

**FREE COMPONENTS FOR FREE DESIGN COMPETITION!**

# ELECTRONICS WORLD

Denmark DKr. 70.00  
Germany DM 15.00  
Greece Dra.760  
Holland Dfl. 14  
Italy L. 7300  
IR £3.30  
Spain Pts. 780  
Singapore S\$ 12.60  
USA \$6.70

A REED BUSINESS PUBLICATION  
SOR DISTRIBUTION

## + WIRELESS WORLD

OCTOBER 1994 £1.95

### AUDIO

Feed forward  
beats feedback  
for better audio?

### REVIEW

The best schematic  
under Windows?

### APPLICATIONS

New circuits for  
one-chip function  
generators

### DESIGN

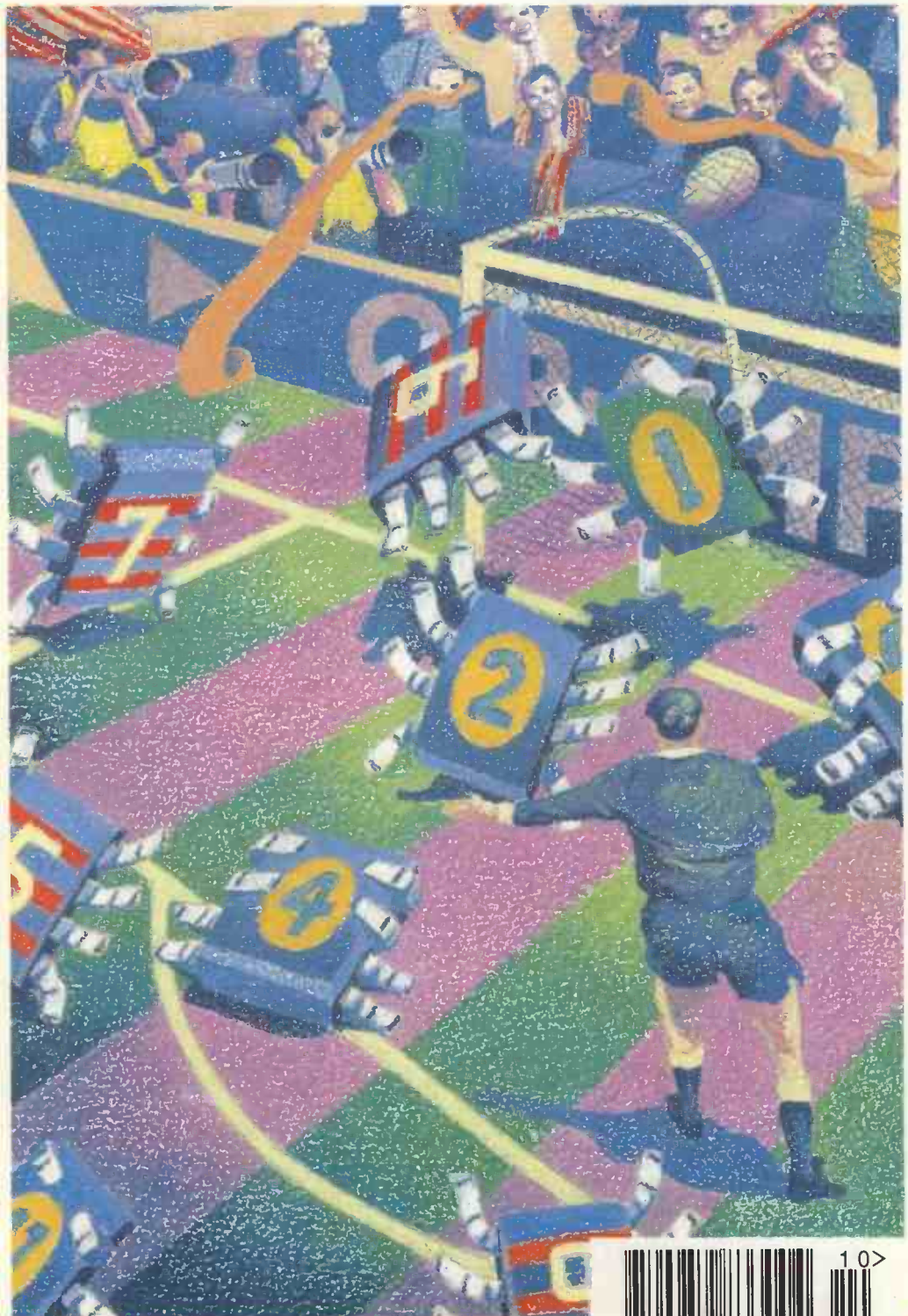
4-Q multipliers  
give the edge to  
wideband systems

### RF ENGINEERING

Signal processing  
at microwave  
frequencies

### COMPONENTS

Light ballast with  
other uses



**UNDER TEST: SMPS vs LINEAR ICs**





# NEW!

# FROM THE MAKERS OF THE WORLDS BEST SELLING UNIVERSAL PROGRAMMING AND TESTING SYSTEM

- \* Ability to program 3 volt devices.
- \* Calibration software to comply with ISO9000.
- \* Batch software for production programming.
- \* High quality 42 pin Textool zero insertion force sockets.
- \* Rugged metal housing and heavy duty screened cable.
- \* Ground control circuitry using relay switching.
- \* Protection circuitry to protect against wrong insertion of devices.
- \* Speed optimised range of programming algorithms.
- \* Supplied with MICROTEC disassemblers for Z8, 8085, 8048, 8051, 6809 & 68HC11.

- \* Programs PIC16 series without adaptor.
- \* Software supplied to write own test vectors for custom ICs and ASICs etc.
- \* One model covers the widest range of devices, at the lowest cost.
- \* Over 2000 different devices (including several hundred MPU's) supported.
- \* Tests and or identifies a wide range of logic devices.
- \* High speed PC interface card designed for use with all types of PC.
- \* No need to tie up a slow parallel port.
- \* More Sunshine programmers sold worldwide than any other of its type.
- \* UK users include BT, IBM, MOD, THORN EMI, MOTOROLA, SANYO, RACAL.
- \* Two year free software update.
- \* Free demo disk with device list available.

The Sunshine Expro-80 Universal Programmer and Tester is the 42 pin version of the immensely popular Expro-60/PC-82. Following that success, the Expro-80 is a PC-based development tool designed to program and test more than 2000 ICs. The culmination of over 8 years production experience has resulted in perfecting this rugged, classically designed programmers' programmer.

Volume production has now enabled us to offer this powerful programmer at a very competitive price for a product of such high quality. The Expro-80 has undergone extensive testing and inspection by various major IC manufacturers and has won their professional approval and support. Many do in fact use the Expro-80 for their own use!

The Expro-80 can program E/EPROM, Serial PROM, BPROM, DSP, PLD, EPLD, PEEL, GAL, FPL, MACH, MAX and MPU. It comes with a 42 pin DIP/SDIP socket capable of programming devices with 8 to 42 pins. It even supports EPROMs to 16Mbit, the PIC16 series of MPUs and many many more without the need of an adaptor. Adding special adaptors, the Expro-80 can program devices up to 84 pins in DIP, PLCC, LCC, QFP, SOP and PGA packages.

The unit can also test digital ICs such as the TTL 74/54 series, CMOS 40/45 series, DRAM (even SIMM/SIP modules) and SRAM. Furthermore it can perform functional vector testing of PLDs using the JEDEC standard test vectors created by PLD compilers such as PALASM, OPALjr, ABLE, CUPL etc. or by the user. The Expro-80 can even check and identify unmarked devices.

The Expro-80's hardware circuits are composed of 42 set pin-driver circuits each with control of TTL I/O and "active pull up", D/A voltage output, ground, noise filter circuit and OSC crystal frequency.

New features include negative programming voltages, 3 volt programming ability, protective circuitry for ICs incorrectly inserted, calibration software to comply with ISO9000, new six layer PCB and voltage clamping to banish noise and spikes.

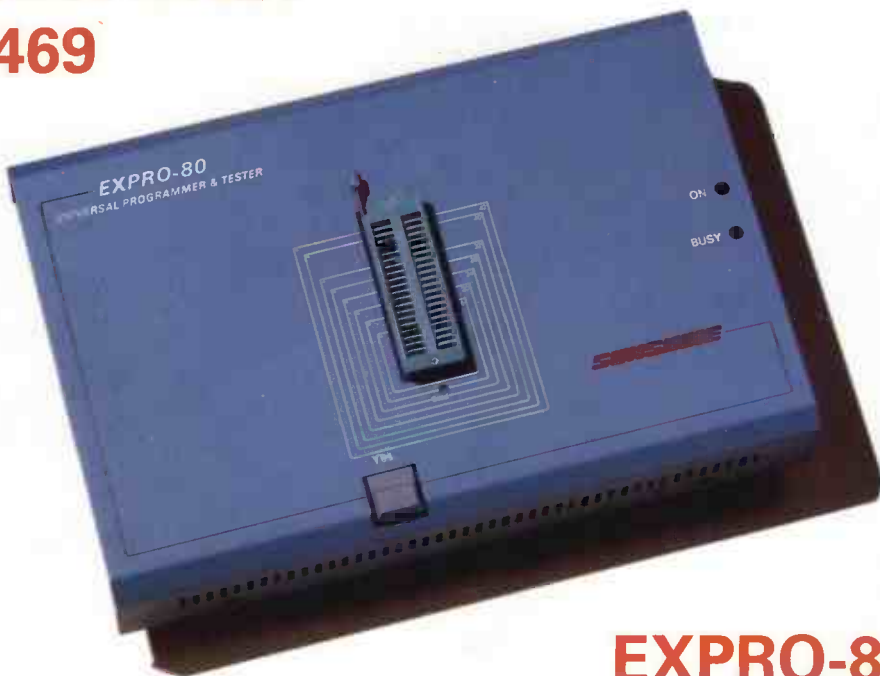
A dedicated plug in card with rugged connecting cable ensures fast transfer of data to the programmer without tying up a standard parallel or serial port. Will work in all types of PC. In addition, there is now the Link-P1 enabling the programmer to be driven through the printer port. Ideal for portables and PC's without expansion capability.

The pull-down menus of the software makes the Expro-80 one of the easiest and most user-friendly programmers available. A full library of file conversion utilities is supplied as standard.

Sunshine's team of over 20 engineers are continually developing the software, enabling the customer to immediately program newly released ICs.

Citadel, a 33 year old company are the UK agents and service centre for the Sunshine range of programmers, testers and in circuit emulators and have a team of engineers trained to give local support in Europe.

## NOW ONLY £469



### EXPRO-80

#### ORDERING INFORMATION

Expro-80 complete with interface card, cable, software and manual **only £469**

Please add £8 carriage (by overnight courier) for UK orders, £30 for export orders and VAT where applicable.

ACCESS, MASTERCARD, VISA or CWO. Official orders are welcome from Government bodies and local authorities.



**CITADEL PRODUCTS LTD**  
DEPT. WW, 50 HIGH ST.,  
EDGWARE, MIDDX. HA8 7EP.

Phone now on: 081 951 1848/9

Our stocked range of own manufactured and imported Sunshine products include:

- \* Super fast EPROM Erasers.
- \* 8Mbit EPROM Programmers:  
ie: 1 gang £149  
4 gang £229  
8 gang £399
- \* Battery operated portable EPROM programmers.
- \* "In circuit" Emulators.
- \* Handy pocket IC testers.



CIRCLE NO. 160 ON REPLY CARD

# CONTENTS

## FEATURES



Cover: Hashim Akib

### VOLTAGE REGULATOR CHIPS: SWITCH TO LINEAR?.....806

Supply voltage can be crucial in defining a system's overall performance, yet regulator IC data sheets rarely tell the full story. Ben Duncan investigates a cross-section of popular devices, both old and new.

serial port. Designed by J. N. Ellis, the board has uses ranging from led switching to managing a control system.

### HIGH-VOLTAGE VERSATILITY .....837

International Rectifier's *IR2151* is a fluorescent lamp ballast driver, but incorporating a 555-type timer and 600V power mosfet drivers, it could have many other applications. The *IR2151* is the subject of this month's free offer and our £1800 design competition on page 840.

### CAPTURE AND LAYOUT FOR PCs.....813

John Anderson looks at whether Protel is justified in adding the word 'Advanced' to their newly upgraded schematic capture and pcb layout packages.

### AUDIO DESIGN LEAPS FORWARD? .....818

Designers have long been aware of the benefits of applying feed forward to audio power amplifiers but so far, attempts to turn these theoretical advantages into practice have never quite lived up to expectations. Has Giovanni Stochino found the answer?

### NEW WAVE MICROWAVES.....829

In his article covering mixers and signal converters, Mike Hosking describes the components and circuits needed to extract information from microwave communication signals.

### MULTI I/O VIA THE SERIAL PORT.....860

By having on-board intelligence in the form of a 68000-family processor, this 64-line i/o card makes up for the sluggishness typical of interfaces controlled via a PC

### IR £1800 DESIGN COMPETITION

By finding a new application for a high-voltage IC comprising power mosfet drivers and a 555-type timer, you could win one of six mosfet designer's kits worth £1800 in total.

Full details on page 837...



## REGULARS

**COMMENT.....795**  
Goodbye, Goodbye.

**NEWS.....796**  
EC in the dark over R&D, Euro screen is clear world leader, Multilevels boost memory, Big TI hopes for the big screen, Video surveillance over the telephone line, Inmarsat improves on GPS services, Eurofighter scrap.

**RESEARCH NOTES.....802**  
Old masters painted in pixels, Robodoc with the hip attitude, Mesfet redesign cuts power needs, Digital laser control puts pulse power on site, Mobile 'phones make for mean street.

**DESIGN BRIEF.....842**  
Active multipliers and their uses as variable attenuators and modulators, explored by Ian Hickman.

**LETTERS.....850**  
Split decision, Listening post, Radar replication, crossover critic, Bussman's I<sup>2</sup>C kits, Historical insight, Discrete behaviour, Big science squashes little projects, Fourier dice.

**NEW PRODUCTS.....855**  
Classified run-down of new electronic products, presented in the industry's most readable format.

**APPLICATIONS.....866**  
Wideband op-amp delivers broadcast-quality video, Function generators use analogue trigonometric synthesiser, Switching with igbts reduces lamp ballast size.

**CIRCUIT IDEAS.....872**  
One-chip air-flow monitor, Monostable flip-flop pulses down to 10ns, Guitar fuzz box uses radio chip, Triggered sawtooth generator from a phase-locked-loop IC, Low battery-voltage indicator, Bench filter evaluator with tuning control.

**In next month's issue:** Making the most of CAD. Owen Bishop takes an in-depth look at CAD from the design engineer's viewpoint, using working circuitry for demonstration. And John Gregg looks at a new generation of atomically engineered magnetic materials. There will also be details of our writers' award – the prize for which is a £4000.

**THE NOVEMBER ISSUE IS ON SALE FROM October 27**



# Programming Solutions

SMART Communications offer the best range of low cost programmers for your every need. Unrivalled device support includes the latest MACH, pLSI, MAPL, PIC, WSI, Atmel, Xilinx and Intel parts.



## ALL-07 Universal Programmer

Pin driver expansion can drive up to 256 pins.  
Supports over 2000 IC's – 3 and 5 volt devices.  
EPROMs, E<sup>2</sup>PROMs, Bipolars, Flash, Serial EPROMs  
up to 16 Mbits parts, over 150 Microcontrollers  
and PLDs, EPLDs, PEELs, PALs, GALs, FPGAs etc...  
Universal DIL (up to 48 pins), PLCC and gang PACs  
– significantly reduces the number of adapters required.  
Powerful full colour menu system.  
Connects to the pc printer port with its own power supply.  
Latest programming algorithms.  
Tests TTL, CMOS and SRAM devices  
– even identifies unknown parts.  
Approved by AMD for their range of programmable logic.

