so doing away with relays. Overload protection is provided. DIP International Ltd. Tel., 01223 462244; fax, 01223 467316.

**Crystals**

**Surface-mount crystals.** New crystals from Total Frequency Control are packaged in resistance-welded metal cases with preformed leads for automatic surface-mounting, special mounts inside the package conferring resistance to shock and vibration. Frequency tolerance over the -10°C to 60°C range is ±3ppm and ageing is 0.5ppm/year maximum; the company points out that this level of performance is not available in conventional s-m packages. Total

Frequency Control Ltd. Tel., 01903 745513; fax, 01903 742208; e-mail, eddie@tfc.co.uk.

**Displays**

**Small graphics panel.** From Nan Ya, the LMCD8078 liquid-crystal display panel provides 320 by 240 resolution and measures 134.5 by 117 by 14mm. It uses a transreflective technique and can be used with no backlight, so saving power. Neither does it need inverting circuitry and therefore also saves space. Mono displays in the range include types with an integral matrix touch screen in which, since no controller is needed, a simple buffer like those in

## PASSIVE

and triacs directly. Arizona Microchip Technology Ltd. Tel., 01628 851077; fax, 01628 850259.

cmos single-chip colour sensor, while the QuartzCapture chip set contains many of the camera dsp functions. Digitised video signals, power and control are all carried by a 9-wire cable. Colour balance and exposure control are automatic, while the user controls focus, colour saturation, contrast, brightness, frame rate and resolution. An anti-flicker mode reduces the effects of fluorescent tubes. VLSI Vision Ltd. Tel., 0131-539 7111; fax, 0131-539 7141.

Memory

Compact flash. New range of compact flash cards by Kingmax is intended to increase the number of pictures stored in digital cameras and the data available to mobile telephone users. Used with a camera, it avoids the need to download the data straight from the camera; many cards may be filled with data at high definition and interfaced to a pc. The range of capacities is 2-16Mbyte and a high-speed buffer allows transfer rates to and from memory at up to 8Mbyte/s, a speed compatible with the fastest digital cameras. Cards are compatible with PC Card services and Socket Services and, by the use of an adaptor, can be plugged into PCMCIA sockets. Premier Electronics Ltd. Tel., 01922 634652; fax, 01922 634616.

Communications equipment

Ring generator. The PowerDsine PCR-SIN01 is a 1W sine generator for telephony, putting out selectable 17, 20 and 25Hz frequencies for different countries. Current taken from 12V or 24V dc is 90mA and rf filtering is included. It is for use in single or dual line applications and an external inhibit control reduces idle power, the control also being used to generate the ringing signal intervals, so doing away with relays. Overload protection is provided. DIP International Ltd. Tel., 01223 462244; fax, 01223 467316.

Crystals

Surface-mount crystals. New crystals from Total Frequency Control are packaged in resistance-welded metal cases with preformed leads for automatic surface-mounting, special mounts inside the package conferring resistance to shock and vibration. Frequency tolerance over the -10°C to 60°C range is ±3ppm and ageing is 0.5ppm/year maximum; the company points out that this level of performance is not available in conventional s-m packages. Total

Please quote "Electronics World" when seeking further information

membrane keypads can be used. These are transmissive or transmissive versions in blue and white or black and white. Anders Electronics plc. Tel., 0171-388 7171; fax, 0171-387 2951.

### Filters

**GSM saw filters.** Surface acoustic wave filters in Fujitsu's *F4* range are meant for applications in the 200-600MHz band, GSM filters being available at 246MHz and 400MHz. Inputs and outputs are balanced and attenuation in the stop band is better than 50dB. Surface-mounting packages measure 5 by 5 by 1.6mm for the 246MHz filter and slightly larger for the 200MHz device. Fujitsu Microelectronics Ltd. Tel., 01628 76100; fax, 01628 781484.

### Hardware

**Joysticks.** Sakae joysticks, meant for plant control, robotics, wheelchairs and games, use conductive plastic tracks and have a life expectancy of up to five million operations. Models cover the range of sizes from minute to huge and can be had in 1, 2 or

**RCA jacks.** Shiuva Chyuan of Taiwan supply RCA jacks in a number of forms and they are now available in the UK. The jacks come in single units or with 2-8-way types, with optional emc screening. They are meant for high-volume use where fast installation is needed. Plating options are gold, half-gold and silver, resulting in a minimum contact resistance of 30mΩ and reliability sufficient for 5000 cycles. Colours can be specified and both horizontal and vertical barrels are available. TW Electronics Ltd. Tel., 01635 278585; fax, 01635 278122.

3-dimensional form with optional switches, being built to ISO9001 standard. They withstand vibration to 10g and shock to 30g and may be supplied with fittings and a choice of knobs. Dust gaiters are available. Techni Measure. Tel., 01527 854103; fax, 01527 853267.

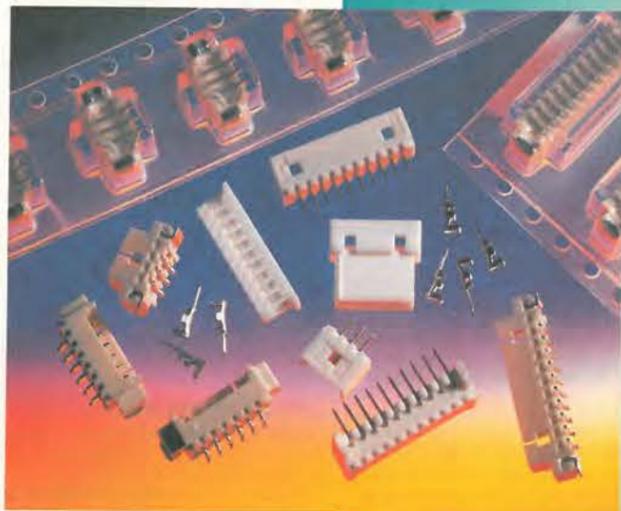
**Ceramic adjusters.** Torayceram tools, now available from Toolworld, are for the adjustment of trimmers and inductors, ceramic business ends avoiding any interference with component characteristics even at high frequencies. A manufacturing process confers resistance to bending forces and the chipping that can occur in zirconia ceramics. The tools come in a range of sizes, with interchangeable bits and with long thin handles for awkward positions. Also available are ceramic tweezers, which provide the same advantages of long life (ten times longer than metal and 100 times longer than plastic) and no magnetic materials. Toolworld Ltd. Tel., 01249 821234; fax, 01249 816723.

**Cable tidy.** Richco International's latest offering is a little plastic bit that clips into a 5mm hole on the edge of a pcb and holds any odd wires coming off the board in a 'saddle'. It is known as an edge holding wire saddle and is made in nylon 6/6, RMS-01 or flame-retardant nylon 6/6 and RMS-19. Richco International Co., Ltd. Tel., 01474 327527; fax, 01474 327455.

**Chip coolers.** Sanyo Denki *San Ace* MC coolers for Pentium and Alpha microprocessors are now available in the UK. They consist of miniature fans with integral heatsinks and come in four sizes from 45mm square by 18mm to 66 by 62 by 30mm, each being made in 5V or 12V versions. A silicone compound is used as a thermal interface. Noise level is low at about 28dB(A), there is locked-rotor protection and an alarm output is optional. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

### Test and measurement

**Acoustics and vibration.** Developed by Müller-BBM GmbH, the *PAK* multi-channel acoustic and vibration measurement and analysis system is based on a Hewlett-Packard VXI front end with an *HP9000 Series 700* workstation to run the *PAK* software under the HP-UX os. Analysis software handles time and frequency domains, octave analysis, order tracking and psychoacoustic analysis; additional parameters for engine analysis can also be captured. Both Yard and Oracle databases are supported and a report generator is provided. Strategic Test and Measurement Systems Ltd. Tel., 01734 795950; fax, 01734 795951.



**Exotic multimeter.** Capable of capturing data 3.3 times per second and of true-rms measurement, the *Escort EDM89S* handheld multimeter measures 500mV-1000V dc and true-rms alternating voltage, 5mA-10A direct and alternating current, 500Ω-50MΩ resistance, frequency, 5nF-50μF capacitance and dBm with selectable reference impedance. A range of features includes automatic or manual dynamic recording, 5000-count digital readout and an analogue bar graph. Bandwidth on ac measurements is 20kHz and there is dual-tone, dual-display logic detection, a relative mode for deviation, audible and visible input warnings and power-saving modes. Feedback Test and Measurement. Tel., 01892 653322; fax, 01892 663719.

**2.4GHz counter/timer.** Available from TTI, the *Tabor 6000* range of GPIB-interfaced counter/timers consists of three models: the *6010*, measuring up to 125MHz, extendable to 1.3GHz; the *6020* to measure to 225MHz and extendable to 1.3GHz; and the *6030* for 225MHz and 2.4GHz. The latter has two independent inputs for frequency measurements up to 300MHz, below which reciprocal measurement is automatically selected. Optionally, a third channel will measure up to 2.4GHz on an input of 15mV. Period and pulse measurements (5ns-2000s) and time interval A to B (0-2000s) can be made, with the provision for up to 500 programmed delay intervals to be inserted between start and stop of the time interval A to B. Stability with an optional oven-controlled time base is 0.15ppm/year. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 450409.

### Interfaces

**GPIB interfaces.** *ComputerBoards Inc.* announces a range of GPIB interfaces for ISA, PCI and PCMCIA, all significantly cheaper

### Connectors and cabling

"Smallest" connectors. *Molex* 1.25 connectors are said to be the smallest available. There are wire-to-board types and wires-to-other-wires versions, all with flat, twin-contact pins pitched 1.25mm, taking 1A maximum and in detachable through-hole form and for surface mounting. With 2-15 connections, the pins have a maximum contact resistance of 20mΩ and insulation resistance of 1GΩ. Connectors are polarised, the headers having friction locks. Hawnt Electronics Ltd. Tel., 0121 784 3355; fax, 0121 783 1657.

than competitors, the PCMCIA board being about half the common price. These GPIB IEEE-488.2 interfaces let any pc function as instrumentation control and data acquisition system. They use the standard CB7210.2 GPIB chip for full talker/listener/controller functions and allow up to 14 instruments to be connected to the pc. Supplied software supports programming under dos, Windows 3.1x and '95. Data transfer rates are up to 1Mbyte/s and the PCMCIA and PCI models are of the plug-and-play type. Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213.

### Literature

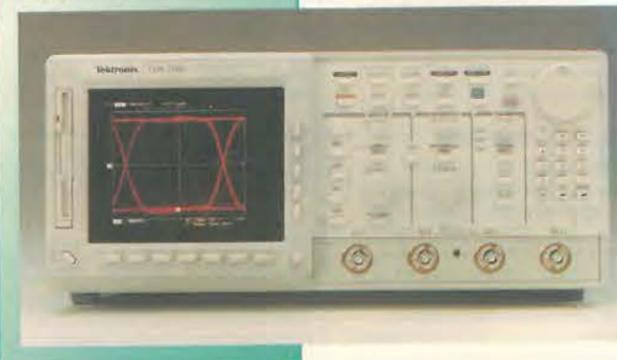
**Optoelectronics.** Onboard Electronics offers a 100-page catalogue of optoelectronic components from *Kingbright*, including super-bright led lamps and bright blue leds. Also described are surface-mounted, shaped and large-sized lamps, led clusters, seven-segment and dot-matrix displays. Onboard Electronics Ltd. Tel., 01256 818222; fax, 01256 840610.

**Relays.** Free from Ashwell Electronics, the 24-page *Teledyne Gentron* data book of solid-state relays, which covers devices from 10A board-mounted types to three-phase, 1000A devices. Ashwell Electronics Ltd. Tel., 01438 364194; fax, 01438 313461.

**Servo amplifiers.** Ninety brush and brushless servo amplifiers for motion control are described in Copley Controls' eight-page short catalogue. Power ratings from a few watts to 20kW, and single-axis and multi-axis types and sub-systems are all included, as are dc psus, transformers and amplifier mounting hardware. Most Copley pwm amplifiers can be made to match specific motors by plugging resistors and capacitors into a no-soldering header. Amplifier features include built-in power filtering or edge filters to reduce output rise rate to prevent rfi coupling to other circuits. Copley Controls. Tel., 001 617 329 8200; fax, 001 617 329 4055.