**£595**

## EMP-20 Multi-Device Programmer

EPROMs, E<sup>2</sup>PROMs, Flash,  
Serial EPROMs to 16 Mbits.  
PLDs, GALs, PEELs, WSI PSDs.  
Intel, Microchip, Motorola  
and Zilog Microcontrollers.  
Fast programming algorithms.

**£325**



## Erasers & pin convertors

AT-701 – Chiprase  
Ultra-violet eraser.  
Very compact  
16 chip capacity  
Built in timer **£95**

Pin convertors  
from DIL to  
PLCC, SOP, SOIC etc...  
**from £50**



## PB-10 Programmer

Low cost programmer.  
EPROMs, E<sup>2</sup>PROMs, Flash and 8748/8751.  
Fast programming algorithms.  
Simple but powerful menu driven software.

**£139**

SMART Communications have a full range of dedicated programmers for the Microchip PIC range of microcontrollers – both single and gang for DIL and SOIC variants.

We also supply a wide range of development tools – Assemblers, Compilers, Simulators and Emulators – for a wide range of microprocessors, especially the Microchip range. Our ROM emulators start at just £99.

**SMART**  
COMMUNICATIONS

2 Field End • Arkley • Barnet • Herts • EN5 3EZ • England

Telephone +44 (0)181 441 3890

Fax +44 (0)181 441 1843

CIRCLE NO. 103 ON REPLY CARD



## Goodbye, goodbye

### EDITOR

Frank Ogden  
081-652 3128

### DEPUTY EDITOR

Martin Eccles  
081-652 8638

### CONSULTANT

Derek Rowe

### DESIGN & PRODUCTION

Alan Kerr

### EDITORIAL ADMINISTRATION

Jackie Lowe  
081-652 3614

### ADVERTISEMENT MANAGER

Richard Napier  
081-652 3620

### DISPLAY SALES EXECUTIVE

Malcolm Wells  
081-652 3620

### ADVERTISING PRODUCTION

Christina Budd  
081-652 8355

### PUBLISHER

Susan Downey

### EDITORIAL FAX

081-652 8956

### CLASSIFIED FAX

081-652 8956

### SUBSCRIPTION HOTLINE

0622 721666  
Quote ref INJ

### SUBSCRIPTION QUERIES

0444 445566

### NEWSTRADE DISTRIBUTION

Martin Parr  
081 652 8171

### BACK ISSUES

Available at £2.50  
081 652 3614

ISSN 0959-8332



I have always promised that I would never allow sporting similes to appear in this magazine. After all, it is simply not cricket. But since this is my last editorial for our magazine, I shall make an exception.

How else can you note the performance of Great British Electronics plc other than to compare it with our national cricket or football teams and their past triumphs? I say this because the rumours are insistent that our last major semiconductor maker, GEC Plessey Semiconductors, is about to be sold off to US company Rockwell. It looks like we are about to say goodbye to our last chance to compete in a \$100bn worldwide industry, a figure which is expected to rise to \$200bn by the turn of the century.

It is worth recalling that just a decade ago, we had five major indigenous semiconductor makers: Ferranti, Plessey, Marconi, STC and Inmos. A similar list for two decades ago would have been double that length. There are a host of complacent voices in the UK Government and the Civil Service who ask if the passing of a national semiconductor industry really matters...

The same voices say that the real value comes from building semiconductors into systems rather than in the making of the devices themselves. They see that wafer lines require astronomic investment, produce irregular returns and don't employ too many people. Contrast this with equipment assembly operations which are undemanding of their bankers and backers while employing any number of redundant miners and shipbuilders.

To anyone who has worked in electronics as I have, who has sat in this office and watched in impotent fury as we have moved down the world technology league table, the seductive voices were wrong, wrong, wrong. I say "were" because, realistically,

the time has long gone when we could have turned the situation around. We are now marginalised in an area fundamental to electronics design.

Semiconductor development and manufacture controls absolutely the design of the end-equipment. We mostly define the nature of a complete system at the silicon layout stage. If we wanted to add significant value in system building, we should have retained control of the enabling technology. We didn't, we haven't while our national competitors have and thus the fists of rage. The picture of Arnie Weinstock abdicating totally from any responsibility to our last major semiconductor concern will present a fitting epitaph to the UK's high technology decline.

Returning to the sporting simile, there are two remaining hopes. Root for the Europeans such as Temic, SGS-Thomson, Siemens and Philips in the hope that they play a few away matches in our country; support our junior league of small silicon design houses which have been singularly successful in contrast to the big league. Either way, we must keep playing the game to retain any sort of advanced technology manufacturing base.

I am saying goodbye to Wireless World after six years in the editor's chair to take up a position with another magazine. I have enjoyed my tenure and I would like to thank both readers and contributors for their support and the help which they continue to give to our magazine. I know that my successor, Martin Eccles, currently WW's deputy editor, will continue to develop this venerable journal towards applied electronic design. This has always been my ambition and I believe it to be one that Martin shares. **Frank Ogden**

*Electronics World + Wireless World* is published monthly. By post, current issue £2.25, back issues (if available) £2.50. Orders, payments and general correspondence to L333, *Electronics World + Wireless World, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS*. Tlx:892984 REED BP G. Cheques should be made payable to Reed Business Publishing Group.  
Newstrade: IPC Marketforce, 071 261-5108.  
Subscriptions: Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 0444 445566. Please notify change of address. Subscription rates 1 year (normal rate) £30 UK and £43 outside UK.  
USA: \$52.00 airmail. Reed Business Publishing (USA), Subscriptions office, 205 E. 42nd Street, NY 10117.

Overseas advertising agents: France and Belgium: Pierre Mussard, 18-20 Place de la Madeleine, Paris 75008. United States of America: Ray Barnes, Reed Business Publishing Ltd, 205 E. 42nd Street, NY 10117. Telephone (212) 867-2080. Tlx 23827.  
USA mailing agents: Mercury Airfreight International Ltd Inc, 10(b) Englehard Ave, Avenel NJ 07001. 2nd class postage paid at Rahway NJ Postmaster. Send address changes to above.  
Printed by BPC Magazines (Carlisle) Ltd, Newtown Trading Estate, Carlisle, Cumbria, CA2 7NR  
Typeset by Marlin Graphics 2-4 Powerscroft Road, Sldcup, Kent DA14 5DT

©Reed Business Publishing Ltd 1992 ISSN 0959 8332



## EC in the dark over r&d

An admission by the European Commission that it does not know what the r&d plans of Europe's major companies are, or how they relate to the EU's own strategy, is expected to create further argument in the UK cabinet.

The Commission plans to create a register of the research and development strategies of Europe's top 500 industrial companies. The aim is to discover the effectiveness of r&d being funded through its

Framework Programme and Eureka.

EC spokesman Michel André said: "European enterprises are responsible for 60 per cent of all r&d undertaken in Europe, but the information we need to evaluate this work is missing."

The admission by the Commission will add weight to the UK government's criticism of the way in which the EC calculates funding for R&D programmes. It will also strengthen the government's view

that cutting back UK funding to the Eureka programme was the right one.

A spokesman for the DTI said that such a situation could not arise in the UK. He said: We run a UK r&d Scoreboard, giving a breakdown on UK high tech companies, and how much they spend on r&d as a percentage of sales and profit. We also have an Innovation Unit linking national programmes, such as Link, into the work being undertaken by industry and academia.

## Euro screen is clear world leader

A new liquid crystal screen for portable computers and video projectors has the remarkable property of self-healing any defects in manufacture.

Developed by Philips Research Laboratories at Redhill, UK, the display uses active-matrix thin-film diode lcd is easier and cheaper to make than conventional lcds. It also gives brighter pictures.

The screen measures 24cm diagonally and is made as a plug fit replacement for the conventional lcd panels currently supplied by Japanese manufacturers. Philips hopes this will encourage firms making portable computers to switch from using Japanese to European displays.

Virtually all screens in today's portable PCs use thin-film transistor technology to control the flow of electricity through the liquid crystal.

The material is sandwiched between two thin glass plates and light-polarising filters. When electricity is passed through the lc

material it reacts to alter the angle of polarisation of any light which is passing through. The filters then work like crossed sunglasses, to create light areas where the crystal and filter polarisations have matching angles and dark areas where they cross.

In thin-film transistor screens, the glass plates have a thin film of amorphous silicon semiconductor material bonded to their surfaces. This silicon is formed into a mosaic of transistors which control the flow of electricity through pixel spots of the lc material to create a pattern of light and dark which displays the text or graphics image. Philips uses silicon diodes instead of transistors. The diodes are easier to make than transistors and need only two wire connections. They work with the capacitance of the lc material to switch between on and off states.

The diodes are made by sandwiching silicon nitride between metal electrodes which are so thin that they are almost transparent.

Because the diodes block less of the light which passes through the screen, the picture is around 10% brighter and has crisp contrast with 256 grades of grey. In practice this means that black areas of the image look much blacker than on conventional screens. The diodes also respond rapidly to the switching current so there is no smear on moving objects.

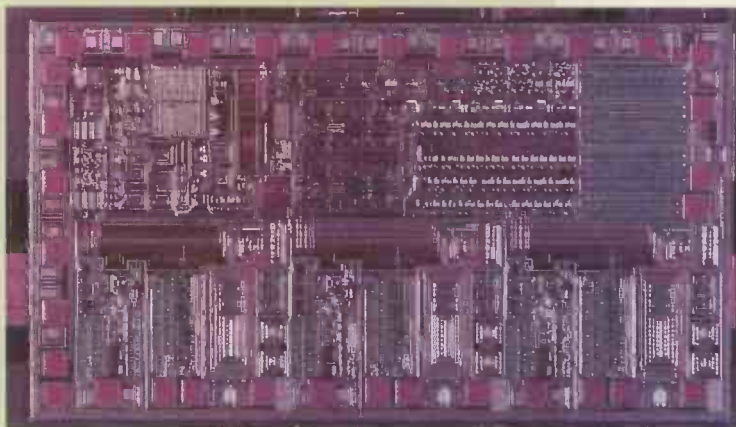
The diodes are easy to mass-produce because alignment of the electrode sandwich is not critical. As long as the two outer electrodes cover at least part of the silicon nitride filling, the diode works as a switch. The filling also has the remarkable ability to self-heal. If it is faulty through a fault in manufacture, and thus passes too much current, its electrical resistance increases to reduce the current.

Philips claims that the diodes are stable in bright light and heat and thus suitable for use in a projector. This means that the new lcd panels can be used in a video projector, where a bright light is shone through a small lcd panel and lens, and onto a large wall screen. Transistor panels break down after a few hours use under these conditions.

Philips began work on the display technology in 1989 and the first manufacturing samples are now rolling off a production line which Philips has jointly constructed with Thomson of France at a factory in Eindhoven, the Netherlands. This was the factory originally built for the ill-fated *Megachip* memory project.

Barry Fox

**Intelligent power dressing: This silicon maze is claimed to be the first dc motor controller chip to bring together high-side drive and low voltage regulator aspects in one surface-mount package. This IC, the Si997CS from Siliconix, is designed for three phase brushless motors and handles between 1-5A of current. Interfacing with microprocessors in photocopiers and printers, the controller will handle over a dozen control and protection functions.**



## NEW LOW PRICE - NEW COLOUR HP141T SPECTRUM ANALYSERS TESTED

- HP141T** + 8552A or B IF - 8553B RF - 1kHz - 110Mc/s - A IF £600 or B IF - £700.  
**HP141T** + 8552A or B IF - 8554B RF - 100kHz - 1250Mc/s - A IF £800 or B IF - £900.  
**HP141T** + 8552A or B IF - 8555A RF - 10Mc/s - 18GHz - A IF £1400 or B IF - £1600. The mixer in this unit costs £1000, we test every one for correct gain before despatch.  
**HP141T** + 8552A or B IF - 8556A RF - 20Hz - 300kHz - A IF £600 or B IF - £700.

## HP ANZ UNITS AVAILABLE SEPARATELY NEW COLOUR - TESTED

- HP141T Mainframe** - £350 - 8552A IF - £200 - 8552B IF - £300 - 8553B RF - 1kHz - 110Mc/s - £200 - 8554B RF - 100kHz - 1250Mc/s - £400. 8555A RF - 10Mc/s - 18GHz - £1000. 8556A RF - 20Hz - 300kHz - £250.  
**HP8443A Tracking Generator Counter** - 100kHz - 110Mc/s - £300 - £400.  
**HP8445B Tracking Pre-selector DC** - 18GHz - £400-£600 or **HP8445A** - £250.  
**HP8444A Tracking Generator** - £750 - 1300Mc/s.  
**HP8444A Opt 059 Tracking Generator** - £1000 - 1500Mc/s.

## SPECIAL OFFER - 14 ONLY HP140T (NON-STORAGE)

- Mainframe Plus 8552A IF Plug-In Plus 8556A RF Plug-In 20Hz - 300kHz Plus 8553B RF Plug-In 1kHz - 110Mc/s. Tested with instructions - £700.**