### Scope for communications

Newly introduced by Tektronix, the *TDS 700C* and *TDS 500C* family of *InstaVu* acquisition digital storage oscilloscopes for use on communications equipment such as switches, routers and videoconferencing equipment, together with a set of accessories to enable connection of optical and electrical signals to the instruments. A feature of the oscilloscopes is the facility for mask testing of communications signals; there are 39 automatic telecomms and datacomms masks and custom masks can be built by the user. In compliance test, the mask for a particular standard is displayed, the signal being scaled and correctly offset for comparison. Statistical tools are included for analysis in the form of statistics and histograms. The two series are available in two and four channel models with sampling rates to 4Gsample/s, up to 8Mbyte of record length and 1GHz bandwidth. Tektronix UK Ltd. Tel., 01628 403300; fax, 01628 403301.



### Emc gaskets

**Holland Shielding Systems** has a new engineering handbook on its range of emc gaskets for electronic enclosures. Most of the gaskets, which are in the 0.8-60mm range of sizes, can be used in existing equipment without design changes by virtue of the self-adhesive backing and low closure force required. The gaskets are in strip form or as ready-made gaskets, are in flame-retardant or high-temperature versions and are also available with an environmental seal. Holland Shielding Systems bv. Tel., 0031 78 6131366; fax, 0031 78 6149585.

### Materials

**Shielding tape kit.** 3M supply an engineering kit for foil shielding tapes to allow engineers to obtain small quantities. The tape provides reliable point-to-point electrical contact for emi/RFI shielding and static draining and is provided with a range of backings and adhesive compounds. Tapes are 0.75in wide and 144in long, replacement rolls being available. Each of the nine tapes in a box is fully described on the box. 3M United Kingdom plc. Tel., 01344 858739; fax, 01344 858758.

**Anti-emi coating.** Chomerics *Cho-Shield 2052* is a conductive coating to give a high level of emi shielding on plastic materials such as polycarbonate, ABS, PC-ABS, Noryl and pvc. It consists of silver-plated copper particles dispersed in a one-component acrylic resin, which works with all available material application methods including high-volume, low-pressure sprays and propeller-agitated pressure pots. The material is abrasion-resistant, stable at high and low temperatures and withstands high humidity and moderately saline fog environments. Parker Hannifin plc, Chomerics Division. Tel., 01628 486030; fax, 01628 476303.

**Thermal grease.** *Easy-Ply* from Redpoint Thermalloy can improve heatsink performance by thirty times. It is applied to the heatsink at the factory and protected by a pull-off



cover until needed, whereupon the whole heatsink with the grease in place is put into position with the size and shape of grease interface tailored to the application. *Easy-Ply* is non-toxic and stable and works over the -40°C to 204°C range, with an indefinite shelf life. Redpoint Thermalloy Ltd. Tel., 01793 537861; fax, 01793 615396.

### Printers and controllers

**Thermal print heads.** Rohm's new series of thermal print heads come in printing widths of 2, 3, 4, 8 or 10in and with 8-dot/mm resolution. All models have Rohm's own drive ics. The *GC20* is a label printer and replaces the *CYS* series; it has superglass protection on the dot line, epoxy ic coating and a shrouded, polarised connector. *GC10* is similar, but smaller. Lowest cost model is the *GH1*, which is a small fax head, meant for epos printers or machines giving receipts. Keatronics Ltd. Tel., 01727 812222; fax, 01727 811920.

### Production equipment

**Metal wrist band.** For static control, TBA ECP has a new metal wrist band that is more comfortable than elasticated types since it can be worn looser and is said to be safer than other metal ones on the market. It is fully adjustable and has a stainless steel linked inner layer with a plastic moulded outer cover, which is immune to scratching and cannot expose the metal, so preserving the wearer from possible contact with live parts. There is a 10mm stud to receive a standard coiled cable. TBA Industrial Products Ltd. Tel., 01706 47718; fax, 01706 46170.

**Piezoelectric pump.** Densitron's *Crystal pump* uses a piezoelectric stack element to give precise control of fluid flow. Metering of the fluid is obtained by varying crystal drive amplitude and frequency to give flows at rates between 0.05μl/min to

**Low-level switching.** EAO-Highland's *84 Series* is a modular system of pushbuttons and indicators that can be assembled to make a wide range of switches by combining lenses, actuators, switches and mountings. The units are suited to low-voltage switching in industrial positions, for example in computer-based controls. Switch ratings are from 50mV to 42V and 10μA to 100mA ac or dc, maximum power rating being 2W and typical rebound time under 1ms. They can be had in aluminium or plastic and flush mount in a standard 22.5mm diameter cutout. Depth behind the panel is 18-31mm and the switches are sealed to IP67, resistance to vibration and shock is high and the metal fronts make them proof against electrostatic discharge. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

380ml/min; frequency can be at frequencies as low as 20Hz when noise might be a problem, although the noise at any frequency is small. Response is virtually instantaneous for the precise metering of small quantities of fluid. The pump body is available in Teflon, polyacetal, stainless steel or other materials to suit different fluids. Densitron Europe Ltd., 01959 700100; fax, 01959 700300.

**Fluid dispenser.** From Camelot Systems Inc., the *CAM/ALOT 680 Series* rotary positive displacement pump or glop dispenser accurately provides encapsulation and flip-chip underfill in precise quantities with no drips; it will pump 10-200mg of fluid to within ±2% by volume. It has a positive needle shut-off and the material is under constant low pressure to prevent cavitation. There

Please quote "Electronics World" when seeking further information

is a micrometer built in to help adjust the gap between the dispensing auger and its seat and the interchangeable cartridge assembly can be cleaned in minutes. A heating cartridge brings the material to the required temperature. Dage Precision Industries Ltd. Tel., 01296 393200; fax, 01296 331585.

### Power supplies

**Micro-controlled 600W psu.** Vicor's FlatPAC family of 50-600W supplies has a microprocessor-controlled front end and now has industry-standard input terminals and high-current output connectors. Input is autoranging. Thousands of configurations are possible from systems with one to three outputs at various powers, the FlatPAC family being modular in design; units contain up to three dc-to-dc converters, each providing up to 200mW, in a choice of chassis-mounted enclosures measuring 35mm high, 219mm long and 64, 125 or 186mm wide. Regulation is 0.05%, ripple 1% pk-pk, efficiency 80-90% and total remote sense compensation 0.5V. XP plc. Tel., 01734 845515; fax, 01734 843423.

**Low-profile 150W supplies.** First arrivals in a new series of low to medium-power supplies from Power-One single and multi-output switched-mode supplies are making an appearance. MPU150 Series units are in 1.5in 1U U-channel cases with optional covers and have power-factor correction to IEC61000-3-2 with a 85-264V ac input range. With air cooling given by the user's system or by an optional fan, each unit will produce 150W and other features include mains fail, current sharing, thermal shutdown, remote sensing and optional remote inhibit. The MPU series meets a truly impressive number of emi, rfi and safety standards. Power-One Europe. Tel., 01769 540744; fax, 01769 540756.

**Compact 25W dc-to-dc.** In a package measuring 2 by 2 by 0.375in, the OB Series of dc-to-dc converters by Amplicon give up to 25W, pin-out being to industry standard. Input is 12-48V dc, efficiency up to 86% and outputs 5/12/15V dc and  $\pm 5/\pm 12$  and  $\pm 15$  V dc, outputs being trimmable by  $\pm 10\%$ . Regulation and stabilisation are both 0.2%, temperature coefficient  $\pm 0.02\%/^{\circ}\text{C}$  and ripple 150mV maximum. Cased or open models are available. Amplicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 01273 570215.

**Charger controllers.** ADP3810/1 by Analog Devices are battery charger controllers offering programmable current limiting and precise voltage limiting for the constant-current, constant-voltage charging of lithium

ion, nickel cadmium and nickel metal hydride cells. The 3810 has its own precision resistors for 1% accuracy on Li-ion cells, while the 3811 uses external resistors for a wide range of output voltages. Control voltage input, which is buffered, takes either an RC-filtered pwm microcontroller output or the divided reference voltage. Analog Devices Ltd. Tel., 01932 266000; fax, 01932 247401.

**Charge-pump converters.** National Semiconductor's LM2660/1 are CMOS charge-pump voltage converters for battery-powered equipment, PCMCIA cards and hard-disk drives. Conversion is 1.5V-5.5V at 90% efficiency, operating current being 120 $\mu\text{A}$  for most loads. Output impedance is 6 $\Omega$ , giving a droop of 0.6V at 100mA. The LM2661 also has a low-current shutdown mode of operation, in which it draws less than 1 $\mu\text{A}$ . National Semiconductor GmbH. Tel., 0049 1805 32 7832; fax, 0049 814103515.

**3W dc-to-dc converter.** Coutant's PP3 low-profile converters have been reduced in price, due to new methods of manufacture and a move to another factory. The PP3-48-12 is the first in the cheaper series and is suited to distributed and modular systems. Input is 32-63V dc, input current at 48V being 90mA. A single 12V, 120mA output is accurate to within  $\pm 5\%$ , ripple is 150mV and efficiency is 75%, with stabilisation and regulation at 0.4% and 5% respectively. Coutant Lambda Ltd. Tel., 01271 865656; fax, 01271 864894.

### Radio communications products

**Receiver chip set.** RF Monolithics' chip-set for its amplifier-sequenced receiver, which needs no frequency changing, for remote-control and security use is available from Acal. ASH chips include a low-loss surface acoustic wave filter for front-end selectivity, a saw delay line and rf circuitry to form the amplifier-sequenced gain and detector stages. Typically, sensitivity is -100dB without the use of heterodyning or regenerative circuits; virtually no rf emissions are produced. Chip-sets for frequencies between 303.825 and 433.92MHz are available, all running on 3V lithium batteries and drawing 1.1mA. Acal Electronics Ltd. Tel., 01344 727272; fax, 01344 424262.

**40GHz up/down converters.** Transmission up-converters and receiver down-converters from Anglia Microwaves are for 40GHz video distribution. The DUC-4042N810 and DDC-4042N610 cost less than travelling-wave tubes and are more reliable, life-expectancy being ten years of full-power operation.



Intermediate frequencies of 1.85-2.15GHz and rf at 40.5-42.5GHz are converted, local oscillator costs being reduced by the use of a multiplier before the mixer stage, which allows the use of X-band instead of K-band components. If/rt conversion gain in the DUC is 20dB to give an rf power output of 1mW, or 200mW with an optional amplifier. Oscillator leakage and sideband noise are a minimum of 20dB below signal. Down-conversion gain in the DDC is 30dB and noise 8dB in ssb operation. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

### Switches and relays

**S-m fuses.** Three new surface-mounted PolySwitch resettable fuses by Raychem are intended for use with Universal Serial Bus ports, protecting against shorts and overcurrent conditions when plug-and-play boards are used. In the presence of a fault, the fuses switch to a high-resistance state, reverting to normal when the fault is cleared. SMD20 satisfies a demand for low resistance (50m $\Omega$ ) and voltage drop on USB ports; miniSMDC110 is for self-powered port protection, having a 1.1A hold current and 160m $\Omega$  resistance; and miniSMDC075 is for bus-powered application, holding on 0.75A and showing 300m $\Omega$  resistance. Raychem Ltd. Tel., 01973 572692; fax, 01973 572209.

### Transducers and sensors

**Level and flow sensors.** Crydom has ranges of liquid level and flow sensors with a large number of options to meet most applications; if a requirement is not available, there is a design service to produce it quickly. Level sensors use float switches operated by reed-switch and magnet in vertical and horizontal

**"Lowest-cost" PIC Ice.** Jointly developed by Neosoft and RF Solutions, ICEPIC Junior-16 is a modular unit that reduces development time and cost by working with all PIC 16C6/7/8/9X processors. It runs in a Windows environment, using the same GUI as others in the ICEPIC family, and is non-intrusive, being capable of source-level debugging in assembler or C at the maximum processor speed. It has a standard Microchip emulation chip, 8K of 16Cxx emulation memory and a fast RS-232 interface for communications with the host at 57.6kba/s. The basic emulator costs £299 and additional modules for other processors £99. RF Solutions Ltd. Tel., 01273 488880; fax, 01273 486661.

configuration and internal or external mounting; materials used for manufacture are specified for the liquid in use, from boiling water to acids. The flow detectors use double-isolated reed switches and are housed in Hoechst Hostaform, which is acetal copolymer. Models in the range work in hot or cold water low-pressure systems and in alcohol or dilute acids and there are variants with triac buffers for improved switching, particularly with inductive loads. Crydom. Tel., 01202 897 964; fax, 01202 891 918

## COMPUTER

### Computer board-level products

**Network controller for cards.** TDS2020 16-bit and TDS9092 8-bit embedded computers by Triangle Digital Services can now be

networked using the TDS2020CAN board, which fits under one of the TDS cards to connect it to a multi-drop RS485 CAN network. Users are then able to, for example, display messages on a remote lcd, toggle relays and lamps in remote equipment, acquire data and control remote equipment. CAN networking is over two twisted pairs over distances of up to 1km, with up to 110 nodes, each optically isolated. Triangle Digital Services Ltd. Tel., 0181-539 0285; fax, 0181-558 8110.

### Computers

**200MHz single-board computer.** Eltech Solutions announces Eurocom 128, a VMEbus single-board computer using the 200MHz Pentium processor, with options of IDE or SCSI hard disk support by way of the P2 connector and a choice of operating software including VxWorks. Its 64-bit wide memory allows the use of 8Mb to 128Mb ram using standard 8Mb PS/2 simms, memory size being automatically detected; memory can be optionally boosted by 256Kb second-level cache and EDO rams with hyper-page mode. Bios is in updateable boot-block flash eeprom and there is a 2K serial eeprom for user's data. A variety of monitors,

both crt and flat-panel displays, is on offer and the PCI-based graphic interface is compatible with the IBM VGA standard as well as backward to the EGA and CGA standards. The board has two asynchronous 16550 compatible serial channels with hardware handshaking and a bidirectional Centronics port supporting the IEEE1284 enhanced mode. Standard pc software is supported. Eltech Solutions UK Ltd. Tel., 01908 260044; fax, 01908 260012.

### Workstation for clean rooms.

Deeco, part of LucasVarity, has produced the SealTouch clean room computer, which has virtually no effect whatever on its surroundings; it is completely sealed and has no need for a keyboard or separate mouse. No fans or filters are needed for cooling, since the computer is housed in a cast aluminium case that acts as a heat sink, and the infrared touch screen and flat-panel electroluminescent or active-matrix lcd colour display are sealed to prevent air entering or leaving. The touch mouse and on-screen keys can be used precisely even when wearing gloves. Lucas Control Systems Products. Tel., 0049 7024 971214; fax, 0049 7024 971240.

### Data communications

**Wireless RS-232.** Radio Data Technology claims its LPRS232 is the first reliable application of radio to data communication using RS-232 protocols. The transceiver is available in 428MHz and 433.92MHz with a range of 120m line-of sight or 30m in buildings, with a longer-range version, the -300 type, providing a range of over 1km. Transmission speed is selectable between 4.8kb/s and 19.2kb/s. Normally, the unit remains in receive mode until data arrives at its RS-232 input or an rf carrier is detected, whereupon the data is transmitted in packets with a header block containing a sync. word, the number of bytes in the packet and a checksum. The unit is compact, measuring 114 by 63 by 17mm, uses a single 8-12V supply and draws 45mA unloaded. Low Power Radio Solutions Ltd. Tel., 01993 709418; fax, 01993 708575.

### Development and evaluation

**Low-cost 68HC(7)05 development.** Motorola has announced JICS, which is a £30 development kit for the 8-bit MC68HC(7)05J1A microcontroller. It contains everything needed for development and debugging,

including assembly programming, editing, software simulation and in-circuit simulation. The kit provides a sample device, cabling, power supply and full documentation. Motorola. Fax, 01354 688248.

### Software

**Power analysis.** Voltech has Windows software for visual power analysis to assist in the remote configuration, control and monitoring of single and three-phase power measurements. The software is designed for use with the company's low-cost PM100/300 power analysers and eliminates the need to program the analyser's front panel, enabling remote set-up, running and recording of measurements including real and apparent power, crest factor, efficiency, harmonic distortion and inrush current. Results are shown graphically or numerically and both ASCII and CSV formats are used for transfer to word processors and spreadsheets. New capabilities conferred by the software include modification of the thd formula, adjustment of averaging depth and the setting of fixed ranges for all power measurements. Voltech Instruments Ltd. tel., 01235 861173; fax, 01235 861174.

# ADVERTISE FREE OF CHARGE

## Subscribers\* to Electronics World can advertise their electronics and electrical equipment completely free of charge

Simply write your ad in the form below, using one word per box, up to a maximum of twenty words. Remember to include your telephone number as one word. You must include your latest mailing label with your form.

\* This free offer applies to private subscribers only. Your ad will be placed in the first available issue.

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

**Trade advertisers - call Joanna Cox on 0181-652 3620**

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


Please send your completed forms to:

Free Classified Offer: Electronics World, L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

# Skin effect

**Nick Wheeler outlines skin effect and describes why it is irrelevant at audio frequencies.**

Everyone involved with electronics will have heard of skin effect. And most will know that it has the effect of increasing the effective resistance of a conductor as signal frequency increases. This is due to the current flow being increasingly concentrated on the outer surface of the conductor.

The effect can be so pronounced that in some cases a thin-walled tube is as effective as a solid conductor. Silver plating and the use of oxygen-free copper are commonly used to reduce the effects of skin effect.

Silver plating reduces resistance of the conductor skin while oxygen-free wire has a fractionally lower resistance than the standard-quality option. Oxygen-free cable can be simulated by simply increasing conductor cross section. The diameter increase necessary to do this is so small as to be negligible.

Note that effective resistance, as referred to above, is also known as 'rf resistance'. It is an ohmic effect, and nothing to do with reactance. It's operation can be detected thermally.

**What causes skin effect?**  
Consider a conductor made up of many strands of thin uninsulated wire, and carrying an alternating current. Current flowing through any single strand produces a field which cuts through the bulk of the surrounding conduc-

tors. In effect, these conductors form shorted turns as they are in intimate contact.

Currents flowing in the shorted turns oppose that flowing in the specimen strand, but those currents have to go somewhere. It is easy to show that they concentrate on the outer surface of the conductor bundle, or in the case of a single large conductor, on the surface.

Fields associated with the outside surface intersect less conductor material. As a result, the opposition to current flow is less on the surface, which is where it then flows. This effect depends strongly on increasing frequency and – because of the larger cross-sections involved – with increasing sizes of solid or uninsulated stranded conductors.

### Stranded versus solid conductors

Imagine a conductor comprising 55 uninsulated strands of 0.1mm diameter copper, such as RS356-167. This has a copper cross-section of 0.43mm<sup>2</sup> and an equivalent solid diameter of 0.74mm.

At high kilohertz and megahertz frequencies, this cable performs very much the same as 22SWG solid, with a diameter of 0.71mm which has, as predictable from theory, fractionally less rf resistance. A conductor made up of 15 strands of enamelled 36SWG, amounting to a cross-sectional area of 0.425mm<sup>2</sup>, as opposed to the 0.43mm<sup>2</sup> of the 55 uninsulated-strand wire, has about half the rf resistance at frequencies in the 1 to 2MHz region. This is, I think, as high as you need to consider if you are interested in audio.

Note that these principles are not new. They have been known and applied since the earliest days of radio, in the form of Litz wire.

### The facts

It is a matter of simple scientific fact that – to three decimal places – a conductor of 0.2mm outside diameter has negligibly more rf resistance at 100kHz than its dc resistance. What this means is that, up to this frequency, the current distribution is uniform across the conductor cross-section, thereby making oxygen-free copper and silver plating irrelevant for

audio work.

At 1MHz the rf resistance is up by 9.5%, where silver plating and so on really do start to be useful. On the other hand a conductor of 2mm outside diameter has 2.625 times the rf resistance, compared with dc resistance, at the significantly low frequency of 10kHz.

Figure 1 from reference 2, illustrates this, and Table 1, from the same source, summarises some experimentally determined data. Of course, if a conductor of very large cross-section is used, the dc resistance, and consequently the rf resistance, will be low in comparison with the highly variable impedance of the loudspeaker load.

Domestic twin-and-earth cable of adequate cross-section may well be the most cost-effective route<sup>1</sup>. In terms of power loss, rf resistance is irrelevant in audio applications. What matters is that the low output impedance of a good amplifier may not be seen as effectively damping hf loudspeaker transients.

### In summary

What this boils down to is that cables made up of many strands of thin uninsulated wire offer no advantages over the same cross-section of solid wire, except mechanical flexibility. Separately insulated multistrand cable can offer genuinely superior performance.

It would be prohibitively expensive to make up a coaxial cable of which the outer braid was composed of insulated wires, commoned at each end, and with an insulated multi-strand inner, but this must be the ultimate cable. ■

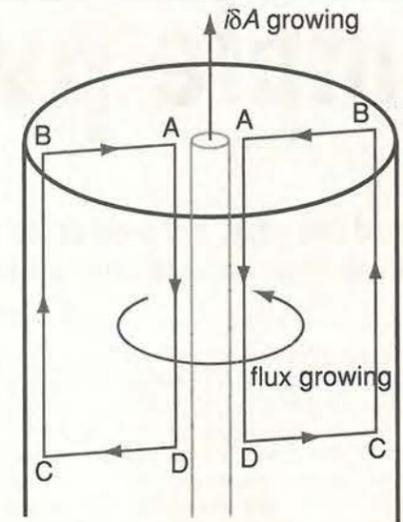
### Reference

1. Speaker Cables, C. Bateman, EW Feb 1997
2. Services Textbook of Radio Volume 1 HMSO 1956.

### Skin deeper

The following is an extract from reference 2.

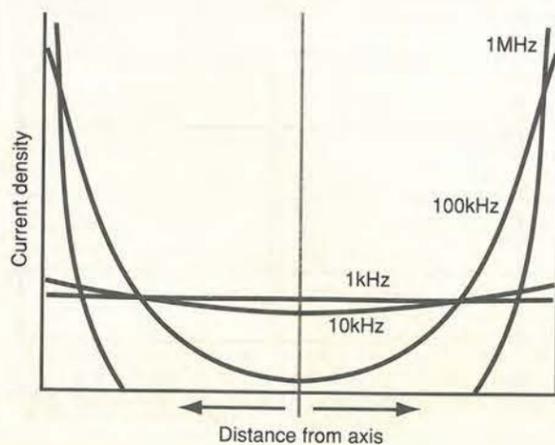
Current density in this wire is  $iA/cm^2$ . Current  $i\delta A$  flows through an area  $\delta A$  on the axis of the wire and grows, creating magnetic field  $H$ . Through any radial section of the wire, such as ABCD, flux due to  $H$  is growing, resulting in an emf between A and D along the axis, and from C to B on the outer side. This emf tends to reduce current flowing along the axis and increase that flowing along the outside of the wire.



*Skin effect. Any change in current along the axis causes induced voltages which oppose this change along the axis and promote it in the outer regions.*

Table 1. Effect of frequency on rf resistance in two wires with different diameters.

Frequency (Hz)	Wire diameter	
	2mm	0.2mm
10	1	1
100	1	1
1k	1	1
10k	1.095	1
100k	2.626	1
1M	7.7	1.095
10M	23.8	2.626
100M	74.7	7.7



Current distribution across a 2mm conductor at various frequencies demonstrates skin effect.