Marconi TF2088 - 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 to £600 - old or 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 - HP8447F - 1-1300Mc/s £400.  
 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 - 8418 - 8740 - 8741 - 8742 - 8743 - 8746 - 8650. From £1000.  
 Rcal/Dana 9301A - 9302 RF Millivoltmeter - 1.5-2GHz - £250-£400.  
 Rcal/Dana Counters 9915M - 9916 - 9917 - 9921 - £150 to £450. Fitted FX standards.  
 Rcal/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 - 85-7892A  
 Gould J3B test oscillator + manual - £200.  
 Tektronix Mainframes - 7603 - 7623A - 7613 - 7704A - 7844 - 7904 - TM501 - TM503 - TM506 - 7904 - 7834 - 7104 - 7623 - 7633.  
 Alltech 757 Spectrum Analyser - 001 22GHz - Digital storage + readout - £2000.  
 Marconi 6155A Signal Source - 1 to 2GHz - LED readout - £400.  
 Barr & 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.  
 Rcal/Dana 9300 RMS voltmeter - £250.  
 HP 8750A storage normalizer - £400 with lead + S.A or N.A Interface.  
 Marconi TF2330 - or TF2330A wave analysers - £100-£150.  
 Rcal/Dana signal generator 9082 - 1.5-520Mc/s - £500.  
 Rcal/Dana signal generator 9082H - 1.5-520Mc/s - £600.  
 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 - £2.5k.  
 Systron Donner counter type 6054B - 20Mc/s - 24GHz - LED readout - £1k.  
 Rcal/Dana 9083 signal source - two tone - £250.  
 Systron Donner - signal generator 1702 - synthesized to 1GHz - AM/FM - £600.  
 Tektronix TMS15 mainframe + TMS506 mainframe - £450 - £850.  
 Rhodes & Schwartz power signal generator SLRD-280 - 2750Mc/s - £250-£600.  
 Ball Efratom rubidium standard PT256B-FRKL - £1000.  
 Farnell electronic load type RB1030-35 - £350.  
 Rcal/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.  
 HP180TR, HP182T mainframes £300-£500.  
 Fluke 8506A thermal RMS digital multimeter. £400.  
 Philips panoramic receiver type PM7900 - 1 to 20GHz - £400.  
 Marconi 6700A sweep oscillator + 6730A - 1 to 2GHz - £500.  
 HP8505A network ANZ + 8503A S parameter test set + 8501A normalizer - £4k.  
 Rcal/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 - 436A or B - 436A - power meters + powerheads - Mc/s - 40GHz - £200-£1000.  
 Bradley oscilloscope calibrator type 192 - £600.  
 Barr & Stroud variable filter EF3 0.1Hz - 100Kc/s + high pass + low pass - £150.  
 Marconi TF2370 spectrum ANZ - 110Mc/s - £900.  
 Marconi TF2370 spectrum ANZ + TK2375 FX extender 1250Mc/s + 1st gen - £1.5k.  
 HP8614A signal generator 800Mc/s - 2.4GHz, new colour £400.  
 HP8616A 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 8671A syn microwave 2 - 6.2GHz - £2k.  
 HP 8683D S/G microwave 2.3 - 13GHz - opt 001 - 003 - £4.5k.  
 HP 8660 A-B-C syn S/G. AM + FM + 10Kc/s to 110Mc/s PI - 1Mc/s to 1300Mc/s - 1Mc/s to 2500Mc/s - £750-£2800.  
 HP 8640B S/G AM-FM 512Mc/s or 1024Mc/s. Opt 001 or 002 or 003 - £800-£1250.  
 HP 8656A S/G AM-FM 0.1 - 990Mc/s - £1500.  
 HP 8622B 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 4261A LCR meter + 16038A test leads - £400.  
 HP 4271B LCR meter 1MHz digital meter + 16063A test adaptor - £850.  
 HP 4342A Q meter-22kHz - 70Mc/s 16462A + qty of 10 inductors - £850.  
 HP 3488A HP - IB switch control unit - £500 + control modules various - £175 each.  
 HP 3561A Dynamic signal ANZ - £3k.  
 HP 8160A 50Mc/s programmable pulse generator - £1400.  
 HP 853A MF ANZ + 8558B - 0.1 - 1500Mc/s - £2500.  
 HP 8349A Microwave Amp 2 - 20GHz Solid state - £1500  
 HP 3585A Analyser 20Hz - 40Mc/s - £4k.  
 HP 8569B 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 - £500.  
 HP 5370A Universal time interval counter - £450.  
 HP 5335A Universal counter - 200Mc/s - £500.  
 HP 5328A Universal counter - 500Mc/s - £250.  
 HP 6034A System power supply - 0 - 60V - 0 - 10 amps - £500.  
 HP 3960A 3964A Instrumentation tape recorders - £300-£500.  
 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 PM5390 RF syn - 0.1 - 1GHz - AM + FM - £1250.  
 Philips PM5519 Colour T.V. pattern generator - £250.  
 S.A. Spectral Dynamics SD345 spectrascope 111 - LF ANZ - £2500.  
 Tektronix R7912 Transient waveform digitizer - programmable - £400.  
 Tektronix 496 Analyzer 1kHz - 1.8GHz - £3.5k.  
 Tektronix TR503 + TM503 tracking generator 0.1 - 1.8GHz - £1k - or TR502.  
 Tektronix 578 Curve tracer + adaptors - £900.  
 Tektronix 577 Curve tracer + adaptors - £900.  
 Tektronix 1502/1503 TDR cable test set - £1000.  
 Tektronix 7L5 LF analyser - 0 - 5Mc/s - £800. OPT 25 - £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 - £250-£1000.  
 Kikusui 100Mc/s Oscilloscope COS6100M - £350.  
 Farnell PSG520 Signal generator - £400.  
 Nicolet 3091 LF oscilloscope - £1000.  
 Rcal 1991 - 1992 - 1988 - 1300Mc/s counters - £500-£900.  
 Tek 2445 150Mc/s oscilloscope - £1400.  
 Fluke 80K-40 High voltage probe in case - BN - £100.  
 Rcal Recorders - Store 4 - 4D - 7 - 14 channels in stock - £250 - £500.  
 Rcal 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.  
 Schlumberger 5229 Oscilloscope - 500Mc/s - £500.  
 Solartron 1170 FX response ANZ - LED display - £280.  
 Wiltron 610D Sweep Generator + 6124C PI - 4 - 8GHz - £400.  
 Wiltron 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 - £2500.  
 Dummy Loads & power att up to 2.5 kilowatts FX up to 18GHz - microwave parts new and ex equip - relays - attenuators - switches - waveguides - Yigs - SMA-APC plugs - adaptors, etc.  
 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 - Rcal 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-SYNCRS-TRANSMITTING AND RECEIVING EQUIPMENT ETC.

**Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No: (0274) 684007. Fax: 651160**



## Multilevels boost memory

Intel has revealed that it is developing new flash memory technology which will enable a single storage cell to hold two or more bits of data.

The technology, dubbed *Multilevel Cell*, dramatically increases a chip's storage capacity without needing any more memory cells. Intel says the technique will be applied to memories for cost sensitive mass storage applications such as PCMCIA cards, digital audio and digital photography.

Multilevel Cell technology is simply the ability to write and read four (for 2-bit storage) or more voltage levels on the flash memory's floating gate storage cell. This compares with the conventional two levels for single bit storage and implies the use of three internal reference voltages.

Dr Stefan Lai, Intel's director of flash technology, said the technique has been demonstrated on a 16Mbit die storing two bits per cell. However, Lai also reported Intel engineers have experimented with three bits (eight voltage levels) and even four bits (16 voltage levels) per cell. "Our goal is to provide a 1Gbit

flash memory this decade based on four bits per cell and a 256Mbit die," said Dr Lai. The chip would need a 0.35µm process.

Intel's move has interested other flash memory manufacturers. Hitachi engineers in Japan said they were aware of multilevel cell technology but had no plans at present to implement it. They identified tighter process control and slower read times, because the cell has to be compared to a minimum of three reference voltages, as the two principal drawbacks.

Giulio Casagrande, technical manager of SGS-Thomson's flash memory division, said Intel's development made sense. "If you want to address the solid-state storage market, then multilevel cell technology is just one of the alternatives that may provide the breakthrough needed to significantly reduce the cost per bit," said Casagrande. But he questioned the scalability of the approach, suggesting the read voltage would need boosting as Intel progressed to smaller geometry processes.

Dr Lai reports that the main engineering problems to be

overcome are designing sufficiently accurate reference voltages and boosting the read currents from the cells. He does not consider the more stringent signal-to-noise constraints (to maintain adequate s/n margin between levels) to be outside the bounds of Intel's existing 0.6µm process even for 16 voltage levels.

"We feel comfortable at 16 levels even down to a 0.1V margin between levels. The process is the most developed part of the technology," said Dr Lai.

"The read access times are slower but that's not really because we are reading two bits but rather that the sense currents are smaller and take a longer time to charge up the column. So we are looking at more sensitive techniques and are looking at a parallel read operation.

"Reference voltage accuracy is the big issue at the moment. The voltages need to be stable across a range of operating conditions and although there are external references that provide the accuracy, the challenge will be building an internal reference," he said.

Simon Parry, *Electronics Weekly*.

*The ultimate train set: Managing the Jubilee line extension of the London Underground could be carried out from a computer terminal. Datel Technology has demonstrated an information management system in a £60m project for the railway. Real-time information from the platforms, signalling and surrounding area will be available from the ten stations on the line.*

## Big TI hopes for the big screen

Texas Instruments looks as though it will lead the market for PALPlus decoders with the launch of Britain's first widescreen TV service using PALPlus technology later this year.

Channel 4 has announced plans to broadcast at least 500 hours of PALPlus 16:9 format material a year starting in October. The £1.5m

cost incurred by Channel 4 is being split between the EU and Nokia Consumer Electronics, which will launch a 28in PALPlus tv to coincide with the start of services. The set will cost £1299.

TI is the only company with a highly parallel digital signal processor aimed at pixel processing and suitable for handling the

PALPlus decoding in tvs. It could maintain that position until dedicated PALPlus chipsets become available, and they are not expected until next year end at the earliest. "Everyone is using the Texas chip," confirmed Dr Helmut Stein, head of r&d at Nokia Consumer Electronics.

Called the SVP, the TI chip enables three dimensional processing of an entire line of the picture at a time. The chip integrates 960 processing elements in a single-instruction, multiple-data architecture. The number of elements is sufficient for a 16:9 picture format and is quick enough to cope with 16MHz sampling.

A more powerful version of the chip is due at the end of this year.

It will be four times faster, integrate more on-chip program memory and integrate 1024 processing elements – sufficient for 16:9 format pictures using computer-compatible square pixels.

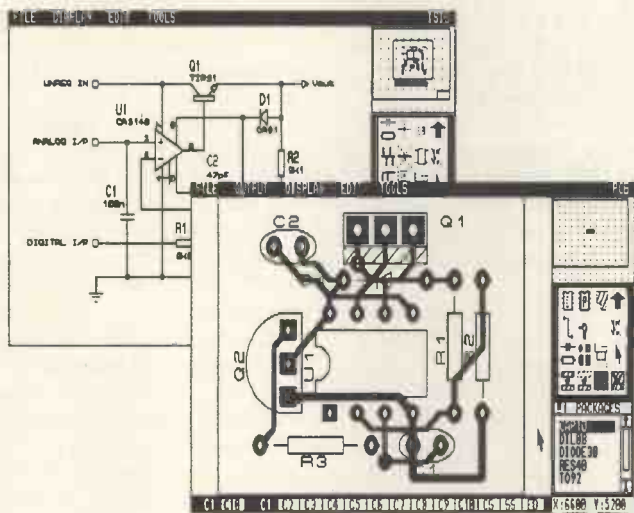
Three German tv stations are already making regular PALPlus broadcasts. Belgium is due to start this year, and Holland and Italy next.





# POWERFUL SCHEMATIC CAPTURE, PCB DESIGN AND AUTOROUTING ALL FOR JUST £395...

**PROPAK AR** for DOS provides all the features you need to create complex PCB designs quickly and easily. Draw the circuit diagram using the powerful facilities of ISIS DESIGNER+ and then netlist into ARES AUTOROUTE for placement, autorouting and tidy up. Advanced real time design rule checks guarantee that the final PCB will correspond exactly with the schematic thus saving you from costly layout errors and time consuming debugging.



- Attractive, easy to use graphical interface.
- Object oriented schematic editor with automatic wire routing, dot placement and mouse driven place/edit/move/delete.
- Netlist generation for most popular CAD software.
- Bill of Materials and Electrical Rules Check reports.
- Two schemes for hierarchical design.
- Automatic component annotation and packaging.
- Comprehensive device libraries and package libraries including both through hole and SMT parts.
- User definable snap grids (imperial and metric) and Real Time Snap to deal with tricky SMT spacings.
- Manual route editing features include Auto Track Necking, Topological editing and Curved tracks.
- Autorouting for single, double and multi-layer boards.
- Non autorouting PROPAK is available for just £250 if you do not need or want the router.
- Full connectivity and design rule checking.
- Power plane generator with thermal relief necking.
- Graphics support to 800x600 Super VGA.
- Output to dot matrix and laser printers, HP and Houston plotters, Postscript devices, Gerber and Excellon NC machines plus DXF and other DTP file formats.

## CADPAK Two Programs for the Price of One

### ISIS SUPERSKETCH

A superb schematic drawing program for DOS offering Wire Autorouting, Auto Dot Placement, full component libraries, export to DTP and much more.

Only  
£79

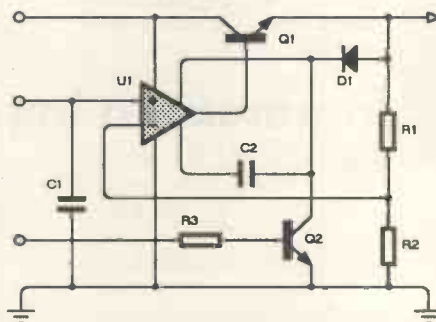
Exceptionally easy and quick to use. For example, you can place a wire with just two mouse clicks - the wire autorouter does the rest.

### PCB II

High performance yet easy to use manual PCB layout package. Many advanced features including curved tracks, auto track necking, DXF export, Gerber and NC file generation, Gerber viewing and more.

Alan Chadwick writing in ETI (January 94) concluded...  
"At £79 I thought this was an excellent buy."

## ISIS ILLUSTRATOR Schematic Drawing for Windows



From  
£99

Running under Windows 3.1, ISIS ILLUSTRATOR lets you create presentation quality schematic drawings like you see in the magazines. Furthermore, when the drawing is done, transferring it to another document is just a matter of pasting it through the Clipboard.

Now used by a number of prominent technical authors to illustrate their latest books and magazine articles.

**Labcenter**  
Electronics



Call us today on 0756 753440 or fax 0756 752857 for a demo pack - state DOS or Windows. Multi-copy and educational discounts available.

WE HAVE MOVED - NOTE NEW ADDRESS

Prices exclude p&p (£5 for U.K.) and VAT. All manufacturers' trademarks acknowledged.

53-55 Main St, Grassington, North Yorks. BD23 5AA.

CIRCLE NO. 105 ON REPLY CARD

## Video surveillance over the 'phone line

Video surveillance technology developed for the US army by Iterated Systems of Atlanta, Georgia, will soon let unattended cameras in art galleries, car parks and office buildings catch thieves, vandals and terrorists. It relies on fractal compression of moving images and plays a clever trick to send clear moving pictures of any suspicious behaviour down an ordinary 'phone line. Since the system also works over a cellphone link, the camera can be in a field.

The pictures display any distance away on an ordinary personal computer, and are recorded on an ordinary floppy disk. To save money on phone charges the camera automatically dials the telephone number of the display PC only when it registers motion. The same technology can be used for low cost videoconferencing.

Until now videophones have only been able to send very blurred moving pictures down ordinary domestic telephone lines. Thieves are only recognisable if they obligingly remain still and pose close to the camera. Systems which deliver high quality pictures rely either on ISDN digital telephone lines or work only over very short distances.

The US military wanted to put a video camera on a remote-controlled vehicle, and send it into a dangerous area, while relaying high quality moving pictures by low quality radio links. Iterated Systems had

already developed fractal technology to compress high quality still pictures into small volumes of digital code. The company made the compressor work fast enough to code moving pictures from a video camera.

Coding a picture by fractal compression reduces the number of digital bits needed to capture good quality by a factor of around thirty. The fractal compressor works by breaking each picture down into component shapes, like pieces of a jigsaw, and then rebuilding the picture by arranging basic shapes which have been previously stored in a library. Conventional picture compression systems work by breaking the picture down into a mosaic of tiny picture points or pixels, and coding each one separately.

Despite the powerful compression achieved with fractals, the number of bits per second needed to display a full screen picture of clear motion is still far too many to send over long distances by a POTS ("plain old telephone service") line. POTS lines, and cellphone links, can reliably carry only around 10 kilobits/second, and at best 20kbits/s.

Iterated Systems gave the US military a clever compromise. At the beginning of the surveillance session, the camera takes around 10s to transmit a high quality still picture of the whole area under surveillance. This picture is frozen

on the screen of the display PC. The operator then singles out a small 'window' area of the picture, such as a vulnerable doorway or valuable painting on a wall. The camera now provides a moving image for just that part of the picture.

Because the selected area of the screen can be relatively small, the quality of the moving image is high, but the bit rate within phone line limits. So the overall impression is of a clear picture of the whole area, with an equally clear view of any motion in those areas which need surveillance.

After initial setup, the telephone connection is broken to save money. But as soon as the camera registers any motion in the selected image area it automatically dials the telephone number to connect with the PC, and triggers an alarm to alert the operator.

Alan McKeon, Iterated System's Vice-President of Sales and Marketing, recently demonstrated the system working on ordinary telephone lines between London and Atlanta. Clear moving pictures of an office worker's head and shoulders appear in the middle of an overall, frozen view of the office room.

The compression circuitry will be built into a video camera, along with a telephone modem and auto-dialler, and sell for around £750. All the user then needs is a desktop PC, ordinary phone line or cellphone. Iterated Systems Ltd 0734-880261.

*Drive to nowhere: Not in a jam around London but in a driving simulator. Researchers at the University of Iowa have created a virtual highway on the car windscreen. The aim is to collect data for new research into vehicle safety, highway design and driver training.*

*Three computer-generated images provide the driver with a realistic illusion of moving at speed while also feeling bumps in the road and hearing the wind rushing by. This virtual reality experience includes the sensation of a violent rear end shunt.*



## Inmarsat to improve on GPS services

Inmarsat, the international satellite operator, has signalled its intention to compete head-to-head with existing US and Russian global positioning (GPS) satellite services, inviting potential GPS service providers to bid for navigation transponders on its next generation Inmarsat-3 satellites.

Inmarsat claims the new satellites, to be launched at the end of next year or early 1996, will offer a more accurate positioning service than the existing military-owned US Global Positioning System and Russian GLONASS (Global Navigation Satellite System).

In addition, Inmarsat says it will provide an independent "integrity monitoring" service for the existing GPS networks. As well as the navigation signals, the satellites will broadcast an additional signal which corrects errors in the US and Russian services. The move could enable civil airlines to start using GPS for navigation for the first time. Until now airlines have been put off by the unreliability of existing services.

The satellite organisation says Inmarsat 3's correction signals will

pinpoint the position of users to within 10m, compared to the 50m currently achievable by using the US service alone. ■

## Eurofighter scrap

A call that the Eurofighter manufacturing collaboration should be scrapped due to soaring development costs has come from the German opposition Social Democrats. But the German defence minister Volker Ruhe has defended the multi-billion DM project which is being financed by German, British, Spanish and Italian taxpayers.





## PROGRAM 8 CHIPS IN THE TIME IT TAKES FOR ONE!

At £645 costing around half the price of slower gang programmers, the Speedmaster 8000 gang programmer uses a simple 2 button operation in stand-alone mode. PC operation gives comprehensive file handling and editing functions. Capable of gang and set programming it supports 32 pin EPROMs to 8M with no adaptors required. Programming cycle times of only 23 seconds for 8 27C010's mean your throughput can now be faster than ever before.

CIRCLE NO. 106 ON REPLY CARD

## ROM/RAM EMULATOR PLUG IN CARDS

Using these expansion cards your programmer can run as if there's an EPROM or RAM plugged into the target socket. Available as 8 bit wide 128k x 8 as standard, upgradable to 512k x 8, and 16 bit capable of emulating 40 pin EPROMs. They can emulate both 5V and 3.3V devices.

CIRCLE NO. 107 ON REPLY CARD

## PACKAGE ADAPTORS

A full range of package adaptors is available for non DIL devices and parts with more than 40 pins. Prices from £65.

CIRCLE NO. 108 ON REPLY CARD

DISTRIBUTORS  
 BENELUX: +3255313737;  
 CYPRUS: 02485378;  
 DENMARK: 048141885;  
 FINLAND: 070039000;  
 FRANCE: 0139899622;  
 GERMANY: 060827421615;  
 GREECE: 019020115;  
 ITALY: 02457841;  
 JAPAN: 053865501;  
 NORWAY: 063840007;  
 SINGAPORE: 04831691;  
 SOUTH AFRICA: 0119741211/1521;  
 SPAIN: 013270614  
 USA: Distributors required.

## FREE SOFTWARE UPGRADES! - KEEP UP TO DATE WITH NEW DEVICES

Before you choose your programmer, check out the cost of ownership. While other manufacturers charge for every update or require expensive libraries and modules, ICE Technology programmers

support the whole range of devices at no extra charge\*. And keeping up to date is FREE for life at no charge on our BBS service.

Just dial on: +44(0) 1226761181, and download the latest version.

Disk based upgrades are available free in the first year, and a small administration charge made for each subsequent disk.

\* for DIL up to 40 pins.

CIRCLE NO. 109 ON REPLY CARD

## AT LAST, AN AFFORDABLE 3V AND 5V UNIVERSAL PROGRAMMER!



The latest universal programmers from ICE Technology, the Micromaster LV and Speedmaster LV, now support programming and verification of 3.3V devices, now you can test devices at their actual operating voltage.

They offer wider device support than ever before, the majority requiring no adaptor. They will operate from battery or mains power,

making them flexible enough whatever your programming needs.

Not only that, as new devices come onto the market we give free software upgrades and the units' modular design, with easy upgrade path, protects your investment.

Available now and priced from £495 they are everything you'll need for programming, chiptesting and ROM emulation.

## FEATURES

- ◆ Widest ever device support including: EPROMs, EEPROMs, Flash, SPROMs, BPROMs, PALs, MACH, MAX, MAPL, PEELs, EPLDs Microcontrollers, etc.
- ◆ High speed, programmes a PIC16C54 in 0.5 secs (Micromaster LV).
- ◆ Up to 84 pin device support with adaptors.
- ◆ Connects directly to parallel port - no PC cards needed
- ◆ Built in chiptester for 7400, 4000, DRAM, SRAM.
- ◆ Lightweight and operates from mains or battery.
- ◆ Optional 8 or 16 bit wide ROM/RAM emulator.
- ◆ Designed, built and supported in the UK.
- ◆ FREE software device support upgrades via bulletin board.
- ◆ Next day delivery.

CIRCLE NO. 110 ON REPLY CARD

### Speedmaster LV

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

£495

### MicromasterLV

As above plus support for over 90 different micro controllers without adaptors, including PICs, 89C51, 87C751, MC68HC705, ST6, Z86 etc.

£625

### 8 bit Emulator card

Expansion card containing 8 bit wide ROM RAM emulator, includes cable and software. 128K x 8.

£125

### 16 bit Emulator card

Expansion card containing 16 bit wide ROM RAM emulator, includes cable and software. 128K x 16.

£195



Call now to place your order, for more details or a free demo disk, or call our bulletin board to download the latest demo. Alternatively clip the coupon or circle the reply number.

Name: .....

Position: .....

Company: .....

Address: .....

Tel: .....

Fax: .....

EWV OCT

ICE Technology Ltd. Penistone Court, Station Buildings, Penistone, South Yorkshire, S30 6HG, UK.

Tel +44(0)1226767404, Fax +44(0)1226370434, BBS +44(0) 1226 761181

All major credit cards accepted



# RESEARCH NOTES

Jonathan Campbell

## Old masters painted in pixels

The EC programme to put high-resolution copies of Europe's greatest art masterpieces onto CD-ROM could take a leap forward with development of a camera that delivers high resolutions, rapidly and from a much smaller unit than previously. The new digital camera has been developed by Lindsay MacDonald of Crosfield Electronics and Reimar Lenz of Munich's Technical University ('An Ultra-

is slow, cumbersome and limited to two-dimensions. MacDonald and Lenz believe their camera could change that.

Like previous digital cameras, the Marc camera makes use of micro- and macro-scanning to boost the resolution of conventional ccd arrays.

In micro-scanning, a mask is fitted over a standard low resolution ccd array to make the sampling apertures smaller. Using piezo-electric actuators, the chip can be moved in two dimensions across the image plane allowing partial images to be captured at each sampling point. These can then be assembled in the correct pixel sequence by computer. Colour images are obtained by using a ccd sensor with built-in colour filter stripes and image quality is comparable to 35mm film. The sensors are low-price and the camera is easy to set up, though the piezo-electric actuators must be carefully calibrated and the small aperture means high levels of illumination must be used. But the technique has been used to produce high resolution commercial cameras.

Macro-scanning involves step-moving the camera and lens assembly in front of the scene, by the width and height of the ccd array, to build a complete image by a series of patches. Speed of acquisition is rather slow because the sensor has to be moved about 10mm and must be allowed to settle between adjacent patches. But with

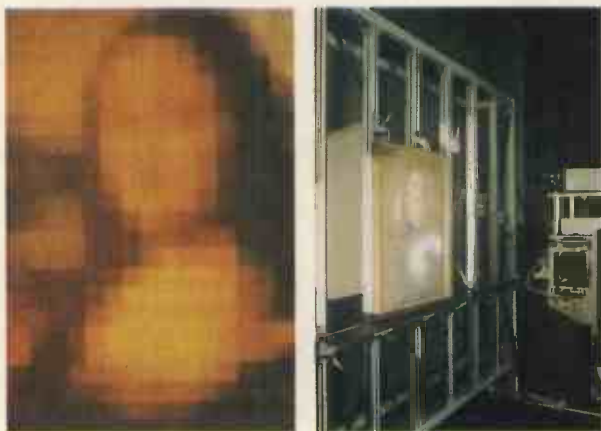
sufficient positioning precision, defect-free images can be obtained.

Cameras combining micro- and macro-scanning are already in use, digitising fine art at the National Gallery in London and Neue Pinakothek in Munich.

But the problem is that they are so big, as they need to incorporate a massive rigid frame to make accurate patch movement possible. As a result, pictures must be removed from the gallery to be processed in the laboratory.

The new Marc camera combines micro- and macro-scanning behind a stationary lens so that the need for a large x-y external position mechanism is eliminated. As the image perspective is not altered, the developers say that, with a suitable lens, 3-d objects of arbitrary size can be processed, resolution of the system is limited only by diffraction and the image field size of the lens.

The camera is currently undergoing final debugging before it is used later this year scan in a series of Flemish masters. During digitisation, each patch needs only 4s to micro-scan with an additional 0.7s to reposition. So a full size image can be acquired in less than five minutes. But the greatest advantage is that the camera can be used on pictures still hanging in position in the gallery. The result is faster processing, no transport problems or extra insurance cover and no worries over humidity damage for what are extremely valuable pictures.



*Monalisa, left, through the eye of a predecessor of a micro-scanning camera designed for digitally archiving works of art, right.*

High Resolution Digital Camera', *The Journal of Photographic Science*, Vol 42, pp. 49-51) within the European Marc research project.

Marc - Methodology for Art Reproduction in Colour, part of the Esprit programme - aims to produce digital representations of fine art for high quality printing or for electronic manipulation and distribution. But current, high resolution digital camera technology

## Robodoc with the hip attitude

Hundreds of thousands of people every year undergo surgery to replace hips with artificial implants. But currently in the US, a brave few are being operated on by a rather unusual surgeon - a robot.

The Robodoc surgeon takes over from the human one in cutting the cavity in the thigh bone into which the implant is pushed. Results have shown that the robot's accurate preparation and positioning of the cavity means patients have a better than usual chance of walking properly again.

Trials are still in the early clinical stages. An initial ten-patient single-centre study has been successfully completed and now researchers are in the middle of a 300 patient, multi-centre test.

The robot has been developed by a US team from IBM and Integrated Surgical Systems. In early tests it was used in veterinary clinical trials on dogs needing hip replacement surgery.

The researchers report an order of magnitude improvement in surgical precision compared to manual

broaching for cementless hip replacements. Russel Taylor of the IBM TJ Watson Research Center, and colleagues, claim the robot is a step forward in the evolving partnership between humans (surgeons) and machines (computers and robots), a relationship that seeks to complete a task better than either can do alone.

Robots have been used for limited tasks in surgery before. But the group says that the hip replacement application requires ten-times greater accuracy than other uses,



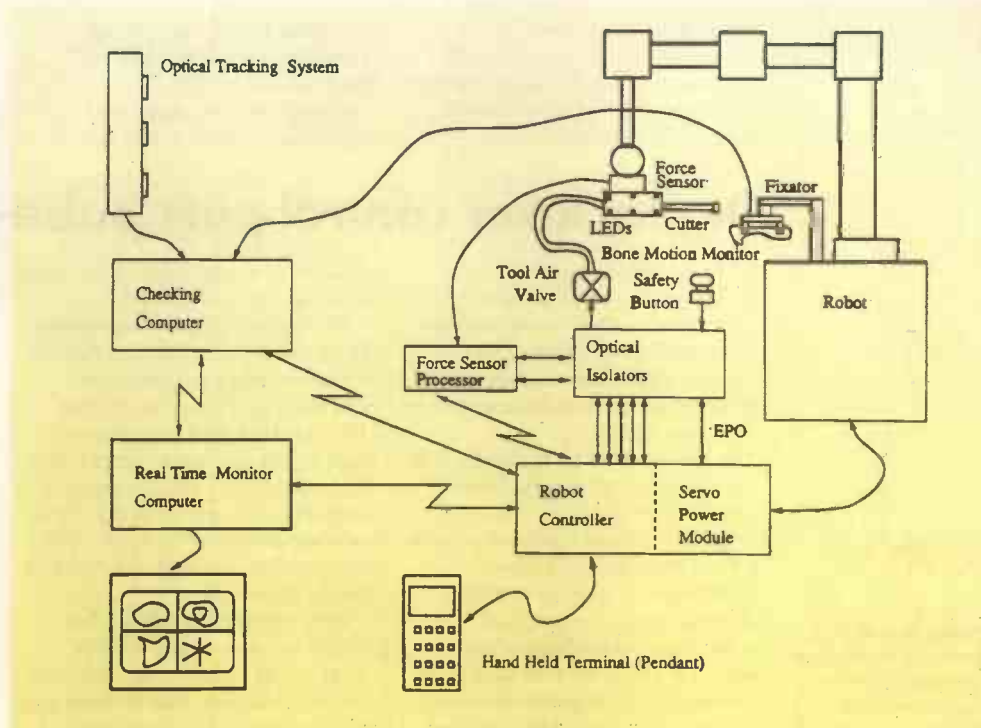
while the shapes to be cut are more complex. Safety is more important and the working volume must be much less constrained.

For the patient, preparation for robot surgery begins prior to the operation, with the implanting of three titanium pins through a small skin incision into the thigh bone. A computer tomography scan is then made of the leg, and the pins are located relative to the coordinate system of the CT images. The surgeon selects a hip implant module and determines its position, using the CT data, which is written to disk for use in the operation. During the surgery, the sterilised robot is brought into the operating theatre and the patient data disk loaded. When the patient is ready, his or her thigh bone is fixed rigidly to the robot base and the three titanium pins exposed.

The robot then orientates itself using these pins and computes the transformation from CT coordinates to robot coordinates. Cuts can be made by the robot to produce the desired implant shape at the planned position and orientation relative to the pins.

The human surgeon monitors the robot both visually and by observing a graphical display showing successive cuts. When cutting is complete the thigh-bone is unclamped and the robot is moved out of the way. Plainly, when cutting into a human body, constant position checking and protection against machine failure is vital. But the researchers say there as yet have been no problems.

One of the main needs has been



that the human must be in charge at all times, a complex requirement as the surgeon must also trust the system to some extent. Researchers say the system has worked well in surgery and the total surgery time was comparable to manual broaching. A future development could be addition of a head-up display that shows the surgical plan superimposed on the actual patient. It will surely be some time before such robots become part of the scene in normal NHS hospitals. Researchers will need to develop an integral coin slot and pay meter for a start.



*Robodoc's participation in a total hip replacement marks the first time in US medical history that robotics technology has been actively employed in an invasive surgical procedure.*

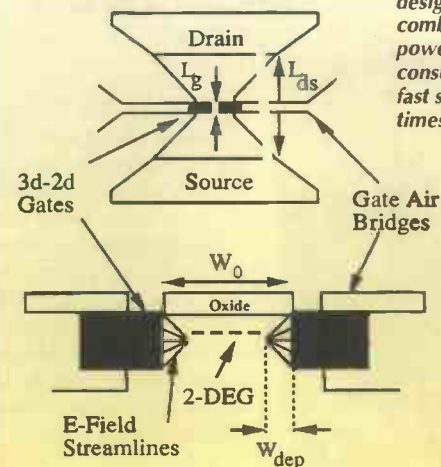
## Mesfet redesign cuts power needs

Announcement of a 2d mesfet that makes big cuts in the power consumption/delay product could pave the way for greater vlsi scaling and longer battery life. Conventional fet power needs put an upper limit on vlsi size, while reducing power consumption will detrimentally affect switching speed.

But using a novel design of 2d mesfet, where opposing Schottky side-gates modulate channel width, WCB Peatman and colleagues at the University of Virginia (*IEEE Electron Device Letters*, Vol 15, No 7, pp. 245-247) say they have practically eliminated the narrow channel effect which limits the minimum power consumption in conventional fets.

The power/delay product of a fet is determined by the energy stored in the gate capacitor and is determined by the gate capacitance plus parasitic capacitance, multiplied by the square of gate voltage swing needed to switch between on and off. In the Virginia 2d mesfet, gate design is based on a lateral metal-2d electron gas (2deg) junction, having geometry very different to that of conventional fet devices. Junction capacitance of the 3d-2d Schottky diode is dominated by the direct contact to the 2d electron gas, and the parasitic capacitance is small compared to the junction capacitance.