## Halcyon Electronics Off-Air Frequency Products

**We manufacture a range of Off-Air Frequency products including frequency standards, sources and disciplined standards including GPS, Customised units also available**

**Precision Frequency Source**  
1kHz to 16MHz sinewave output, 0.0001Hz resolution, Easily settable via decade switches, VCXO backup as standard

**Off-Air Frequency Standard**  
1MHz, 5MHz and 10MHz, outputs, Options include Sinewave, Signal inhibit and Audio Warning

CIRCLE NO. 128 ON REPLY CARD

---

**We are well known for our quality new and used test equipment. Our list is extensive, ranging through most disciplines. Call for details**

CIRCLE NO. 129 ON REPLY CARD

## Halcyon Electronics

423 Kingston Road, Wimbledon Chase, London SW20 8JR  
Phone: 0181 542 6383 Fax: 0181 542 0340

CIRCLE NO. 130 ON REPLY CARD

## WE HAVE AN EXCELLENT CHOICE OF QUALITY, FULLY GUARANTEED USED TEST EQUIPMENT

<p><b>OSCILLOSCOPES</b></p> <p>TEKTRONIX 465 Real-Time Scope.....£300</p> <p>TEKTRONIX 475 Real-Time Scope.....£425</p> <p>TEKTRONIX 475A Real-Time Scope.....£475</p> <p>H.P.1725A 275MHz Real-Time Scope.....£450</p> <p>MEGURO MO 1254A 50MHz Real-Time Scope.....£200</p> <p>HAMEG HM605 60MHz Real-Time Scope.....£250</p> <p><b>DIGITAL OSCILLOSCOPES &amp; DSO ADAPTORS</b></p> <p>H.P.54501A 100MHz Digitising Scope.....£1400</p> <p>YOKOGAWA DL1200 4 Channel 100MHz, Digitising Scope.....£1000</p> <p>THURLBY Digital Storage Adaptor DSA524 £250</p> <p><b>SIGNAL GENERATORS</b></p> <p>TEKTRONIX SG503 Levelled Sine Wave Generator.....£700</p> <p>TEKTRONIX PG506 Calibration Generator.....£850</p> <p>FARNELL LFM4 Sine/Square Wave.....£50</p> <p><b>GENERAL TESTERS</b></p> <p>POLAR TONEOHM 700.....£40</p> <p><b>MULTIMETERS</b></p> <p>SELECT TEST AVO.....£35</p> <p>TAYLOR AVO.....£35</p> <p>AVO Fet Tester TT167.....£85</p>	<p><b>OSCILLOSCOPE CALIBRATORS</b></p> <p>BRADLEY 192 Volts/Time/Pulse Edge.....£400</p> <p><b>POWER SUPPLIES</b></p> <p>BRANDENBURG 5kv Supply.....£300</p> <p>VARECO 2A 30v Variable PSU.....£40</p> <p><b>TEST BRIDGES</b></p> <p>MARCONI Universal Bridge TF2700.....£100</p> <p><b>EX-DEMO STOCK, (12 MONTHS GUARANTEED), EXCELLENT CONDITION ACTIVE PROBES</b></p> <p>ARMEX FSP 500 500MHz Switchable, (x1/x10).....£350</p> <p>ARMEX FP 500 500MHz (x10).....£250</p> <p><b>BRAND NEW AND BOXED DIFFERENTIAL PROBES, (WITH 12 MONTHS GUARANTEE)</b></p> <p>GOULD PB57 100MHz, 400v, x10/x100.....£450</p> <p>GOULD PB54 300MHz, 6v, x1/x10.....£450</p> <p><b>BARGAIN BASEMENT</b></p> <p>SANGAMO S82 Current Meter.....£20</p> <p>TEKTRONIX 106 Square Wave, Signal Generator.....£50</p> <p>TEKTRONIX 191 Constant Amplitude, Signal Generator.....£50</p> <p>VARIOUS DVM'S.....£25</p>
---	--

Please call for stock availability and details. Carriage for units over £200 is £12. Carriage for units under £200 is £8. VAT to be added to the total value of the order. User manuals are supplied if possible. Used equipment guaranteed.

## ARMEX ELECTRONICS LTD.

TELEPHONE: 01492 580080 FAX: 01492 580081  
19, FFORDD SAM PARI, CONWY MORFA INDUSTRIAL ESTATE, CONWY, N. WALES LL32 8HH.

CIRCLE NO. 131 ON REPLY CARD

# Simple pwm power amp

Designed for efficient low-frequency and dc power driving, Richard Lines' pwm amplifier can deliver up to 5A at 25V.

This note describes a pulse-width modulated amplifier capable of producing a unipolar output of up to 25V at 5A. Designed for simplicity, the circuit is based on an *LT1074CT* switch-mode power supply IC from Linear Technology. It is suitable for use in servo systems, or as a heater driver or thermoelectric cooler, where power conversion efficiency is a priority and the control signal is a few hertz or less. The design is especially useful in low-voltage high-current applications, where a standard linear regulator would waste a lot of power.

## Circuit operation

The chip has an internal oscillator running at 100kHz. The square wave generated is pulse width modulated with a duty cycle controlled by the voltage on pin 2 (out). The chip's main output appears at pin 4 (switch); this is the dc input chopped according to the duty cycle.

Components  $D_1$ ,  $L_2$ ,  $C_4$  form the conventional flyback circuit and low pass filter. Inductor  $L_2$  needs some consideration: the magnetic core needs to be large enough not to saturate at peak currents.

My prototype consisted of 32 turns of 1mm

wire on an *RM400* pot core. If the full 5A output is needed then the inductance should be dropped to 50 $\mu$ H in accordance with the device data sheet. Capacitor  $C_4$  needs to be rated at the power supply voltage since the output voltage will rise to this level if the load is accidentally connected.

The feedback pin connects internally to the error amplifier input. In the usual power supply circuit, it samples the output voltage via a potential divider. Also, the output pin connects internally to the error amplifier output. This makes it possible to build an inverting amplifier from the error amp with gain set by  $R_1/R_3$ .

I found a swing of something less than 1V at pin 2 enough to sweep the duty cycle from 0% to the chip's maximum of about 90%. In the prototype application, an offset current was required into the summing junction. This is provided by  $R_2$  from a regulated 5V source.

Components  $R_4$  and  $C_3$  are recommended by the manufacturers for circuit stability. Capacitor  $C_2$  was found necessary for the same reason.

It is important that  $D_1$  is a high current Schottky barrier type. Resistor  $R_5$  and  $C_5$  were fitted to reduce ringing; they are not necessary and are not recommended by the chip manufacturer on the grounds of slightly reduced

efficiency. However the output was less noisy with them fitted and this was an important consideration. An obvious alternative is to fit an extra low pass section in the output lead.

The chip contains an analogue multiplier. This is used to reduce the duty cycle with increasing supply voltage thus keeping the output voltage approximately constant – depending only on the control input. Without this circuit element, any power supply variations would be seen in the output in proportion to the duty cycle. The presence of the analogue multiplier gives a useful degree of ripple rejection.

Input filter  $L_1/C_1$  is recommended to stop switching transients getting back into the general power supply. Capacitor  $C_1$  should be close to the IC.

## Setting up

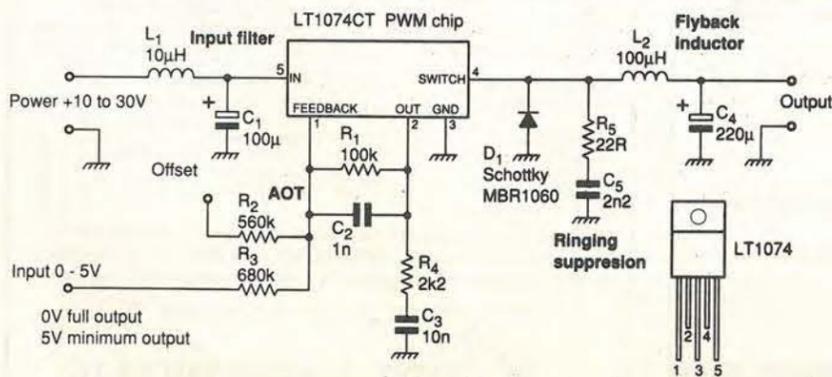
First consider the maximum duty cycle required. This will depend on the ratio of output voltage to power supply voltage and don't forget to allow about 1.5V lost in the switching transistors.

With the input open circuit resistor  $R_2$  should be adjusted so as the output voltage is about half the expected maximum with a suitable dummy load connected. Check the waveform on pin 4 and see if the duty cycle is as expected.

Now adjust  $R_3$  if necessary to ensure that the output goes from nearly 0V to the expected maximum as the input control voltage goes from 5V to 0V. Pin 1, feedback, will always be at 2.21V with respect to ground if the circuit is operating correctly.

I used this circuit as part of a temperature controller servo loop. With a power supply of 15V, the prototype produced 0 to 11V with the component values shown. This was used to run a small heater of 10 $\Omega$  resistance.

Efficiency was measured at over 80%, except for very low outputs. The circuit is quite linear over the middle 80% of the range but deviates at both extremes. This was not of significant for me since the circuit was inside a temperature controller loop.



Designed as part of a temperature controller servo loop, this circuit produced 0 to 11V with the component values shown using a 15V supply. The controller was used to run a small 10 $\Omega$  heater. Zero volts at the input gives full output while 5V gives minimum output.

**The Headphone Amplifier Box**  
Balanced or unbalanced microphone or line input to headphone output  
Professional portable units operating from an internal PP3 battery or external mains adaptor



- \* Precision transformerless balanced input
- \* Bridged headphones output drive
- \* Sensitivity selectable over a wide range of input levels
- \* Low noise and distortion
- \* High common mode rejection
- \* Loop through facility
- \* Extensive RFI protection

**The Balance Box** (precision mic/line amplifier) –  
**The Phantom Power 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 http://www.confordelec.co.uk/catalogue/

CIRCLE NO. 132 ON REPLY CARD

WE HAVE THE WIDEST CHOICE OF USED OSCILLOSCOPES IN THE COUNTRY

PHILIPS PM3756A Dual Trace 40MHz Delay Cursors	£1750	H.P. 5342A Frequency Counter 10Hz-24GHz	£1750
PHILIPS PM3755 Dual Trace 350MHz Delay Cursors etc	£1500	H.P. 5340A Frequency Counter 10Hz-18GHz	£750
N.P. 5420SA Displaying Oscilloscope 50MHz	£750	MARCONI 2435 Frequency Counter 10Hz-20Hz	£400
TEKTRONIX 2445 4 Channel 150MHz Delay Cursors	£1500	MARCONI 2437 Universal Counter/Timer DC-100MHz	£175
TEKTRONIX 7454S Dual Trace 100MHz Delay Cursors	£800	MARCONI 2438A Frequency Counter 10Hz-500MHz	£225
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep	£400	MARCONI 2434 Frequency Counter 10Hz-80MHz	£125
TEKTRONIX 465 Dual Trace 100MHz Delay Sweep	£400	RACAL 1998 Frequency Counter 1.3GHz	from £850
TEKTRONIX 2215 Dual Trace 60MHz Delay Sweep	£400	RACAL 1991 Universal Counter/Timer 150MHz 9 digit	£450
PHILIPS 3095 2-1 Channel 100MHz Delay Sweep	£700	RACAL 9916 Frequency Counter 10Hz-500MHz	£150
PHILIPS 3095 1-1 Channel 50MHz Delay Trace/Delay	£500	RACAL 3906A Universal Counter/Timer 10Hz-200MHz	£200
PHILIPS PM3217 Dual Trace 50MHz Delay Sweep	£200	MARCONI 2010 True RMS Voltmeter with GPIB	£850
GHULD 05110551 Dual Trace 50MHz	£200	FLUKE 8842A Digital Multimeter 5 1/2 digit True RMS	£500
GHULD 052000 Dual Trace 20MHz	£200	FLUKE 77 Handheld Digital Multimeter 5 1/2 digit	£75
HUSSEI 5530A Dual Trace 35MHz	£200	RACAL 5301A True RMS Multimeter 100Hz-1GHz	£275
PHILIPS PM2020 Dual Trace 15MHz	£200	H.P. 8150A Programmable Precision Pulse Gen 50MHz	£1250
HITACHI V209 Dual Trace 20MHz Mono/Battery	£400	PHILIPS PM5132 Sweep Func Gen 0.1Hz-2MHz Sine/Sq/Tri etc	£250
PHILIPS PM97 Dual Trace 50MHz Scopometer Dig Storage	£700	H.P. 3320A Func Gen 0.1Hz-120MHz AM/FM Sweep/Trip/Gate etc	£400
TEKTRONIX Tekemeter TM855 True RMS MM/Analog/Sweep	£500	PHILIPS PM5175 Pulse Gen 1Hz-50MHz +/-20V	£3000
LEADER LC1000 DMM/Scope 200MHz Digital Storage LCD	£300	WAYNE KERR 3245A Precision Inductance Analyser	£2000
TEKTRONIX 105340 Digital Storage 100MHz 500 Mega Sampler	£1400	WAYNE KERR 4225 Automatic LCR Meter 0.25%	£450
TEKTRONIX 2230 Digital Storage 100MHz Cursors	£600	WAYNE KERR 8424 Digital Component Meter LCR	£150
TEKTRONIX 2210 Digital Storage 50MHz Cursors	£700	MARCONI 2305 Modulation Meter 500kHz-2GHz	£2250
TEKTRONIX 468 Dual Trace 100MHz Dig Storage	£750	RACAL 9098 Automatic Modulation Meter 1.5MHz-2GHz	£300
HITACHI V505A Dual Trace 40MHz Dig Storage	£500	SAVOSDA 252 Automatic Modulation Meter	£150
BUCKMAN 5932 Dual Trace 20MHz Dig Storage	£400	RACAL/DANA 9104 RF Power Meter 1MHz-1GHz 10mW-300W	£325
GHULD 1425 Dual Trace 20MHz Dig Storage Cursors etc	£400	H.P. 355A Wave Analyser 12Hz-50MHz LED Readout	£800
TEKTRONIX 468 Dual Trace 100MHz Delay Analog Storage	£400	H.P. 845A Vector Voltmeter 1MHz-1GHz	from £200
H.P. 1741A Dual Trace 100MHz Analogue Storage	£400	H.K. SMITH Antenna Test Set type 12-602-4	£2000
TEKTRONIX 434 Dual Trace 25MHz Analogue Storage	£250	TEKTRONIX 760 Stereo Audio Monitor	£1500