Transconductance is said to be higher than achievable in conventional 1 $\mu$ m fets suffering



*Unusual mesfet design that combines low power consumption with fast switching times.*

from the narrow channel effect while threshold voltage and sub-threshold ideality factor are reported to be comparable to state-of-the-art hemfets. Gate capacitance is

estimated to be  $0.8\text{fF}/\mu\text{m}$  per sidegate, or about half that of conventional hemfets.

Overall, the device shows a significant reduction in power

consumption without loss in speed, and the researchers believe it could have very good prospects for ultra low power circuit applications in the future.

## Digital laser control puts pulse-power on site

**H**eavy section welding – expensive and traditionally carried out in-shop – could become a practical process for use on-site following a breakthrough in welding power obtained from cheaper, lower power lasers.

Researchers led by Stefan Scott at the University of Alberta report (*Applied Physics Letters*, Vol 65, No 3, 1994) development of a multi-kW cw laser demonstrating significantly improved welding properties over conventional technology. At the heart of the system is a CO<sub>2</sub> burst-mode PIE (photoinitiated, impulse-enhanced, electrically-excited) laser. The pie process involves applying dual-

superior to normal cw welding at the same average power level.

Peak optical power is reported to be up to three times greater than cw operation, while the multi-kW average output power is retained. The drawback with conventional high-power cw laser systems is that they need large capital investment and can prove unreliable in constant duty applications. They also allow only average power to be controlled during operation.

Deep penetration welding has tended to focus on peak-power, short-duration, high-frequency laser pulsing. Although such systems give deep penetration, average laser beam power is low. Unfortunately, average power (along with peak intensity) is one of the main factors that makes economical welding possible. But the Alberta researchers say their unit is the first pulsed laser system capable of high peak power, pulse-periodic operation at multi-kW average power levels.

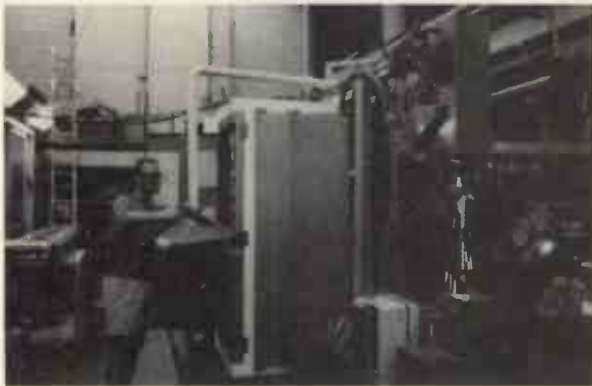
Continuous-wave operation is achieved using low-level digital pulse excitation of a pentode hydrogen thyatron pulser circuit while burst mode is obtained by manipulation of the digital trigger signal. Gating the cw excitation trigger produces basic burst mode operation. The project is built around a 30kW cw pie laser originally designed for application in the oil and gas pipeline industries.

At present the team can weld, using its modified system, 1m diameter pipe and straight sections up to 3.5m in length. The apparatus

has also been used to blind-weld heavy plate onto structural members – as found on large oceanic oil tankers and military vessels. This marine application requires penetration of 0.75in to weld through the 0.5in steel plate onto a 0.5in web.

Alberta says the task was completed at an average laser power of only 9kW.

*Alberta researchers squeezing high-power performance from a low power burst mode laser welding X-70 pipeline steel.*



polarity 10kV photoionisation impulses coupled with high voltage dc excitation to produce a highly controllable large-volume discharge. A digitally controlled hydrogen thyatron circuit is used to produce the impulses. Penetration with the pie laser is claimed to be 50% better, and the weld profile far

## Mobile phones make for mean streets

**N**o car-bore worth his wheels feels properly dressed without a dashboard full of in-vehicle route-finders and journey information systems. But are we in danger of giving too little attention to the actual mechanics of controlling the car?

A recent Swedish study showed that, despite what we think, we can't even make a hands-free mobile phone call without affecting our driving and, surprisingly, we are most influenced when the road conditions seem the safest.

The research was carried out by Håkan Alm and Lena Nilsson of the Swedish Road and Transport Research Institute. They tested the effects of using a hands-free phone on driver reaction time, lane position, speed level and workload. What they found (*Accident Analysis and Prevention*, Vol 26, No. 4, pp. 441-451), using a driving simulator, was that driving definitely worsened and, against expectations, driver reaction times slowed most when carrying out the easiest tasks. In the hardest conditions, only lateral position was affected. So if the map-reading phone-talking satellite-tracking auto-pilot speeding past at 100mile/h is just wobbling in his lane a little, don't worry. The time to be concerned is when he slows down...

**...but will it fly?** Helicopter robots able to navigate their own way around an arena, and tracked robots able to manipulate objects on the ground were all busy pumping their servos at the Association for Unmanned Vehicle Systems annual aerial robotics competition. Unfortunately no one machine was yet able to combine both functions – though the AUVS says this day is not far off.

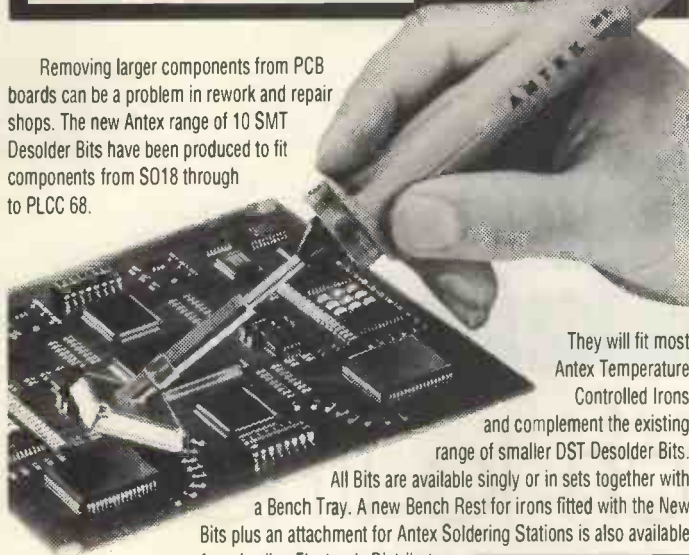
As usual the competition was held at Georgia Tech's Bobby Dodd stadium and Georgia Tech was among the seven different institutions fielding teams. First prize went to the students from the University of Southern California whose 'behavioural-based approach' impressed the judges.





# New low-priced Desolder Bits from Antex

Removing larger components from PCB boards can be a problem in rework and repair shops. The new Antex range of 10 SMT Desolder Bits have been produced to fit components from SO18 through to PLCC 68.



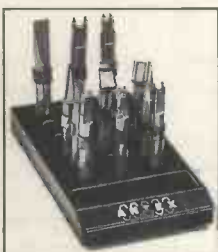
They will fit most Antex Temperature Controlled Irons and complement the existing range of smaller DST Desolder Bits.

All Bits are available singly or in sets together with a Bench Tray. A new Bench Rest for irons fitted with the New Bits plus an attachment for Antex Soldering Stations is also available from leading Electronic Distributors.

## ANTEX

Antex (Electronics) Ltd.

2 Westbridge Industrial Estate, Tavistock, Devon PL21 8DE  
Tel: (0822) 613565 Fax: (0822) 617598



CIRCLE NO. 111 ON REPLY CARD

# KENWOOD

TEST & MEASURING INSTRUMENTS  
A SUPERB RANGE OF OVER 100  
QUALITY INSTRUMENTS.

Available from  
**B.K. ELECTRONICS**



- FM-AM Signal Generators ★ Colour Pattern Generators ★ Video Signal Analyser ★ Video Timing Analyser ★ Video Noise Meter
- ★ Distortion Meter ★ Waveform Monitors
- ★ Vectorscopes ★ Audio Generators ★ Wow and Flutter Meters ★ Electronic Voltmeters
- ★ Digital Multimeters ★ Function Generators
- ★ Frequency Counters ★ Bus Analyser
- ★ Resistance Attenuator ★ Oscilloscopes ★ Fully Programmable Digital Storage Oscilloscopes
- ★ Regulated D.C. Power Supplies

A free, 50 page colour brochure, including price list, is available on request. Please make your request on company headed notepaper, by post or by fax, to:

**B.K. ELECTRONICS**

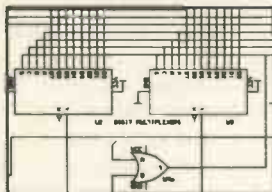
Unit 1 Comet Way,  
SOUTHEND-ON-SEA,  
Essex, S82 6TR.  
Tel: 0702-527572  
Fax: 0702-420243



CIRCLE NO. 112 ON REPLY CARD

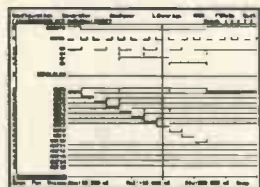
## Electronic Designs Right First Time?

### Schematic Design and Capture

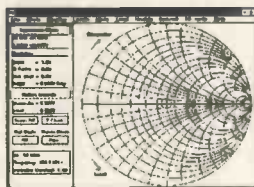


Create your schematics quickly and efficiently using EASY-PC Professional. Areas of the circuit can be highlighted on screen and simulated automatically using PULSAR, ANALYSER III and Z-MATCH our simulation and design programs.

### Digital and Analogue Simulation



Modify the configuration and change component values until the required performance is achieved.



### PCB Design



The design, complete with connectivity, can then be translated into the PCB. The connectivity and design rules can be checked automatically to ensure that the PCB matches the schematic.

Visa, MasterCard, Amex welcome

### Affordable Electronics CAD

EASY-PC: Entry level PCB and Schematic CAD	£98.00
EASY-PC Professional: Schematic Capture and PCB CAD. Links to ANALYSER III and PULSAR.	£195.00
EASY-PC Pro' XM: Greater Capacity, XMS Version.	£245.00
PULSAR: Entry level Digital Circuit Simulator ~ 1500 gate capacity.	£98.00
PULSAR Professional: Digital Circuit Simulator ~ 50,000 gate capacity.	£195.00
ANALYSER III: Entry level Linear Analogue Circuit Simulator ~ 130 nodes.	£98.00
ANALYSER III Professional: Linear Analogue Circuit Simulator ~ 750 nodes.	£195.00
Z-MATCH for Windows: Smith Chart based problem solving program for R.F. Engineers.	£245.00
FILTECH: Active and Passive Filter design program.	£145.00

No penalty upgrade policy. Prices exclude P&P and VAT.

### Number One Systems Ltd.

Ref WW, Harding Way, St. Ives,  
Huntingdon, Cambs. PE17 4WR, UK.

For Full Information Please Write, Phone or Fax.

Tel: 0480-461778  
Fax: 0480-494042

CIRCLE NO. 113 ON REPLY CARD



**Ben Duncan measures and compares important, rarely documented regulator performance features through three generations of linear ICs and the latest micropower switching types.**

# Voltage regulator chips: switch to linear?

**A**n unsuitable choice of regulator can have repercussions that are more catastrophic and far-reaching than others. Even the best data sheets for linear regulators, from companies like Linear Technology and National Semiconductor, do not tell you everything; important graphs are absent and documentation has not progressed in years.

With switching regulators, there is even more to know, and yet less is graphed in proportion. This article charts important ac and transient domain performance results that are sparsely – and decreasingly – charted by makers.

## The line-up

For this evaluation, nine monolithic ICs were chosen, three linear devices and six switchers. For uniformity, all were configured to regulate to +5V. Since there is an increasing tendency to distribute regulation around pcbs<sup>1</sup>, some low current parts operating at less than 1A were included, and testing carried out at both 105 and 225mA.

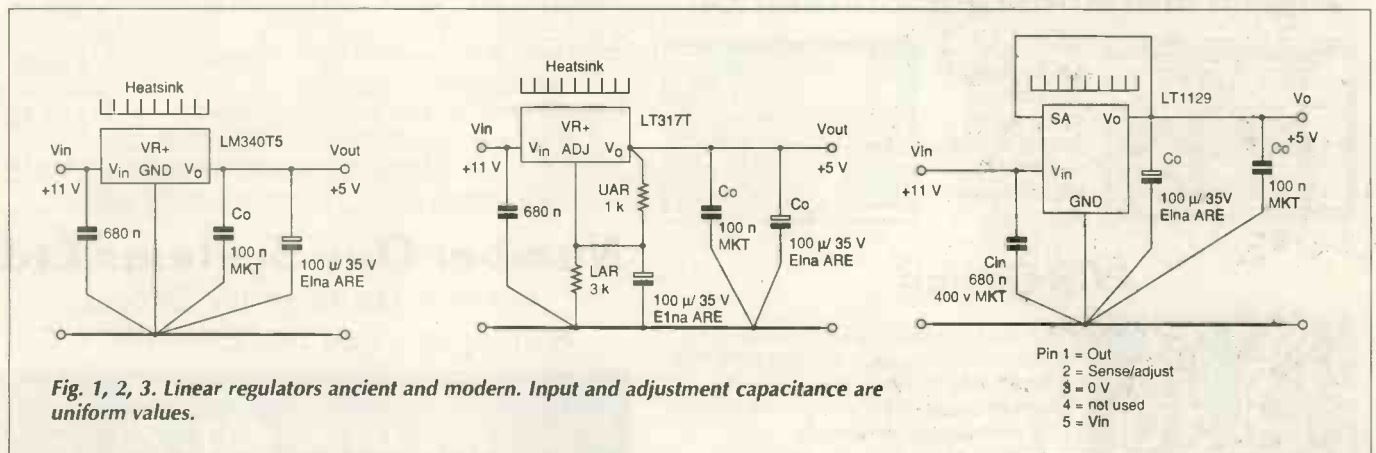
In several cases, both fixed and adjustable

voltage versions of a particular regulator are available. Below, an asterisk indicates that the results shown are for an adjustable type.

Beginning with the linear ICs, the *LM340* represents the top grade of classic fixed type, while the *LT317* is a premium example of the adjustable variant that is almost as old. The less well known *LT1129*\* is a recently introduced low dropout (0.4V), 700mA part. It has a low quiescent current that is claimed not to increase when the regulator is unloaded. Figures 1-3 show the test configurations.

All the switching regulators were chosen for their low external component requirements, Fig. 4. Ignoring the IC and input and output decoupling capacitors  $C_{in}$ ,  $C_o$ ,  $C_{o2}$ , the *LM2576* uses the fewest – just an inductor and a diode. The *LA962* requires the most, totalling seven, namely two resistors, three capacitors, one inductor and a diode.

Throughout, the switching regulators are differentiated by their current ratings. The first three are in plastic dual-in-line packages. Maxim's *MAX639* is a step-down switching IC rated at up to 225mA. Its current-limiting 'pulse frequency modulated' scheme yields





high efficiency over a range of loads†.

Linear Technology's *LTC1174\** is a multipurpose switching converter. Here it is configured as the others are made: as a step-down (buck) regulator. Maximum output current of 600mA can be stepped down to 340mA by strapping. The integral switch is mosfet, quiescent current is 130µA and switching frequency is adjustable, up to a higher than average 200kHz.

Within the *LT1176* step-down switching IC is an integral 1.2A bipolar transistor switching at a nominal 100kHz. Response to voltage changes is speeded by using a multiplier in the loop.

SGS-Thomson's *L4962* is a 1.5A step-down switching IC in a Heptawatt seven legged T0220 packaging. It operates at 150kHz. While requiring more parts than others, it includes soft-start. At 50V, the input and differential voltage ratings are higher than any of the preceding ICs.

Finally, National Semiconductor's *LM2576\** is a similar category of device in a Pentawatt packaging. Operating at up to 63V in its HV version, this device is rated at 3A and switches at a fixed 52kHz.

**Tests and application**

Measurements are focused on graphical performance information readily obtained with a modern If test set, but scarcely documented by makers, namely:

- Intrinsic noise versus frequency
- Ripple rejection versus frequency
- Spectra of ripple caused by abrupt, repetitive load change.