THIS IS JUST A SAMPLE - MANY OTHERS AVAILABLE

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 1401 with 8554L & 8528B 500kHz-1250MHz

H.P. 1411 with 8555L & 8528A 1kHz-110MHz

H.P. 1415 with 8555L & 8528A 1kHz-110MHz

MARCONI 172370 with TK2373 30Hz-1250Hz

FARNELL 172370 30Hz-110MHz

H.P. 3580A Osc-50MHz

H.P. 3582A Dual Channel 75kHz

H.P. 8435A Tracking Generator/Counter

H.P. 8444A Tracking Generator

H.P. 8620C Sweep Osc with 86220B 1.8-5GHz

H.P. 8620B Sweep Osc with 86220B 0.01-7.4GHz

H.P. 8658A Synthesised Sig Gen 0.1-500MHz

MARCONI 2017FMAM Signal Generator 10kHz-1024MHz

MARCONI 2019A Synthesised FMAM Sig Gen 80kHz-1040MHz

MARCONI 2019 Synthesised FMAM Sig Gen 80kHz-1040MHz

H.P. 8640B Phase Lock Evn Sig Gen 500kHz-512MHz

H.P. 8640A FMAM Sig Gen 500kHz-1024MHz

FARNELL 70520 Synthesised FMAM Sig Gen 10kHz-520MHz

FARNELL 55520 Synthesised FMAM Sig Gen 10-520MHz

FARNELL 17520 Transistor Test Set

MARCONI 17261 Sweep Generator 1-320MHz

H.P. 8616A UHF Signal Gen 1.8-4.5GHz

H.P. 8614A UHF Signal Gen 800MHz-2.4GHz

H.P. 8655A 0.01-220Hz

ALITECH 727 0.001-200Hz

ARTRIS MS208 10kHz-1GHz (slight shadowing on storage)

H.P. 185 with 8558B 10MHz-150MHz

H.P. 1411 with 8558A & 8528B 10MHz-180Hz

H.P. 1411 with 8558A & 8528B 500MHz-1250MHz

H.P. 1411 with 8558A & 8528A 1kHz-110MHz

H.P. 14



## Charge alkaline cells

I read with interest the article on recharging of alkaline cells in the March 1997 issue of *Electronics World*. There are two points that appear to be missing. They are of a supplier of suitable pcbs and a supplier of the special value resistors  $R_e$ ,  $R_f$  and  $R_i$ .

With the aid of a standard 12-segment switch unit it would be possible to configure it as a 3-pole-4-way unit so as to be able to switch between the various battery types/ratings for each charger unit and a double switch unit for a pair of chargers?

Even better would be a 4-pole-4-way switch so that the respective socket could be switched as well so ensuring that the switch position matched the cell(s) being charged.

Philip T. Bellamy  
Britten  
Switzerland

## Rod replies

Some consideration was given to producing a pcb, but it was shelved as it was thought not to be an economic proposition at that time.

However, it is likely that I will be producing another article on recharging silver-zinc button cells using the same techniques, and I will be designing a pcb for this. If this article is published, the pcb will be designed to accommodate alkaline cell charging too.

It is possible to switch between cell types using a multi-pole mechanical switch, but the contacts needs to be good quality. I tried this with wafer switches, but the reliability of the contacts fell off rapidly with use so I did not consider it to be very safe. As you may have noticed from the article, the accent was on safety.

If this type of switching were to be attempted, I would suggest a switch with gold-plated contacts and a good wiping action, totally enclosed to exclude dust. I have yet to discover a reasonably priced switch of this specification.

You would also have to ensure that a high charge was never administered to a small cell by wrong switch selection. This is easy to avoid in practice – use individual cell holders for each cell type rather than the expendable "universal" cell holders you often see in commercial battery chargers.

As for the 'special' resistors, no special values are needed. Need I explain the trick?

Thank you for your interest.

## Noise in emc

Ann Baker's letter in the January issue, and also a recent editorial on the subject of emc prompts me to write to you.

My credentials include a major paper entitled 'Crosstalk (Noise) In Digital Systems' in *IEEE Trans Comp. EC-16*, Dec. 1967 and a major paper in *IEEE/IEPE Proceedings (IERE Pub. No 60)* of the September 1984 International Conference on emc entitled 'The Fundamentals of Electromagnetic Energy Transfer'. In addition, I was employed as the 'emc expert' on sundry major British weapons projects including Stingray.

Working in the USA in 1965 on military equipment design, I knew that the emc requirements for military weapons were fraudulent – a slush-fund where US Navy admirals and the like presumably owned most of the stock in the accredited test houses.

Don White later became king of the pseudo-technical aspect of emc, and had his 'academy' suitably situated near Washington DC. Any 'engineer' appointed 'EMC Expert' on a mirror British weapons project would pay £400 for the Don White 'Bible' and copy slabs of it into his reports – duly to join the torrent of paper going into the MOD.

An attendant at a Don White seminar told me that Don was anxious to get hold of my books.

The key point is that the technical level of competence of the emc sub-culture is the lowest of any branch of electrical and electronic engineering. There will be no correlation between whether two modules have passed the emc tests, and whether they subsequently interfere with each other. This is because the theoretical basis for these tests is hopelessly flawed.

When I heard, some fifteen years ago, that Britain would join up with Europe on emc standards, I telephoned the government department responsible and could find no evidence of any technical element in our government's decision making on this matter. The whole thing was just a paper empire.

Europe EMC standards, which follow the US Don White style, will only result in products made in

Europe costing some 10-20% more, and it will also drive out small companies and stop the manufacture of customised products. Companies in the one-off business are closing down.

In 1956, when I graduated in engineering, I took up electrical engineering, not mechanical. This is because civil and mechanical engineering had nonsensical, unscientific standards and

regulations. These nonsenses – such as the fact that the architecture of a Roman Point high-rise was not culpable when it collapsed because he kept within regulations – has now taken over electronics.

The decadence of the IEE has meant that we could not work through it to protect our industry against the phoney emc nonsense.

After 30 years of emc talk and enforcement, you cannot work your

## Q & A

**Q** This aspect of digital signal processing which puzzles me. Consider a system sampling at 40.000kHz whose input is a sine wave just below the Nyquist frequency at 19.999kHz. Initially, assume that the sampling points coincide with the peaks of the input signal; the output from the a-to-d converter will alternate between maximum and minimum values.

A quarter of a second later, the system will have taken 10 000 samples but the input signal has only completed 4,999.75 cycles. The sampling points thus now coincide with the zero-crossings of the input signal, and the output from the converter will be zero.

After another quarter-second, the system has taken 20 000 samples and the input signal has completed 9 999.5 cycles. The sampling points once again coincide with the peaks of the input signal, only the other way up; the output from the converter alternates between minimum and maximum values.

After three-quarters of a second, the converter output will be zero again; and after a whole second, we are back to the starting point with maximum and minimum converter output.

When this signal is replayed, the output from the digital-to-analogue converter will not be a signal at 19.999kHz. It will be at 20.000kHz squarewave, whose sharp corners will be knocked off by the analogue filter following the d-to-a converter to give a 20kHz sine wave, whose amplitude falls to zero twice per second and whose phase reverses at the points of zero amplitude. This would be heard, by those golden-eared individuals whose hearing extends up that far, as a high-pitched whine going 'wuhwuhwuhwuh'.

More generally you can see that, for an input signal close to the Nyquist frequency, the output signal will be a sine wave at the Nyquist frequency, whose amplitude falls to zero at a rate of twice the difference between Nyquist and signal frequencies. So when attempting to record a 20kHz signal on a cd, you would expect an output from the cd player of a 22.05kHz whine – inaudible – and 4.1kHz whine – very audible.

Now I have heard many criticisms made of cd players, some more rational than others, but a tendency to transform the high frequency content of the input signal into strange whines and buzzes further down the scale was never one of them.

I have occasionally come across writings which purport to knock down this paradox. They generally start out by describing such a signal as I have done – perform some mathematical juggling which leaves me floundering – and triumphantly announce that in some manner averaged over many cycles we do get a 19.999kHz sine wave after all. But surely any filter able to perform such magic would have to delay the signal for many cycles to 'see what's going on'?

In the example above, unless the filter had a time delay of over a second, you would surely still get a high-pitched whine going 'wuhwuhwuhwuh'.

Could someone please explain in as non-mathematical a way as possible why we apparently, do not?

Chris Bulman  
Bedford

lap-top in an aeroplane, and a car's brakes come on when you operate your mobile telephone. You cannot listen to your fm radio while your computer mouse is on.

At the same time, I cannot get any theatre in which to debate the theoretical base of these problems with the emc punkah-wallahs.

Ivor Catt  
St Albans  
Hertfordshire

## Crossover distortion and Miller capacitance

I read Prof. Cherry's letter with great interest concerning the position of the stabilisation capacitor in an audio amplifier<sup>1</sup>. I fully agree that the position recommended by Self<sup>2</sup> is inappropriate for reducing crossover distortion. I am sure, however, that most of your readers will realise that the position Self suggests, Fig. 1, is incapable of allowing crossover distortion to be fully suppressed.

Consider a simple output stage which has no bias applied as shown in Fig. 2. If the driver stage had to

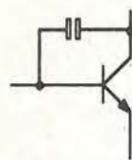


Fig. 1. Miller compensation.

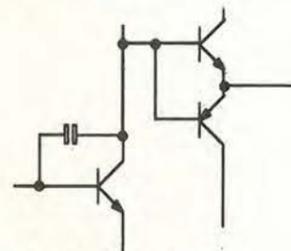


Fig. 2. Unbiased Class B amplifier.

provide a continuous signal for a given input, the collector voltage will have to move in a very short time, tending towards being infinitesimal, by, about  $1.2V - 2V_{be}$  – to ensure a continuous output current. The maximum speed at which a practical circuit could respond would be limited by the current which could be dumped into or extracted from the compensation capacitor, increasing the Miller effect, according to the equation,

$$\frac{dV}{dt} = \frac{i}{C}$$

Clearly, the larger the capacitor the higher this current would be. The burden for the charging current falls on the transistors ahead of the voltage amplifier stage. This causes

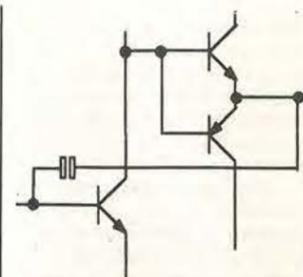


Fig. 3. Cherry's recommendation.

the concerns about the input stage overhead during fast signal peaks. In turn this endorses Prof. Cherry's view that fairly large resistors are needed in series with the input stage emitters to avoid possible transient intermodulation distortion. For example, a 1mA current source could only charge a 220pF capacitor at 4.5MV/s. Although high, this is comparable with a 60kHz signal at 20V amplitude.

In a circuit which has a bias, normally intended to avoid the 'dead-band', some considerable reduction in crossover distortion is achieved, according to Self's results, although he admitted problems with residual distortion, which as I have indicated cannot be cured by his capacitor position.

Prof. Cherry's alternative position for the feedback stabilisation capacitor is to connect it to the amplifier output stage, Fig. 3. I have seen this once before, in a publication by RCA<sup>3</sup>.

When I built a similar circuit, I did not experience any instabilities, but for other reasons the circuit was not particularly suited to high fidelity applications. Recently, I have built a fully complementary circuit using higher frequency transistors and I did observe some oscillation. However, I did not use damper capacitors across the drivers, as Cherry recommends, so there is a possibility that this will cure the problem.

My continuing concern with the capacitor is that even eliminating the effect it has on the driver transistor, it will still load the input stages. This of course is why Lohstroh and Otala developed an amplifier which explicitly did not use capacitors to roll the gain off in the Miller position<sup>4</sup>.

Despite some criticism by Cherry, the Lohstroh and Otala approach has not to my knowledge been shown to be incorrect in any way as a methodology.

What Cherry and Self suggest is that lower distortions are possible using the conventional feedback method; except for the concerns that I have discussed in this letter.

I accept that transient intermodulation ought to be fully suppressed provided Cherry's

observation – that the input resistors need to be high enough to prevent the input stages from ever cutting off – is met. This means that they have to drop a voltage at least as large as the input peak voltage. They will seriously reduce the open-loop gain if the input is to be as high as 1V rms – another point Cherry has made.

Another point to note is that often, designers involved with high-frequency amplifiers do not use Miller capacitors because of the degree to which they slow the design.

Many designers trying to minimise Miller capacitor effects use local feedback and low or medium impedance load resistors to define the gain of the voltage amplifier stage more precisely. Therefore, I do not accept that Self's amplifier can be given the label 'blameless' while the compensation capacitor could overload the input stages.

Perhaps if Self were to agree to increase his input resistors, and consider moving the compensation capacitor to the position Cherry advocates, Self's design would get rid of residual distortions he has been trying to eliminate recently.

If Self were to reoptimise his design, I suspect that there would be absolutely no grounds for any distortion components arising anywhere. It would then be very interesting to compare a Cherry nested differentiating feedback loop design<sup>5</sup> with a re-optimised Self amplifier and a Lohstroh and Otala.

I doubt that a critical listener could discern the differences. All three aim to avoid all known distortions; but could one really tell the difference between 0.03% and .003%? The Lohstroh and Otala design does peak at 0.1% at 20kHz, but then the nested differential feedback loop approach does not minimise hf distortion.

Finally, I still urge amplifier designers to listen to the type of music that their designs are intended to amplify. Try isolating one instrument from another while listening. Can you pick out a harpsichord cleanly in a Brandenburg? Or follow the 'cellos in a Beethoven symphony?

While this introduces a degree of subjectivism into the debate I will state for the record that poor designs absolutely fail this musical test – even though single instruments may sound reasonable. Good designs will not, whether or not the listener perceives any other subjective quality. Designs which pass this test include Bailey's 30W amplifier (from 1968) and Lohstroh and Otala's.

I would be happy to see these statements quantified by perhaps analysing the output from speakers digitally, using a microphone to

record the output, and comparing the results to the original. This ought to be one way in which the amplifier designers could finally lay to rest this subjectivism – as well as being able to evaluate the effects of speaker performance on the overall result.

J.N. Ellis  
Tavistock  
Devon

## References

1. Cherry, EM, 'Ironing out Distortion', *Electronics World*, pp. 577-583, July 1997.
2. Self, D, 'Distortion in Power Amplifiers', Aug. 1993 on, see e.g. part 3: 'The voltage amplifying stage', pp. 818-824, Oct. 1993.
3. Solid State Power Circuits, RCA publication, 1971. See section on audio power amplifiers.
4. Lohstroh, J and Otala, M, 'An Audio Power Amplifier for Ultimate Quality Requirements', *IEEE Trans. Audio and Electroacoustics*, vol. AU-21, pp. 545-551, Dec. 1973.
5. Cherry, EM, 'Nested Differentiating Feedback Loops in Simple Audio Amplifiers', *J. Audio Eng. Soc.*, vol. 30, pp. 295-305, May 1982. See also 'Designing NDFL Amps', *Electronics Today International*, pp. 46-51, April 1983.

## Towards a better World

In the July issue, some published circuits will disappoint without modifications.

In Frank Ogden's fluxmeter, on page 584,  $R_{scale}$  should be an unequivocal 10kΩ. This is because the meter and bridge rectifier are fed from a constant-current source in the feedback path and their resistance is immaterial.

However, this gives arithmetic-mean flux and for peak flux – assuming sinusoidal waveform – the resistor should be 6.32kΩ.

On page 586, Phil Regalia's audio preamplifier will spring to life once the lines crossing just left of the output terminal are joined together. And on page 590, Sujit Little's phase-splitter is useless until the right end of  $R_5$ , joined to  $IC_{2b}$ , is also taken to 0V; but to get the intended gain of 10.1 from  $IC_{2b}$ ,  $R_3$  needs a further 1kΩ in series, since the formula for its negative gain is different from that for  $IC_{2a}$ 's positive gain, being compared with  $(1+R_6/R_5)$ .

B Jones  
London

## Frank Ogden replies

Mr Jones's is quiet correct. The meter resistance is immaterial. This was a moment's mental aberration, doubtless caused by the excessive magnetic flux from the computer monitor on the word processor.

## A difference resolved

In reply to Steve Winder's letter in the August issue, this is essentially a matter of definition; can you define a meaningful input impedance relative to ground when a floating input voltage source has no connection to that ground?

The input impedances for a floating voltage source are the same in the sense that a given voltage must cause the same current in each input. The voltages on them are far from equal, being indeed zero for the cold input, as described in detail in my article.

On mature reflection, it seems more sensible to say that a floating source can only have one meaningful input impedance, in this case between the hot and cold inputs, and we agree that this is 20k $\Omega$ .

Douglas Self  
London

## In defence of anarchy

Referring to the August issue Letters, I won't go into Jim Adam's reasoning because he shows so little of it. Besides, I am no expert. Having just discovered the magazine, I've not even read John Watkinson's loudspeaker article (June issue) so I cannot comment on it.

But when Jim came on like a tendentious boff he annoyed me. Jim Adams vilifies trial and error. No scientist would scorn observation and experiment. Even the best design involves trial, compromise and error. Lack of reference and design formulae in an article isn't bad practice. It is daring, maybe arrogant, but good, showing healthy scepticism of received wisdom, and real wisdom in not pasting human ideas over nature – as if that alone matters.

As to active versus passive, public address firms use active filters to avoid inaccuracy, power and phase problems – and expense. As amplifier costs fall faster than those for large, exacting, passive components, the music industry is buying more active monitors; and where they go, the home listeners often follow. Variable crossovers in amplifiers will preserve their choice.

As a final note, good listening, being subjective, is more about removing vice than adding virtue. Position speakers correctly, drive them moderately, and test them with simple waveforms, noise, and good well-known recordings. That's as objective as a varied world will allow.

Mr Crow  
Bristol

## Music speaker

John Watkinson's article 'Loudspeakers exposed' in the June issue makes much of the bad pulse response of standard loudspeakers.

But this is surely not the point, given that the ear uses a series of transducers responding to pure frequencies?

As regards polar diagrams, the JBL speakers with 'baby's-bottom' tweeter horns have admirable polar diagrams and frequency response. In addition, they are completely transparent for rock enthusiasts in relation to live concerts originally heard through JBL speakers. You could say these are integral parts of the electric guitars used, otherwise inaudible, just as huge speaker cabinets and Leslies had to be considered integral parts of electronic cinema organs.

Bernard Jones  
London

## The future of hi-fi loudspeakers?

It is entirely possible that the nature of hi-fi loudspeakers will change significantly over the coming years. I am not referring to the development of flat drive units, or any other new technology, so much as the likelihood of a large proportion of them becoming active units with active crossovers.

The market for these is currently approximately nil – despite the technical advantages of such an approach. There are strong reasons, however, for thinking this will change, and soon.

## The impact of multimedia

Although the market for bi-amped and tri-amped speakers is tiny, the market for active speakers is now huge, as a result of the recent explosion in the cd rom and multimedia pc market. Multimedia loudspeakers are now sold by the million – and they are all active. They have to be, because computers do not include power amplifiers.

The multimedia sound source is the compact disc, which for domestic listening is well nigh perfect. To make the very best of it, exacting, passive loudspeakers are needed. Of course, one possibility is to plug the computer's audio line output into your stereo system, but this is not always convenient. There is undoubtedly a market for top quality speakers that can be driven directly from computers without the intervening stereo system.

The advent of cd rom means that music cds will increasingly contain other data as well, an expanded 'sleeve notes'. They will also contain pictures of the artists concerned, and no doubt sales material, such as details of other titles on offer, interactive software to allow you to browse it, and something to click on if you want to place an order over the Internet. These developments seem natural and inevitable.

This means that cd-rom, multimedia, and stereo systems are moving closer together. Quality loudspeaker manufacturers will see that to gain as large a market share as possible they will need to offer products compatible with computer line outputs and existing stereo systems as well.

Computer manufacturers are not going to incorporate hefty high-quality power amplifiers into their products. But active loudspeakers can easily enough be made to work with existing stereos by bypassing the existing power amplifier – or at a pinch using the power amplifier output as the input to the active speakers.

Nasty this may be – but it works. You will no doubt be able to go down to your local hi-fi shop and buy a suitable adapter containing no more electronics than a couple of resistors to pad the level down a bit.

The upshot of all this is that there will be continued market pressure to make loudspeakers active, where in the past they have been passive.

## Active versus passive crossovers

Having decided to relocate the power amplifiers into the loudspeaker boxes, the choice as to whether the crossover should be active or passive will be revisited.

A marketplace for active crossovers was always unlikely to arise when the amplifiers and loudspeakers were in separate boxes. All kinds of compatibility issues arise. In practice the most likely to emerge would have been to use a two-way active crossover between the bass and mid units, and a passive one between mid and top unit, if there is one. This has the advantage of avoiding a third amplifier section which would not always be required.

The lower frequency crossover is the more problematic one of the two and three-way passive networks, requiring bulkier and costlier reactive components which tend not to be very linear. Higher crossover frequencies are easier to implement. There are therefore also technical reasons why the bi-amp solution suggested above might have been appropriate.

But there still remain the issues of being able to adjust the crossover frequency, the balance between the low and high frequency outputs, and what happens if you want to switch between loudspeakers. By putting the power amplifiers in the loudspeaker these problems are removed.

Other problems disappear, too. The impedance of the loudspeaker drive units is no longer an external issue. The power amplifier comes with the right voltage and current capacity for the speakers. The top units will be harder to burn out

because they will be driven by a small amplifier. Clipping in the bass amplifier will not harm them.

Active crossovers and multiple power amplifiers become a much more attractive proposition when the amplifiers and drive units are in the same box. This means that the arrival of cd rom is giving the market a strong push in a direction which favours active crossovers. That this will lead to higher sound quality is a welcome bonus.

There are no doubt some hi-fi obsessives who will disagree on this, but their impact on the market will be insignificant. Large numbers of bi-amped loudspeakers will be sold with monolithic power amplifiers like the TDA2030 inside them. They will sound better than the current passive loudspeakers and passive crossover networks driven by separate power amplifiers with monolithic amplifiers like the TDA2030 inside them.

## Digital signal processing

DSP chips are already available which can do the job of an active crossover, and better, too. One thing dsp chips are able to do easily, unlike analogue filters, is introduce longer delays into the high frequency components of the signals, as well as the low frequency ones. This gives far more flexibility where design of the phase response is concerned. Another thing dsp chips are better at is precision and stability, whereas analogue filters are to varying degrees sensitive to component tolerances.

The main issue, however, is cost. The input signal needs to be converted to digital first, processed, and then the results converted back to two or three output channels to be amplified. Ultimately this is no barrier to their use, since the cost of the silicon required to do this is falling continually.

Once the digital threshold has been crossed, all sorts of new possibilities open up. A dsp-based loudspeaker can be made to produce higher quality output by compensating for some of the drive unit deficiencies. In theory, it is possible to completely compensate for the bumps in their frequency and phase responses. In practice of course it isn't anywhere near that easy.

This does not mean it is not worth doing. Such compensation can operate on three levels. Level one is simply to filter the signal to compensate for the 'average' drive unit. Differences between units will mean the results are imperfect, but the improvement will be worth having.

Level two is to compensate for the failings of the units on an individual basis. The response of the loudspeaker is measured after it has been assembled, and the filter characteristics are adjusted for that

particular loudspeaker. This would of course be automated. The results might be held in eeprom.

The third level is to adjust the filter characteristics to get the best from the loudspeaker in its environment. Clearly this is only possible at the top end of the market, where the customer has his new speakers installed for him by an engineer with the necessary equipment to set the system up. This is no wild speculation – equalisation of monitor loudspeakers in their environment has been common practice in the professional recording studio market for years.

DSP chips can do far more than just implement filter algorithms. Remote control is possible. The output signals to the power amplifiers can be limited to prevent burn-out or excessive mechanical stress in the drive units. The bass drive can be limited to prevent excessive excursion of the voice coil. The heatsink temperature can be monitored and the drive levels abated if it becomes too hot.

Once the low cost dsp capacity becomes available, as it inevitably will, these extra frills will be cheap to implement. These loudspeakers will

tolerate gross abuse in a way you cannot possibly say of passive ones.

It is not difficult to predict that there will come a time when a dsp chip specifically targeted at active loudspeaker manufacturers will become available – including one a-to-d converter for the input – three d-to-a converters for the drive unit outputs, and on-board eeprom to hold the filter coefficients.

One of the three converters would be redundant in bi-amped speakers. Fallouts with one of the converters out of specification or not working properly would do for these.

Another likely development is a similar chip with pulse-width modulated outputs instead of d-to-a converters. The PWM outputs would drive switch-mode Class-D amplifiers directly. They would be very easy to implement on silicon.