Switching IC data sheets make efficiency claims, but how often is the efficiency of a linear psu charted? Being long overdue, a uniform assessment is included here.

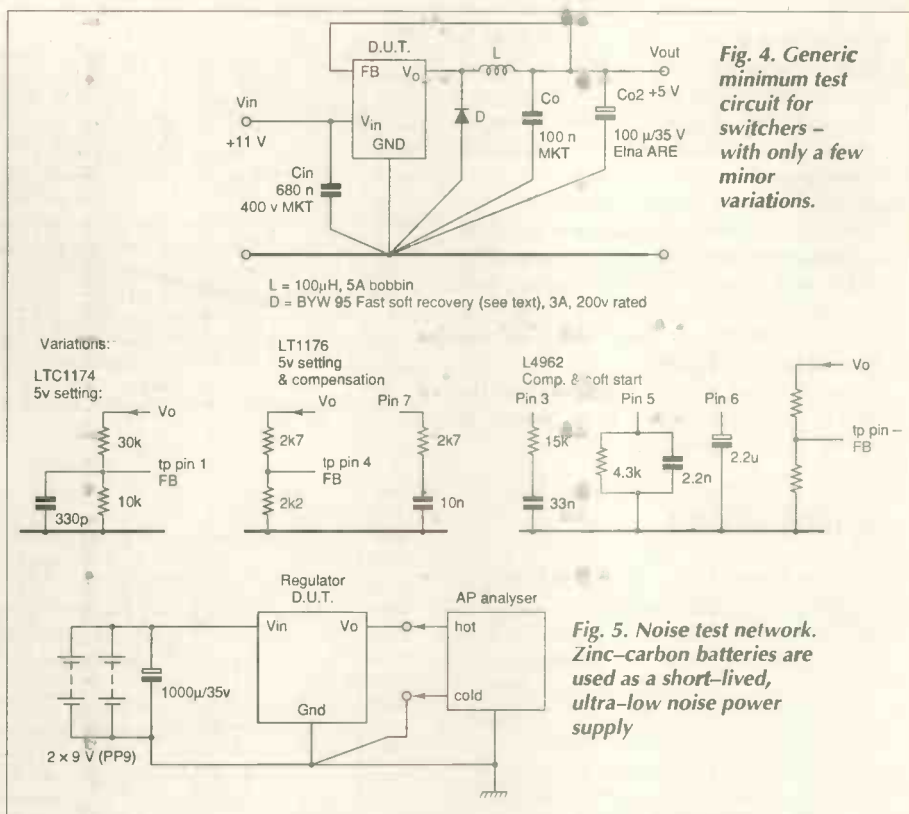
Figure 5 shows the test circuit used for noise tests. Figures 6 to 15 illustrate regulator noise. Getting a clean enough input voltage is the first stumbling block. Loading is stepped to reveal changes that can make a regulator manifest as a current-controlled noise-source. You too may be surprised at the disparity in behaviour patterns – particularly between the switching devices.

Figure 16 shows the ripple rejection test circuit used while Figs 17 to 25 illustrate the results obtained. Part of the test circuit is a 20V rms audio power amplifier having extended hf response. This can handle a 4Ω load and is used to drive the test network.

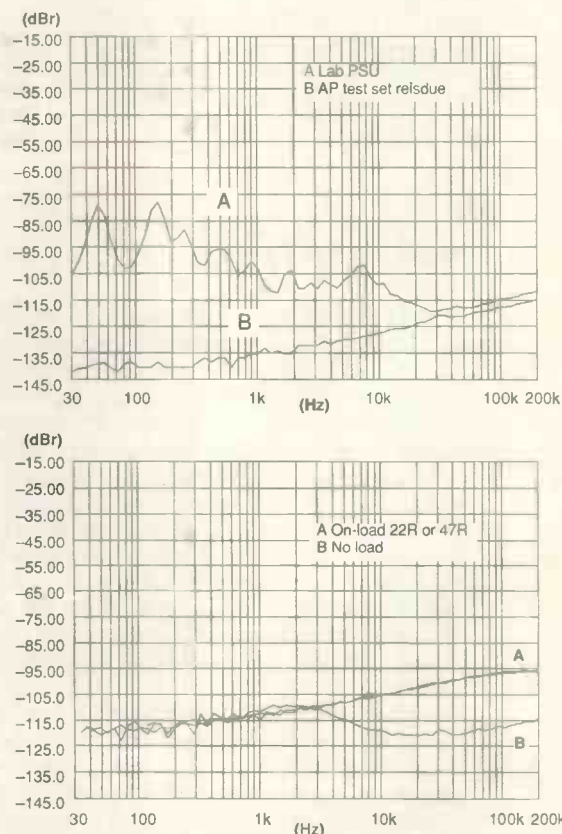
A power amplifier is needed because  $R_{in}$ , at 47Ω, is seen as a load in shunt with the regulator's input. A higher  $R_{in}$  value would reduce loading but also drop the incoming lab supply, when loaded. As a result, it would need to swing above 30V in order to attain the 9V (excluding superimposed AC) required at the regulator input.

Capacitors of 10,000µ+1000µ+1µ in parallel provide resonance-free coupling into the 47Ω,

\*Maxim's *MAX639* was omitted from one of the tests as the initial samples expired readily and a working replacement was not supplied. A process problem may have been the cause.



**Fig. 6. Ideally, measurement of regulator's output noise should not be affected by incoming noise from the dc (raw) voltage source, but it may be, with all of the regulators having less than infinite and perfectly uniform ripple rejection. The upper plot (A) shows a Thurlby lab supply, considered good enough to test sensitive circuitry, measured at the end of 300mm twisted cabling. It helps to recall that -100dBr is 10µV rms and -60dBr is one millivolt. Mid-band noise can be reduced by decoupling the psu output with low inductance elcaps >1000µF, but below 10kHz any sensible array has little useful effect. The lower curve is the AP residue. A pair of 9V primary batteries paralleled with a 1000µF Elna Low-L capacitor yielded a plot identical to this, and were duly adopted it as a 'virtually noise-free' DC supply for measuring the intrinsic noise.**



**Fig. 7. The 20 year old LM340T-5 has equal second lowest noise, exceeding -95dB in all the tested places. Noise character is smooth. Note how noise is identical with either loading (A) yet how much the unloaded noise droops away above 3kHz (B).**

**0dBr=1 volt in all graphs**

contributing less than -1dB additional deviation from 10Hz to 200kHz. The protective zener was added after the more highly stressed DIL-packaged switchers with marginal voltage ratings were vaporised when loading was removed before reducing the lab supply input.

Figures 26 and 27 illustrate the group spectra caused by abrupt load switching. In test circuit Fig. 26, a mosfet is driven with a 10kHz square wave with roughly equal mark:space ratio. This in turn switches the 22Ω load.

Finally, Fig. 29 compares efficiency. Each

regulator was driven at 10V so its burden is about 5V. Loading was kept close to 50% of the rated value using off-the-shelf resistors.

Average (not true rms) input and output currents and voltages were then measured and waste computed from:

$$\% \text{ efficiency} = [(V_o \times I_o) / (V_{in} \times I_{in})] \times 100$$

There are surprises. First, efficiencies of the competent switchers converge at around 70%. This is better than for the linear devices, with  $V_{in}$  being twice  $V_o$ . But remember that if  $V_{in}$  is set much closer to  $V_o$ , linear efficiency can rise to at least 70% too.

Secondly, the dismal efficiency of the *LTC1174* was confirmed with retests at slightly lower current and after a

## Vapid silicon

Both the *MAX639* and *LTC1174* proved instantly destructible by exceeding idiosyncratic voltages (around 11 to 13V) that may not ring alarm bells in analogue design heads. The rejection test network's series resistor  $R_{in}$  (Fig. 16) causes a voltage drop when running loaded. It is easily compensated for by jacking up the input voltage, but had deathly consequences for these chips when the test load was removed even momentarily. This loss prevented the plotting of the input drive level when in the loaded condition. IC designers should think more clearly before making parts with such arbitrary and low breakdown voltages.

## Noise and layout

Even for instrumentation, listening to noise is one of the quickest ways to evaluate its characteristics. One would expect linear regulators to be intrinsically quieter than any switcher. The results show this is mostly true. Excess noise in linear regulator ICs arises mainly from the reference. It has been long established that regulators using plain (cf buried) zener references have a subjectively "gross" noise character. Bandgap-referred (as well as the more modern buried zener-referred) regulators are both measurably quieter and have a smoother, more unobtrusive noise character. Peak noise voltages are up to at least 10 times (20dB) higher than the rms levels plotted. When supplies are bussed about this may couple into a critical node. Fig. 6b amply illustrates why high-end audio perfectionists might dispense with ac mains and the regulators, and opt for cupboards full of car batteries.

All IC regulators demand considered layout. The older fixed types readily oscillate at rf and can even burn out if driven from a distant source without local and quite wideband decoupling. In all test circuits,  $C_{in}$  was 680nF low ESL MKT, placed less than 10mm from the IC legs. Most linear regulator ICs also require typically a minimum of 100µF of output decoupling. The *LT1129* is exceptional, being intelligently designed to be stable with  $C_o$  of under 10µF. However, above 1kHz, the  $Z_o$  and transient response of all this and all other linear regulator ICs employing voltage feedback is increasingly dependent on adequate  $C_o$ .

In all test circuits (Figs. 1 to 4) the stricter standard of a low

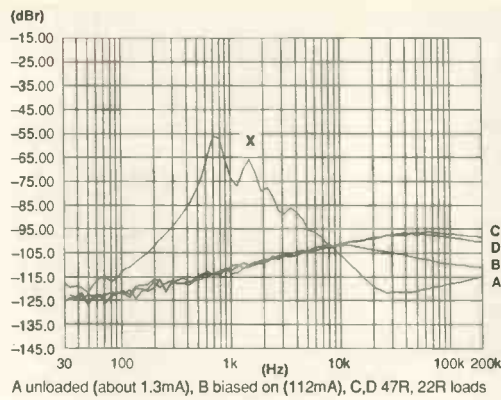


Fig. 8. With an illegally low quiescent current of 1mA, the *LT317* 'rings' at 850Hz, albeit 55dB down [see ref. 3 for explanation]. From the graph, a strong second harmonic (X) is also evident. A strange tonal-noise modulation effect would occur in unfortunate circumstances where current draw dips to very few mA. When the *LT317* is arranged to deliver a minimum of 5 to 7mA, the tone vanishes, and is replaced (middle curve, B) by a smooth white noise that becomes pink noise when viewed from a higher frequency perspective – as noise density is dropping off above 10kHz. At higher currents with the 47Ω and 22Ω loads, audio band noise is unchanged but notice how the hf hinge is shifted up to 65kHz, while noise is about 10dB higher 1.5 octaves either side. Noise character is all-round smooth, as befits a bandgap.

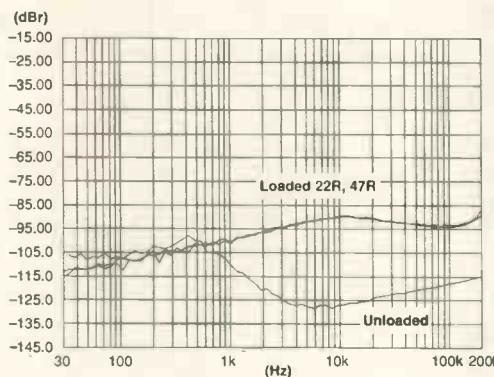


Fig. 9. Listening through the 1/3rd octave sweep, the *LT1129* produced the classic, psychologically disturbing noise (sounding in the mid-band when put through speakers like a deathly Antarctic wind) of a crude zener reference. Lower plot shows noise when unloaded. Note same increase in hf noise with loading irrespective whether this is 47Ω or 22Ω, indicating nil noise modulation over this span of current.

ESL 100µF combined with 100nF low ESL+ESR reservoir capacitors which are mandatory for switching regulators was adopted uniformly throughout, so output decoupling has no appreciable part in performance differences. All 100µF elcaps were matched within +2%. Adjustable linear regulators require the sensing resistor to be connected to output pin, but a sample of the output current is not required, and a wrong, non-starred connection degrades  $Z_o$  and the transient response.

Turning to switchers<sup>2</sup>, we face incisive waveforms with plentiful harmonics. As well as radiating noise, many switchers depend on comparators, and these require robust hysteresis and appropriate filtering so that locally generated noise does not upset the feedback loop(s). As a switching regulator is so easily upset by its own hash, it pays to be kind to it and the environment at the same time, and design the layout for low noise and precision. This is mainly achieved by compact placement, fat star grounds, low inductance, preferably paralleled capacitors of at least two widely spaced values, and the use of adequately rated inductors, preferably toroidal types which radiate least.

With switchers like the *LTC1174* working up to 200kHz and higher, subtler techniques including steps to forestall eddy-currents such as use of Litz wire (plaited conductors) to balance copper losses will be significant. For lowest noise, output (including return) must be taken directly across the output capacitor. Fig. 19c, Fig. 24d and Fig. 25b are plots demonstrating the results of misconnecting the analyser's cold input just a few inches up the 0V wire back towards the power source, instead of coming off the star ground separately.



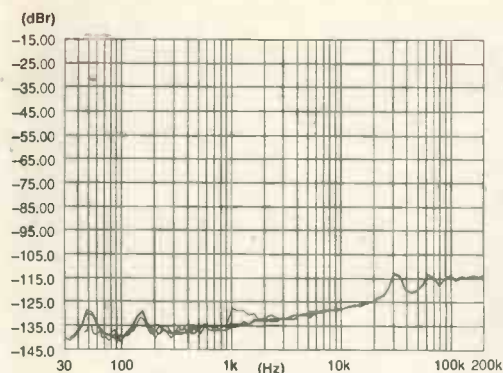


Fig. 10. The prototype of my high power audio regulator [see 4; and discussed in recent issues] was dragged out to show the kind of thing that audiophiles find improves their ability to hear ambient cues and other nuances in recordings: Irrespective of loading, this regulator's noise is indistinguishable from the AP residue in my lab's environment. If anything, the two AP plots are actually the higher of the four here.

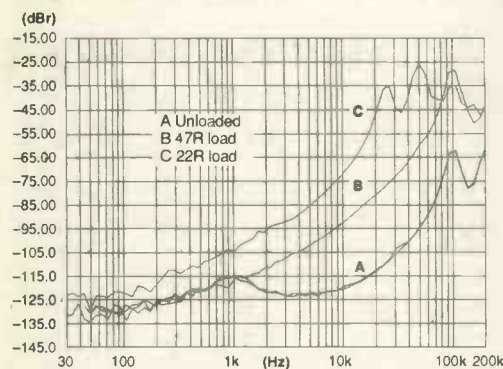


Fig. 13. The LT1176 has commendably low noise below 1kHz, irrespective of load condition. The lowermost curve (A) shows the 100kHz switch frequency, rejected by at least -60dB. The middle and upper curves are for loads of 47Ω and 22Ω respectively. Note that noise increases 20dB for a just over twofold rise in current well away from the maximum current rating of at least 1.2A. The change in noise (ie. noise modulation) might disturb sensitive circuitry drawing discontinuous current. At least noise character is uniformly smooth.

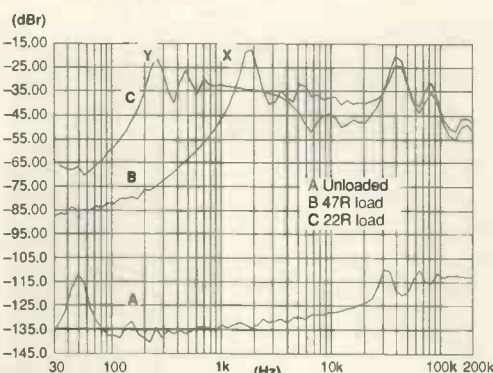


Fig. 11. below The MAX639 is most commendably quiet when unloaded (lowermost), except for 50Hz reception spike (left). Loaded noise is far higher (upper curves). With the 47Ω load, the noise character is rough (like the fixed linears), and curiously includes a 1.8kHz tone (peak at 'X'), as in Fig. 8. With the 22Ω load, switch artifacts are clearly audible; the third octave sweep sounds like a swarm of bees! The bee sound is imparted as the tone spike (at 'X') has shifted down to 250Hz (Y). Overall, noise with this higher loading is unchanged in the decade above 25kHz, is slightly less down to 5kHz, and below 1kHz, 20 to 50dB higher.