Chips like this can be expected to be targeted at the lower end of the market. Use of d-to-a converters and linear amplifiers is still likely to remain the norm where the highest quality is required.

## Design freedoms

The establishment of a market in active loudspeakers will give

designers more freedom. They will no longer be tied to making drive units with impedances designed to match somebody else's drive capability, or to be compatible with another unit connected to the same passive crossover network.

One obvious possibility is to design a loudspeaker so that the bass unit is driven by a bridge mode amplifier, whereas the mid and top drivers are single ended, since the power output required is lower. These would all run off the same power supply.

The top unit might be made with a higher impedance, so its amplifier operates with a sensible output voltage swing, and is more efficient.

All kinds of other possibilities can be imagined. The connections to the drive units are all separately available to the drive circuits giving more design freedom than is available today.

Incorporating more exotic drive units becomes easier. If an unusually low or high impedance needs to be driven, the traditional constraint of having to couple it to a traditional amplifier with the wrong drive capability is removed.

## Beyond the horizon

In the long run, it seems almost inevitable that digital interfaces between hi-fi units will supplant the current analogue ones. Such interfaces already exist in the professional audio equipment market. When this happens the input to the loudspeaker will be a digital one, and the a-to-d converters input to the dsp chip crossover will be eliminated.

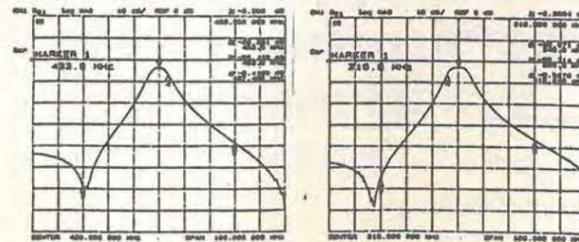
Playing digital recordings will then involve an entirely digital path from the a-to-d converter on the recording studio – or wherever – to the dsp crossover outputs in the loudspeakers.

These things, however, are not imminent – or at least, not as far as I am, aware. Fairly soon, though, we can expect to see more and more active loudspeakers with active crossovers. And we can expect to see more and more dsp crossovers, starting at the top end of the market and working downwards. I, for one, think this will be a welcome development. The days of the separate power amplifier and passive crossover are deservedly numbered.

Alan Robinson  
Holgate York

HELICAL BPF FILTERS FOR SECURITY BAND  
433.9MHZ(DIN) & 310-320MHZ(FCC), WE MAKE MASS PROD.  
T6711A/AA-433.9M(7H2)/T6740A/AA-310-320M(7H2).  
THOSE HAVE GOOD ATEN & BW. SMALL GROUP DELAY, EASY  
MATCHING, ATTRAC. PRICE COMPARISON WITH SAW FILTER.  
FREE SAMPLES FOR EVALUATION, PLS FAX US IMME. TODAY!!

SPEC \ PARTS NAME	T6711A-433.9M(7H2)	T6740A-310-320M(7H2)
f <sub>0</sub> (CENTER FREQ.)	433.9 MHz	310-320MHz
INSERTION LOSS	TYP. 4.5 dB	TYP. 4.0 dB
3 dB BANDWIDTH	TYP. 7.0 MHz	TYP. 8.0 MHz
ATTENU.	f <sub>0</sub> -30MHz TYP. 53.0 dBc	TYP. 50.0dBc
	f <sub>0</sub> +30MHz TYP. 32.0 dBc	TYP. 31.0dBc
RIPPLE	< 1.0 dB	< 1.0dB
RETURN LOSS	> 12.0 dB	> 8.0dB
IMPEDANCE	IN / OUT: 50 $\Omega$	IN / OUT: 50 $\Omega$



IN ADDITION, ANY FO 55M-1.6G YOU MAY DESIGN HELICAL BPF,  
FULL CAT. SUGGEST YOU. --- AGENT WANTED, WELCOME OEM ---

TEMWELL CORP. WELL MADE IN TAIWAN  
FAX: 886-2-5515250/5652287

CIRCLE NO. 136 ON REPLY CARD

## Leading Edge Technology Ltd

Low cost Programmers for all your requirements

### GAL PROGRAMMER

16V8 / 16V8A / 16V8Z 20V8 / 20V8A / 20V8Z

£79.95

- Stylish compact case with quality ZIF socket
- Easy to use software - load/save in JEDEC format
- Plugs into Centronics printer port
- Works on any IBM PC or compatible / laptops / notebooks etc
- Fast and reliable programming using manufacturers algorithms
- Program protection fuses to prevent unauthorised copying
- Supplied with PLAN Logic compiler software
- Complete system with example files, connection lead, and PSU
- Full 12 months parts and labour guarantee



### 128k x 8 EPROM EMULATOR

£89.95

This is the ideal way to test / change 'running' code on CPU based systems. It plugs directly to the printer lead of an IBM compatible computer. There are no internal cards so it is ideal for laptops etc. The unit emulates ALL Eproms from 24 pin 2716 (2k) to 32 pin 27C010 (128k). The memory can be configured as 128k by 8 bits or 2 x 64k by 8 bits. A CPU reset line is provided and the user can select high/low or low/high reset signals. Software supplied (DOS and Windows 3.0/1) has full screen editing and allows you to save and load code with offsets. Full 12 month guarantee.

### MEGAPROM UNIVERSAL EPROM PROGRAMMER

EPROMS / EEPROMS / FLASH EEPROMS / 12C BUS EEPROMS

- Covers all types of Eprom, EEPROM, and flash up to 32 pin
- Fast programming and verification
- Easy to use software - supports Bin / Intel Hex / Motorola S and ASC file formats
- Read / Edit / Verify / reprogram etc
- Supplied with full 12 months parts and labour guarantee

Megaprom runs on any IBM PC / compatible, connects directly to the centronics printer cable and requires 12-18V AC/DC PSU. Low cost makes it ideal for hobbyists and engineers alike. £99.95



### ENHANCED PIC PROGRAMMER

- Programs PIC54, 55, 57, 58A, 61, 64, 65, 71, 75, 84, 620, 621, 622, MEMORY CHIPS, 24LC01, 02, 16, 32, 65
- Read / Write / Copy / Program fuses
- Software supports Microchip, Intel Hex, binary format also supplied with Editor assembler for 54 series and 71/84
- Runs on IBM PC / compatible, connects to the centronics printer cable and requires 12-18V AC/DC PSU. Full guarantee. £69.95

Visit our Website at:

http://www.angelfire.com/free/leadedge.html  
or Email us at:

johnmorr@email.keyworld.net  
Postage/packing not included. No VAT or C/C surcharge

### Leading Edge Technology Ltd

White Rose House, Xintill Street  
Tarxien, PLA 11, Malta  
Phone: (00 356) 678509  
Fax: (00 356) 667484

CIRCLE NO. 137 ON REPLY CARD

# CLASSIFIED

TEL 0181 652 3620

FAX 0181 652 8956

## ARTICLES FOR SALE



### SUPPLIER OF QUALITY USED TEST INSTRUMENTS



CONTACT

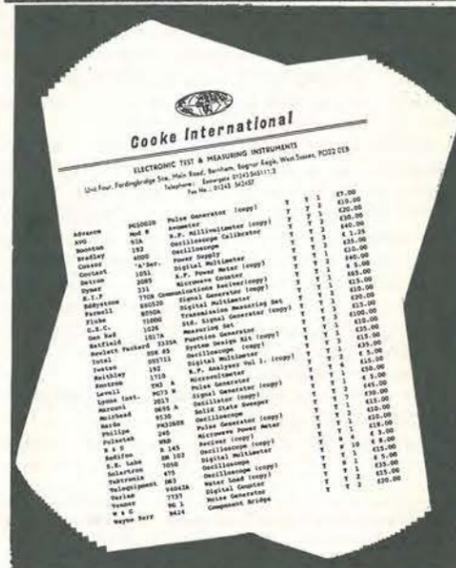
### Cooke International

ELECTRONIC TEST & MEASURING INSTRUMENTS  
Unit Four, Fordingbridge Site, Main Road, Barnham,  
Bognor Regis, West Sussex, PO22 0HD, U.K.  
Tel: (+44)01243 545111/2 Fax: (+44)01243 542457

CIRCLE NO. 138 ON REPLY CARD



### OPERATING & SERVICE MANUALS



CONTACT

### Cooke International

Unit Four, Fordingbridge Site, Main Road, Barnham,  
Bognor Regis, West Sussex, PO22 0HD, U.K.  
Tel: (+44)01243 545111/2 Fax: (+44)01243 542457  
NOW AVAILABLE CATALOGUE ON DISC

CIRCLE NO. 139 ON REPLY CARD

## ADVERTISERS INDEX

Anchor .....	732	Leading Edge .....	789
Armex .....	781	M & B Radio .....	770
Bull .....	712, 784	Number One .....	770
Card Professionals .....	738	Pico Technology .....	738
Chelmer .....	742	Pyramid .....	760
Colomor .....	760	Radiometrix .....	716
Conford .....	783	Radio Tech .....	783
Display Electronics .....	723	Stewart of Reading .....	783
Equinox .....	IBC	Surrey .....	706
Halcyon .....	781	Technology Sources .....	706
Hart .....	747	Telford .....	711
IOSIS .....	760	Telnet .....	716
John's Radio .....	773	Temwell .....	789
JPG .....	706	Tie Pie .....	711
Keytronics .....	724	Ultimate .....	IFC
Labcenter .....	OBC	Weir .....	729
Langrex .....	742		

## RECRUITMENT



### INNOVISION RESEARCH & TECHNOLOGY LTD

... is a fast-growing company with a reputation to do the impossible. We design and develop new products for a host of multinational companies, using new technologies and processes. We offer a competitive advantage to our customers - and an exciting and challenging career for you.

#### WE ARE LOOKING FOR:

- Embedded Software Engineer
  - Hardware Design Engineer (good analogue)
  - Design Technician (new graduates)
- Location: Wokingham, Berkshire - M4, Junction 10.

#### THE RIGHT CANDIDATE MUST HAVE:

- Good HND or Degree in Electronic Engineering
- At least 3 years experience in design engineering (depending on position)
- High professional and quality standards
- Good problem solving and lateral thinking abilities

#### IN RETURN WE CAN OFFER YOU:

- An excellent salary
- Corporate healthcare membership
- Participation in corporate incentive scheme

#### NEXT STEPS ...

Fax, Email or post your CV to Jenny Greenfield  
(Project Development Manager), InnoVISION R&T Ltd.,  
Exa House, Alexandra Court, Wokingham, Berks RG40 2SJ  
Tel: 0118 979 2000 Fax: 0118 979 1500  
Email: Jenny.Greenfield@innovision-group.com

## ADVERTISERS PLEASE NOTE

For all your  
future enquiries  
on advertising  
rates

Please contact  
Joannah Cox on

Tel: 0181-652 3620  
Fax: 0181-652 8956

## ARTICLES WANTED

### VALVES and CRTs AVAILABLE

ONE MILLION VALVES stocked for Audio, Receiving, Transmitting & RF Heating. Rare brands such as Mullard & GEC available. Also MAGENTRONS, KLYSTRONS, CRTs and SOCKETS. Large stocks of Russian and Sovtek items. Please ask for our free catalogues of valves or CRTs.

### VALVES, etc, WANTED

Most types considered but especially KT88 (£60), PX4/PX25 (£60), KT66 (£38), KT77 (£18), EL34 (£15), EL37 (£15), ECC83 (£3). Valves must be UK manufacture to achieve prices mentioned. Also various valve-era equipment e.g. Garrard 301, (up to .£80). Ask for a free copy of our wanted List.

BILLINGTON EXPORT LTD., Billingshurst, Sussex RH14 9EZ  
Tel: 01403 784961 Fax: 01403 783519  
VISITORS STRICTLY BY APPOINTMENT. MINIMUM ORDER £50 plus VAT

### TOP PRICES PAID

For all your valves, tubes, semi conductors and IC's.  
Langrex Supplies Limited  
1 Mayo Road, Croydon  
Surrey CR0 2QP  
TEL: 0181-684 1166  
FAX: 0181-684 3056

### RF DESIGN SERVICES

All aspects of RF hardware development considered from concept to production.