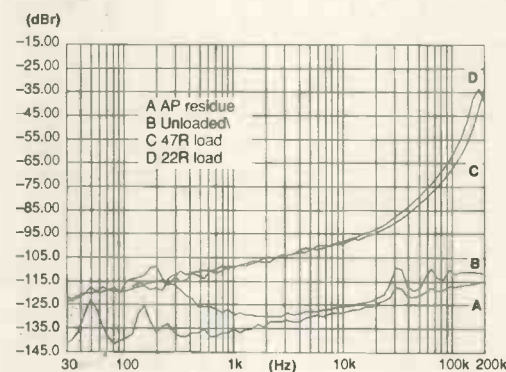


Fig. 14. SGS's L4962 was measured in a later session, so the AP residue was replotted (lowest, A). Compare this to Fig.10. When unloaded, the L4962 is just above the residue and remarkably quiet above 1kHz. Even below 1kHz noise is good for any switcher, at <-105dB. When loaded (47R, curve C), noise rises markedly around the switching fundamental to a -35dB minima. Past this point there is little noise modulation - shown by the negligible change with the 22Ω load (uppermost, D). Noise character is truly excellent for a switcher - as smooth as bandgap linears.

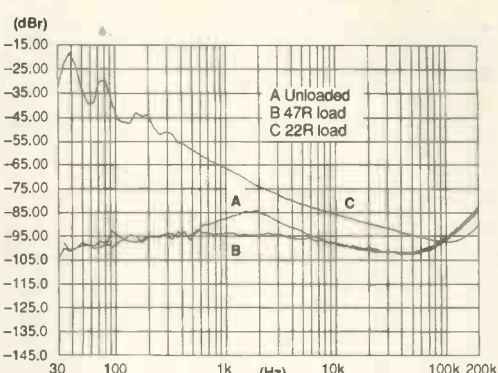


Fig. 12. The LTC 1174 (C for CMOS) switcher is contrastingly noisier (upper curve) when unloaded. A 2k4 fixed load resistor was added to set a more realistic quiescent 'unloaded' current of 2mA. The peak point indicates an unloaded PRF of 40Hz. Measured noise with 47 and 22 ohm loading is almost the same (A,B). But A's peak suggests a low Q version of Fig. 8's resonant phenomenon, about an octave either side of 1.7kHz.

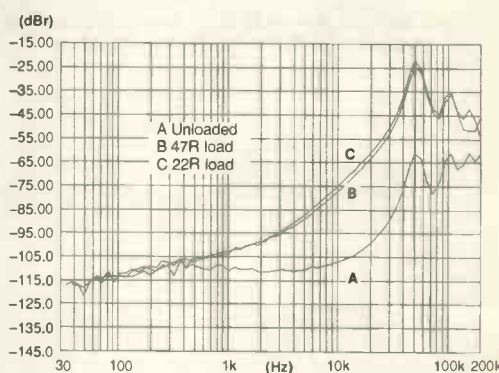


Fig. 15 The LM1576T when unloaded, was as noisy as the L4962 when the latter was loaded. Still, the noise character is similarly smooth. The unloaded plot (A) is quite good in the audio band, but above 20kHz, a train of harmonically related spectra occur, harmonics made visible because this regulator's fundamental is about an octave or two lower than the others at 50kHz. When loaded, the fundamental peaks only 23dB below 1V, and noise is barely changed between the 22Ω and 47Ω loads.

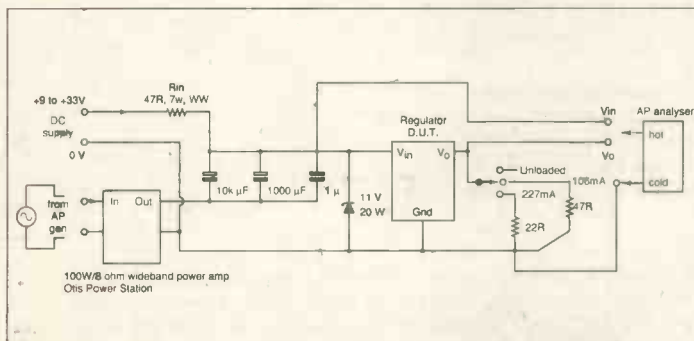
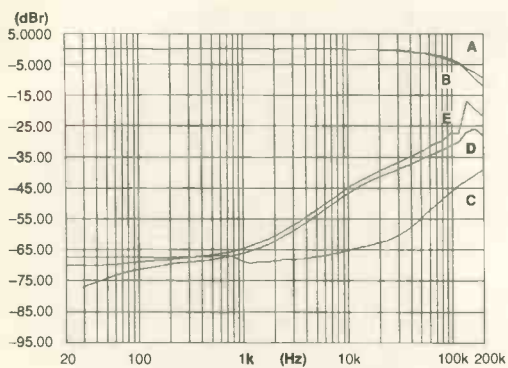
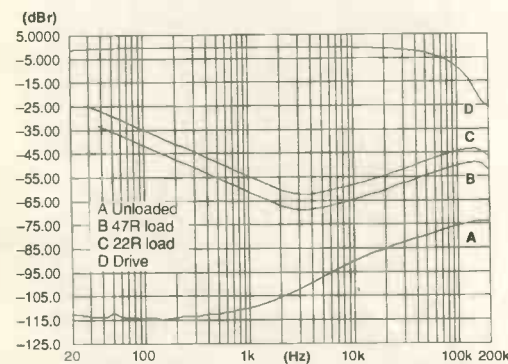


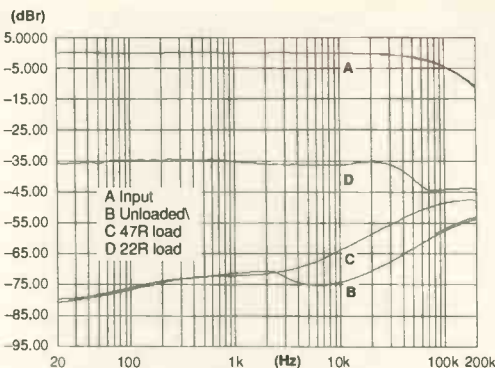
Fig. 16. The Rejection Test Network. Although ripple is fundamentally at power line frequency, one cannot just test at 100/120Hz! The capacitor array, power amplifier and high wattage resistor allows tens to hundreds of milliamperes of incoming DC at 9 volts, to be mixed with 1V rms of sweepable AC from the Audio Precision's generator, with uniform response over 13 octaves (10-200kHz) being preserved at the regulator's input. DC and ac levels have to be finely set to avoid clipping the ac, or overstressing the marginally rated switcher chips; or dropping out on the longest (20Hz) ac peak dip. Any ac appearing at the regulator's output is feedthrough. The amount varies with loading, as open-loop gain is depressed, eg. by beta loss with increasing current.



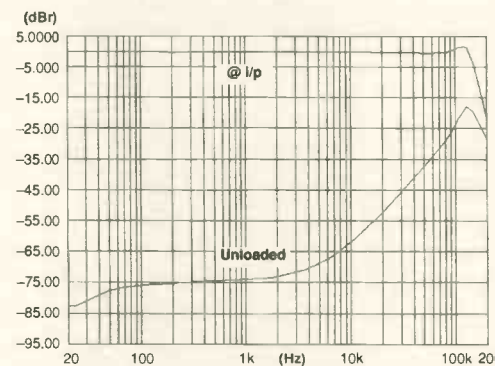
**Fig. 17.** In this and all the subsequent rejection graphs, the upper plot shows the incoming, 1V swept 20Hz to 200kHz swept test signal as applied to the regulator's input. Much of the rolloff above 30kHz, to -12dB at 200kHz, arises because the drive capability required is borrowed from an audio power amplifier, one of the few with extended ultrasonic response to 200kHz. The incoming signal has been plotted with the regulator's output both unloaded (A) and loaded (B), to confirm that the drive reference only changes slightly around 130-200kHz. Rejection is best when unloaded (C). When loaded with 47 and 22 ohms (D,E) rejection improves slightly below 200Hz but reduces markedly above 1kHz. Note also how rejection barely changes (mainly below 200Hz) with the more than two fold load increase, and how the heavier loading (E) has the best rejection of all below 1kHz, better than the unloaded case.



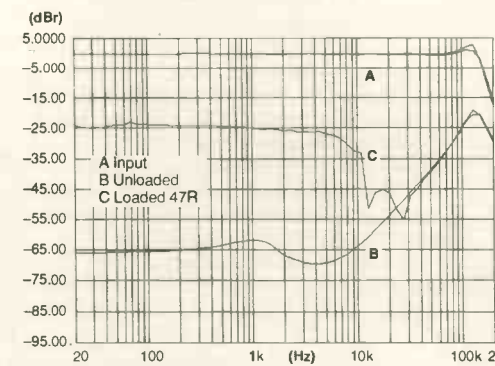
**Fig. 20.** High power reference regulator for audio. The input shows about 10dB extra attenuation at 200kHz (D), showing imperfect buffering at hf. Unloaded rejection beats all the regulator ICs. Rejection degrades greatly with slight loading, most markedly at LF, where the outcome is least audible. Note the psychoacoustic tuning; after having accepted decay with loading, deepest rejection has been tuned to the ear's most sensitive region, about 3.5kHz. Loading was the same 105/225mA as other regulators. Further up the scale of this regulator's far higher operating capacity (up to 35 Amperes) rejection improves, where again it matters most.



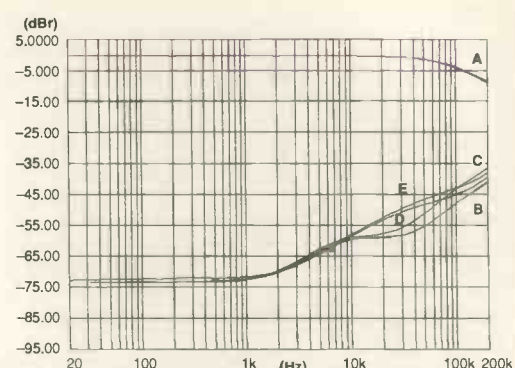
**Fig. 18.** The LM340 still sets standards, at least at low currents. Whether unloaded (B) or loaded with 47Ω (C), rejection below 3kHz is the same within tolerance and at least -70dB. Above 3kHz, the loaded condition is consistently about 12dB less good but still manages to exceed -45dB. With the heavier (22R) load, rejection is degraded to a less healthy -35dB uniformly with frequency (D). The 30kHz step-down is curious; answers please. Note all three load conditions show identical input levels (A, uppermost), suggesting the input is well buffered at hf.



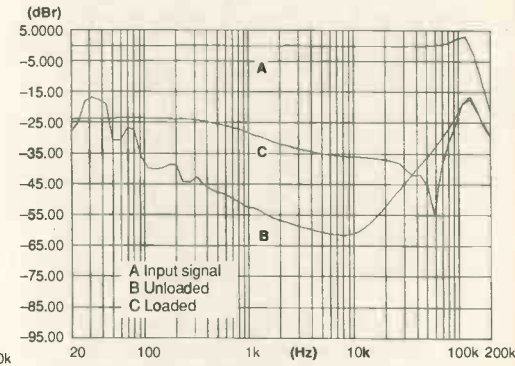
**Fig. 21.** The MAX639's unloaded rejection is excellent below 3kHz, being better than -70dB. But rejection decay sets in markedly above 10kHz and well before the 125kHz switching frequency. See footnote on p807.



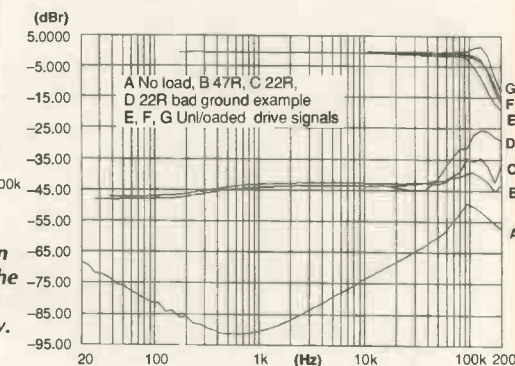
**Fig. 23.** LT1176 has quite good rejection in the audio band before loading, but with 47R, rejection decays to an unimpressive -25dB at 6kHz. With the input drive (uppermost), note the peaked-up then steeper rolloff at 120kHz, the switching frequency.



**Fig. 19.** With the LT317, loaded and unloaded rejection is identical below 10kHz. Above, the 22 and 47Ω load conditions (D,E) are no more than 10dB worse than the best unloaded case (B) at 30kHz, re-converging above. Curve C shows the effect of the unloaded case with a bad ground connection; here the analyser's 'cold' input was coupled to ground several inches back from the output capacitor towards the supply input.



**Fig. 22.** Unloaded, the LTC1174 has marginally good (>-40dB) rejection between 200Hz and 20kHz, but both modestly loaded (47Ω) and unloaded, it offers a paltry less than -30dB of rejection at line (50/60Hz) and switching (>50kHz) frequencies. "Unloaded" includes the small 2mA bias established earlier (Fig.12). Notice also that the upper, reference plot of the incoming test signal is peaking slightly just above 100kHz, a sign that  $Z_{in}$  is affecting the driving amplifier's stability.



**Fig. 24.** (Bottom right) Unloaded, the L4962 displays its best rejection around 600Hz, with a negative resonance. When loaded, rejection is a more modest 45dB but is uniform with frequency and load up to 50kHz. Noise at the switching frequency is also at least 15 and up to 30dB lower than any of the other switcher ICs. It is clearly amongst the cleanest switchers. Above 100kHz, the loading effect on the source is slight but more varied than others. Curve D shows the same bad ground connection as in fig.19 (C). Notice how the result is less catastrophic.



cool-down period. Thirdly, you might imagine that the *LT1129* would be slightly more efficient than a 'normal dropout' regulator with emitter follower output. But this is clearly not so for real-world test condition, where  $V_{in}$  is higher than it might be.

All the switching regulator ICs were successfully applied by reference to the data sheet alone. And all four switching device makers offer some in-depth advice on critical layout and critical component specification for optimum performance. Linear Technology's *LTC1174* data sheet had the most explicit physical layout recommendations while National's showed the IC internal workings most clearly in relation to the outside world. Physical layout was on five-node analogue *Veroboard* (RS 433 911). Positioning of major critical parts was organised for shortest lead lengths, then repeated within  $\pm 3\text{mm}$  for each different device.

## Conclusions

Beginning with noise, the benchmarks are set by my own regulator circuit. Similar op-amp-based regulators after Sulzer<sup>5</sup>, set even higher or similar standards as do ones yet to be published by Walt Jung<sup>6</sup> which I have had a

chance to consider.

For the quietest regulator with the best rejection and lowest output impedance, you need to look at ICs other than those labelled as regulators. On the other hand, while these op-amp based designs are not expensive against performance, they will cost many times more than an IC like the *LM340T*, which is typically under 40p in bulk. The more discrete design will also occupy more space.

Returning to explicit regulator ICs, easily the all-round quietest are *LM340* and *LT317*. In this instance, the latter is slightly quieter below 1kHz, and the former above. With the switchers, *L4962* is the clear leader, staying below -95dB up to 20kHz under the three test conditions. Considering just noise in the audio band, it comes close to equalling the *LM340*. *LM2576* is next best. Such a pattern suggests that switcher noise can be curtailed by using an IC with plenty of reserve current capability.