WATERBEACH ELECTRONICS

TEL: 01223 862550  
FAX: 01223 440853

### MICRO CCD CAMERA

High definition and sensitivity  
>380 lines < 0.1 Lux 92 deg. lens  
1/3" b/w PCB. 12V 75mA  
38\*38\*30mm  
Standard 1 Volt 625 line video o/p.  
ONLY £64.95  
inc uk. p&p, and VAT  
Send cheque or PO. to  
ReTech Ltd., Unit 1,  
Dorcan Business Village,  
Swindon, SN3 5HY.  
Send sac, for details and latest  
list of AV. and Satellite offers

### PRECISION SHEET METAL SERVICES

We specialise in the manufacture of small sheet metal parts for the electronic industry; chassis, screening cans, cases etc., sizes under 30cm. SMALL/MEDIUM QUANTITIES. QUICK TURNAROUND. Please write, fax or phone for quotation  
HARRISON ELECTRONIC SERVICES  
Century Way, March, Cambs. PE15 8QW  
Tel/Fax: (01354) 651289

MEGGAR INSULATION TESTER. up to 2500V, hand cranked, excellent condition, leather case, accessories and leads: £300 ono. Tel: 01793 724151.

WANTED - any AVO model 8 with hopelessly damaged movement. Tel: 01326 312901.

TEKTRONIX 145 PAL Genlock Test Signal Generator, 148 Insertion Test Signal Generator, EV4020 Vectorscope, EV4040 Waveform Monitor. All manuals. Tel: 01383 419282.

TWO TEKTRONIX 561A oscilloscopes. Trolley, manuals, plug ins. Good working order. £60 pair. Details tel: 01273 553505.

FOR SALE: complete volume of Electronics World/Wireless World from 1945-1983. Plus selection of technical books. For further information please tel: 01920 870289.

FLUKE 867B graphical multi meter, five months old, with leads and manual: £550 ono. Tel: 01482 815625.

## Test & Measurement Instruments

A chance to profit  
from your own ideas!

An established U.K. manufacturer of test & measurement instruments is looking for new product concepts.

They would like to hear from design engineers with innovative product ideas that could lead to joint developments on either a fee or royalty basis.

In the first instance, please write giving an outline of your product concept along with details of your own experience and capabilities.

Detailed disclosure, should the idea be pursued, would be subject to an intellectual property agreement protecting your rights.

Write to: Box 111, Electronics World, Third Floor,  
Quadrant House, The Quadrant, Sutton. Surrey. SM2 5AS

# ELECTRONIC UPDATE

Contact Joannah Cox on  
0181-652 3620

A regular advertising feature enabling  
readers to obtain more information  
on companies' products or services.

**A world of colour LCD**

From microsystems

## Comprehensive new LCD brochure

The widest range of colour LCDs, LCD monitors and plug and play kits available in the UK, all in one easy to use brochure, is now available FREE!

It includes products ranging from 2.9" monitors to 16.1" colour LCD screens, mono/colour STN TFTs and touch screen technology from the worlds leading manufacturers.

Phone Trident today for your free copy.

Tel.: 01737 765900  
Fax: 01737 771908

CIRCLE NO. 140 ON REPLY CARD

## New for '97 Free Data Acquisition Software Tool

DAQ Designer 97 is a free system configuration software tool for the PC that takes you through your application step-by-step, asking you questions, and recommending all the right equipment, including: PC plug-in DAQ boards, PCMCIA DAQ cards, Signal Conditioning and Sensor Interfacing, Cabling and Software.

Call National Instruments for your free copy on (01635) 523545

CIRCLE NO. 141 ON REPLY CARD

Feedback TEST & MEASUREMENT

## NEW Feedback T&M Catalogue

The latest edition of the Feedback Test & Measurement catalogue is now available. Over 60 pages packed with more than 800 products divided into over 20 sections. The catalogue is indexed for both product and manufacturer and is fully illustrated. Whether you are looking for an individual product, a complete workstation, or a solution to a particular Test & Measurement need the NEW Feedback catalogue will solve your problems, send for a copy NOW!

CIRCLE NO. 142 ON REPLY CARD

JENSEN

## NEW JENSEN TOOLS CATALOGUE

Colourful new Catalogue, hot off the press from Jensen Tools, presents unique new tool kits for service/support of communications equipment. Also latest test equipment from many major manufacturers. Includes hard-to-find tools, PC/LAN diagnostics, bench accessories, static control, technical manuals and more.

Ring 0800 833246 or Fax 01604 785573 for a free copy. Jensen Tools, 10-12 Ravens Way, Northampton NN3 9UD

CIRCLE NO. 143 ON REPLY CARD

"THE COMPLETE PROGRAMMING SOLUTION FOR 8051 MICROCONTROLLERS & MUCH MORE"

# MICRO-PRO THE STATE-OF-THE-ART PROGRAMMER

**NOW SUPPORTS AVR MICROCONTROLLER FAMILY**

**UNLOCK NEW LIBRARIES**

µC E<sup>2</sup> FLASH FPGA Configurator

Atmel - 89C, 89S (see table below)  
Philips/Intel - 87C-51/52-Fx  
Dallas - 87C520  
Comes as standard

Atmel E<sup>2</sup> - 24C, 25C, 28C, 59C, 93C  
FLASH - 29C, 49F  
Order Code: MPW-LIB-MEM-AT  
**£75.00**

FPGA Serial Configurators  
Atmel, Xilinx, Altera etc.  
Order Code: MPW-LIB-CON  
**£75.00**

**A Security Dongle is required for the above libraries Order Code: MPW-LIB-SEC £24.00**

**Features Include**

- Micro-Pro for Windows™ Programmer Interface Software
- FPGA hardware ensures future device support
- Supports most DIL devices up to 40 pins without an adaptor
- Adaptors available for many other package types

Order code: MPW-SYS **£149.00** ▲

## The Atmel 8051 FLASH microcontroller family

Atmel Part Code	89C51	89C52	89C55	89S8252	89S53	89C1051	89C2051
Flash Code ROM (bytes)	4K	8K	20K	8K	12K	1K	2K
RAM (bytes)	128	256	256	256	256	64	128
EEPROM	-	-	-	2K	-	-	-
In-system re-programmable	-	-	-	YES	YES	-	-
I/O Pins	32	32	32	32	32	15	15
16-bit Timer/Counters	2	3	3	3	3	1	2
Watchdog timer	-	-	-	YES	YES	-	-
Interrupt sources	6	8	8	9	9	3	6
Serial UART (full duplex)	YES	YES	YES	YES	YES	-	YES
SPI Interface	-	-	-	YES	YES	-	-
Analogue comparator	-	-	-	-	-	YES	YES
Data pointers	1	1	1	2	2	1	1
Package Pins (DIL)	40	40	40	40	40	20	20

## C51 Microcontroller Starter System

**UPGRADE to 8K NOW AVAILABLE**

- ✓ Optimising C Compiler
- ✓ Macro Assembler
- ✓ Software Simulator
- ✓ Device Programmer
- ✓ Evaluation Module
- ✓ Atmel AT89C2051
- ✓ Hardware/Software Documentation

**Plus FREE Atmel CD ROM data book**

Order code: AT-89C-2K-ST **£199.00**

**KEIL SOFTWARE**

Translator: C51 Compiler

▲ KEIL Integrated Development Environment - C compiler + Assembler output restricted to 2K total program code.

**In-Circuit Parallel Programming Adaptor**

**Now you can re-program the entire 89C & 89S Atmel Microcontroller families in-circuit**

Order code: AD-8051-ICPP **£125.00** (Requires Micro-Pro Programmer to operate)

**EQUINOX TECHNOLOGIES**

The Embedded Solutions Company

Visit our web page at: [www.equinox-tech.com](http://www.equinox-tech.com)  
Email: [sales@equinox-tech.com](mailto:sales@equinox-tech.com)  
229 Greenmount Lane, Bolton BL1 5JB UK

SALES: 01204 492010 TECHNICAL: 01204 491110 FAX: 01204 494883 (INTERNATIONAL DIALLING CODE +44 1204)  
Equinox reserves the right to change prices & specifications of any of the above products without prior notice. E&OE. INTERNATIONAL DISTRIBUTORS REQUIRED

CIRCLE NO. 144 ON REPLY CARD

All the information you need on  
**top UK Companies** -  
available on a single CD.  
**Kompass CD Plus** -  
the only business CD you'll need!



- Contains:** 60,000 companies • 42,000 classifications • 17 different search criteria
- Used for:** Cost-effective purchasing • New business lead generation • Fast, effective research  
• Financial, credit and sales planning • Corporate structure data
- Allows for:** Downloading • Printing • Networking

Kompass CD Plus - information, not just raw data - unbelievable value for money.

Call 0800 521393 for more details and prices.

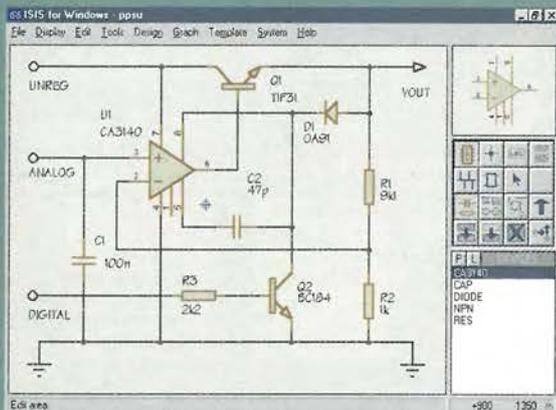
Please quote reference CDP 1.

CIRCLE NO. 144 ON REPLY CARD

# PROTEUS

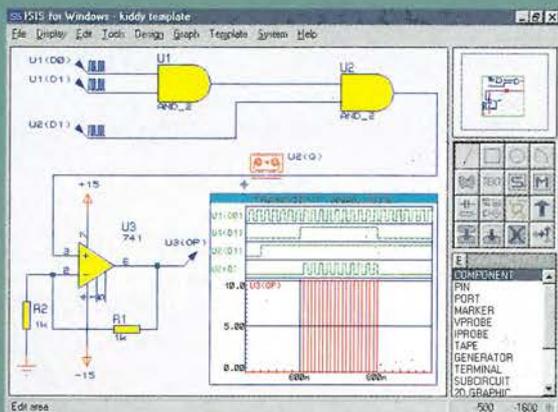
## Schematic Capture

NEW Version IV



- Produces attractive schematics like you see in the magazines.
- Netlist, Parts List & ERC reports. • Hierarchical Design. • Full support for buses including bus pins. • Extensive component/model libraries. • Advanced Property Management.
- Seamless integration with simulation and PCB design.

## Simulation



- Non-Linear & Linear Analogue Simulation. • Event driven Digital Simulation with modelling language. • Partitioned simulation of large designs with multiple analogue & digital sections. • Graphs displayed directly on the schematic.

# The IV<sup>th</sup> Generation

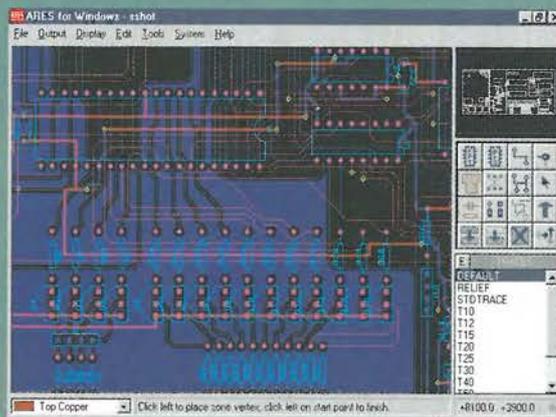
## New Features

- Component Auto-Placer
- Pinswap/Gateswap Optimizer
- Background Regeneration of Power Planes
- Enhanced Autorouting with Tidy Pass
- Full Control of Schematic Appearance
- Extensive New Component Libraries

Available in 5 levels - prices from £295 to £1875 + VAT. Call now for further information & upgrade prices.

## PCB Design

NEW Version IV



- Automatic Component Placement. • Rip-Up & Retry Autorouter with tidy pass. • Pinswap/Gateswap Optimizer & Backannotation. • 32 bit high resolution database. • Full DRC and Connectivity Checking. • Shape based gridless power planes. • Gerber and DXF Import capability.

**"PROTEUS**  
is particularly good  
**with its rip-up-and-retry autorouter"**  
EWW January 1997

Labcenter  
Electronics

Write, phone or fax for your free demo disk, or ask about our full evaluation kit.  
Tel: 01756 753440. Fax: 01756 752857. EMAIL: [info@labcenter.co.uk](mailto:info@labcenter.co.uk)  
53-55 Main St, Grassington. BD23 5AA. WWW: <http://www.labcenter.co.uk>

Fully interactive demo versions available for download from our WWW site.  
Call for educational, multi-user and dealer pricing - new dealers always wanted.  
Prices exclude VAT and delivery. All manufacturer's trademarks acknowledged.