As for "ripple" (really broadband ac) rejection, the *LM340* exhibits the best figures until it falls apart - at a load current of one fifth of its 1.2A rating (Fig. 18 curve D). The *LT317*'s rejection hardly varies with load current, but all load conditions share the earlier onset of decaying rejection above

1kHz. High frequency rejection might improve with improved adjustment pin decoupling - not an option with *LM340*.

The *LT1129* is again a slight backwards step from twenty year old technology. Only two of the switchers shows rejection across the range of loading that is remotely acceptable for plumbing around a sensitive analogue circuit. Again, this is SGS's *L4962*, with its near uniform loaded rejection of -45dB, ie. 6mV rms per every 1V rms of ripple sawtooth, with *LM2576* again not far behind. In a real application, the hf (>10kHz) rejection of the switchers will likely be improved markedly if inputs are EMI filtered.

Faced with abrupt load switching, and taking the ripple at fundamental as an indicator of output impedance ( $Z_o$ ), then the familiar linear duo *LM340* and *LT317* have the lowest  $Z_o$  and maintain the overall cleanest supply, but are still perturbed more than 22dB compared with the BDR linear benchmark regulator.

The *LT1129* is by contrast fundamentally worse than even the most perturbed of the switchers, with a closed loop, loaded  $Z_o$  that is 6 to 11 times greater than the follower type outputs.

## Test conditions

The tested parts were either fixed 5V models or if adjustable, were set to output +5V. As the ICs' maximum rated load current varied from 225mA upwards, and the surprisingly puny PP9 batteries used for noise testing could not support much more than 225mA on-load tests were performed with 47 and 22 $\Omega$ , 2% CF load resistors, drawing a nominal 105mA and 225mA respectively.

Note: Throughout the following text and graphs, 0dB<sub>r</sub> = 1 volt rms. -60dB<sub>r</sub> = 1mV. -120dB<sub>r</sub> = 1 $\mu$ V. "Unloaded" means, unless stated, that there is only the load of the test equipment - typically under 100 $\mu$ A.

Fig. 25 Unloaded, the *LM2576* is quiet and commendably so at ultrasonic frequencies. Again, the outcome of poor grounding practice is shown (B), this time with marked effect. Loaded response (C,D) behaviour is akin to the *L4962*, only not quite so good by some 7dB.

Fig. 26. Abrupt load switching test network. A mosfet switches the 22 $\Omega$  load in and out at about 12kHz with a consistent (though approximate) 50/50 mark-space ratio. The test set is then set to plot the third-octave spectra above 10kHz to 200kHz. If  $Z_o$  were zero, or the feedback were instantaneous and the slew and loop gain infinite, there would be no spectra. The spectral levels give a proportional indication of each regulator's averaged, dynamic output impedance - the product of the static  $Z_o$  and transient response.

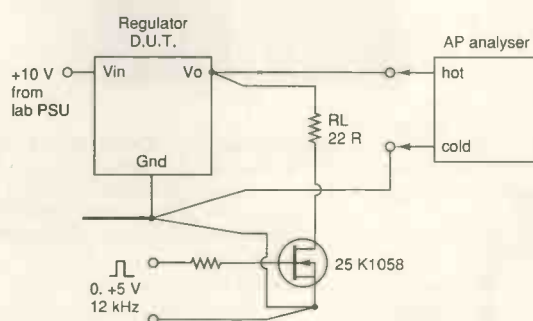
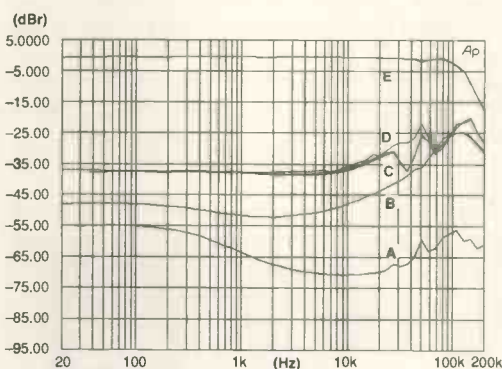
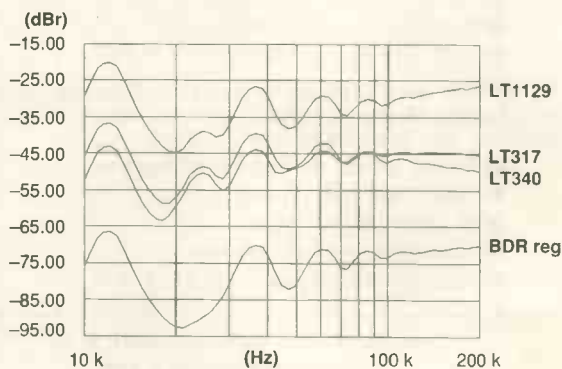
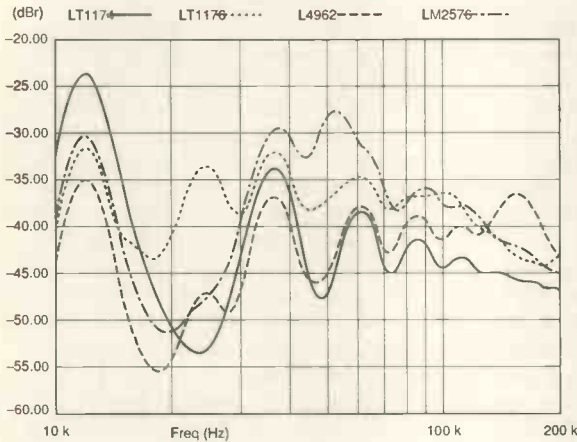


Fig. 27. These abrupt load switching spectra are a new way of looking at a related characteristics simultaneously: Voltage and current step as well as  $Z_o$  and slew induced perturbations mapped into the frequency domain.

The Audio Precision spectra show how a 12kHz clock (with clean rise and fall of about 1 $\mu$ s) driving a rather abusive 22 $\Omega$  load would appear on the supply rails at the regulator output. In other words, the results are based on direct, optimum nodding. The performance on real pcbs won't get any better and will likely be worse if the clocked supply conductors even remotely share with any other currents. Of the linears, *LT1129* has the highest spectra indicating higher impedance and inferior damping. The bandgap twins, *LM340* and *LT317* have at least 14dB better performance. *LM340* is up to 4dB better than *LT317* below 60kHz and vice-versa above 100kHz. My high current audio regulator has the lowest artifacts, up to 30dB below the best regulator ICs. Note how each regulator follows a recognisably similar set of inflexions.





**Fig. 28. Turning to the switchers, the inflexion pattern is devoid of correspondence with the exception of the fundamental. At this point (12kHz), the order of performance is similar to the feedthrough ranking, with LTC74 the clear loser (fundamental 24dB below 1V) and L4962 the clear winner. Yet, by 200kHz, the chaotic traces have exactly reversed the positions. Averaging by eye over the bandwidth displayed suggests that (i) the L4962, followed by the LTC1174, will maintain the cleanest rails, (ii) the LT1176's rails will be the noisiest, followed by the LM2576. The MAX639 does not appear; see below.**

As for the other switchers, the by now familiar L4962 is least perturbed at the fundamental, but still near three times (10dB) more than the LM340. Note the wide, individualistic swings in ripple above the fundamental of all the switchers other than (oddly) LTC1174.

On the basis of these results, regulator IC ac/transient performance has not improved since Linear Technology's first efforts 11 years ago.

Low dropout regulators, while a boon for battery systems, should be used with care in sensitive circuitry powered off-line as their ac (20-200kHz) rejection and output impedance

(hence transient line and load regulation) are both inferior to normal dropout parts.

Analogue circuitry employing switching regulators may require considerable rf filtering and stout decoupling. Even if EC or other EMC regulations do not make this mandatory, hash pickup may well affect performance. In this case, the cost of fixing this (in money, space and weight) may exceed the cost of using a linear regulator with a slightly larger heatsink from the outset. In summary – and with the possible exception of applying SGS-Thomson's SMPS chip – before, while and after switching to switchers, designers must perform regular reality checks!

**Efficiency – a score card**

Efficiency, at 50% rated load

LT 1176	71.5%	576mA
L4962	70.5%	710mA
LM2576	69.0%	1.4A
LT317	52%	710mA
LT1129	49%	333mA
LTC1174	23%	215mA

$V_{in}$  9.5V  $\pm$ 0.1V;  $V_o$  5V  $\pm$ 0.1V

**REFERENCES**

1. R Widlar, *A versatile monolithic voltage regulator*, NSC AN-1, Nov '67.
2. R Widlar, *Designing switching regulators*, NSC AN-2, Mar '69.
3. E Dietz, *Understanding and reducing noise voltage on three-terminal voltage regulators*, EDN (USA)
4. B Duncan, *PSU regulation boosts audio performance*, EW+WW, Oct '92.
5. M Sulzer, *A high quality power supply regulator for operational amplifier preamplifiers*, The Audio Amateur (USA), 2/1980.

The author wishes to acknowledge the assistance of Anzac, Linear Technology, Macro Marketing and Maxim. ■



The G-TRON 08ERD Electric Radiation Detector will indicate by beeping the presence of any alternating electric field radiating from cables carrying electricity. This unit will indicate 240V at a distance of about 15cms, depending on cable layout, and about 30 metres from electric pylon cables carrying 132,000 volts. Overall sensitivity 4 volts per cm. It can be used to:

- Warn of electric pylons tens of metres away.
- Check the field strength from all electrical apparatus.
- Check if cables are live.
- Monitor automotive ignition.
- Price: £19.98 inc. Battery, P&P & VAT.

The G-TRON 08MRD Magnetic Radiation Detector will measure the presence of any alternating magnetic field from 50 to 500 nanotesla. Use to measure the field from:

- Electric cables above and underground.
- Meters and switchboards.
- All electrical apparatus.
- Automobiles and electric trains.
- Price: £29.85 inc. Battery, P&P & VAT.

Designed & Manufactured in the U.K. by

**GLAZERTRON LTD**

Upnor Road, Lower Upnor, Rochester, Kent ME2 4UY

Tel: 0634 712699 Tech-help: 0634 294030 Fax: 0634 712891

CIRCLE NO. 114 ON REPLY CARD

MEGAPROM device programmer. EPROMS, E2PROMS, and FLASH memories from 2k (2716) to 8 Meg (27C080). Runs on IBM PC via the centronics port using standard printer cable. Works on all PC compatibles, laptops, and notebooks. No special port requirements.

Uses approved programming algorithms. Very fast program and verify 27C512 (64K Bytes) in 45 seconds.

Full screen editor software supports Bin, Intel Hex, Motorola S and Asc formats. **Only £99.95**

Top quality components used throughout including production ZIF socket.

Requires external power supply 18-25v AC or DC @ 250ma. (optional extra £6.50)

**PICPROG** Programs Pic16C54-55-56-57-71-84. Centronics port interface same as Megaprom.

Powerful editing software to Read, write & copy Pic devices including data memory in Pic16C34.

Unit supplied with IBM software & 12 months parts & labour guarantee. **Only £69.95**

Requires external power 15-20v AC or DC @ 250ma. (optional extra £6.50).

**EPROM EMULATOR** Works on ANY computer with centronics printer port. Data sent to the printer appears in the target board Eprom socket. Emulates from 1k to 32k Byte (27C256) roms, board switchable. Power supplied from target Rom socket (less than 10ma). Very fast download.

Software supplied for IBM PC to convert and send Intel Hex, Motorola S, ASC and Bin files. **Only £49.95**

Board supplied with software and 12 months parts and labour guarantee.

**PC SCOPE** Convert your IBM PC into a Storage Oscilloscope with our A/D converter. Simply plug into the printer port (no power required). Sample rate 10k to 30k per second.

Software supplied for Scope and Voltmeter. A/D source to write your own programs. **Only £29.95**

**DEVELOPMENT SOFTWARE**

Develop software on your IBM PC for other Microprocessors, Controllers, Pic's etc. Software has fully integrated Text Editor, Assembler, Disassembler and Simulator.

The Simulator displays all registers along with disassembled code program counter, Condition code register. The user can single-step, go with breakpoints, watch memory etc. change any/all registers/memory locations at any time (on the fly).

Code can be Saved to disk and/or downloaded directly to your EPROM Emulator. All software supplied with sample ASM files and user documentation.

Very powerful software as supplied to universities, colleges ITECS and Industry. Available for the following:--

MCS8051/52/552 series Software £19.95 MCS8048/49 series Software £19.95

PIC16C54/516/7 Software £29.95 PIC16C71/84 Software £29.95

HD636809 Software £49.95

**LOW COST PIC ICE (In-Circuit Emulator)**

Plus into the printer port and runs in conjunction with the PIC development simulator software.

Appears to the target system as a normal Pic device including OSC2 and RTCC in/out. Runs in real time from the IBM PC changes made to File registers reflected on target.

Supplied with Software of your choice Pic54-57 or Pic 71/84 **Only £89.95**

All hardware carries a 12 months parts and labour Guarantee. No VAT payable.

Please add £1.50 for Carriage. SAE or TEL for further details.

**JOHN MORRISON DEPT WW**

4 Rein Gardens, Tingley

West Yorkshire

Tel (or Fax): 0532 537507



CIRCLE NO. 115 ON REPLY CARD



# From capture to layout

*Protel's new pcb design and schematic capture packages both have the prefix 'Advanced', but with so many excellent products on the market how do they compete? John Anderson investigates.*

The company known for *Easytrax* and *Autotrax*, Protel, has recently launched *Advanced Schematic 2*. In addition to providing schematic capture, this package executes front-end tasks for *Advanced PCB* – a new pcb design tool covered later in this review.

First launched as *Schematic for Windows*, this product retains the same object orientated editor, but adds many new features. These include library searching, drag and drop editing, and guided wiring.

The software is supplied with professionally produced, comprehensive user, reference and library reference manuals. In addition, there is a strange document entitled the *Environment Guide*, and a software-protection dongle plugging into the parallel port. Installation follows normal Windows procedure, involving a 'set-up' program which unpacks the files and installs its own group in file manager.

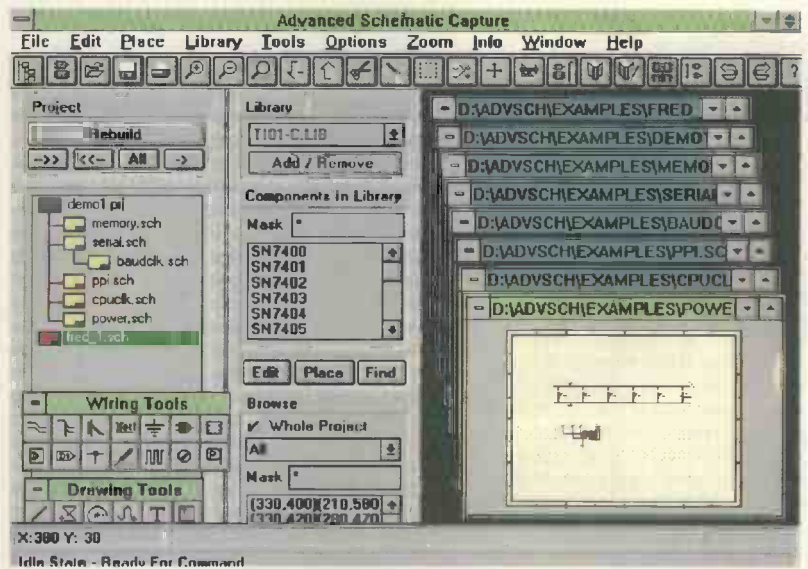
On initial start up, you are taken to an interrogation screen where you are prompted for access codes. These are codes that unlock specific features of the software – the review version had an eight-digit code for the schematic capture module.

## Editing

The system requirements state that a minimum screen resolution of 800 by 600 is needed. This type of specification is quite unusual and it was not until I ran the program that the reason for this requirement became apparent. There are two dialogue panels, namely the Component Browser and Project Manager, which in standard vga take over half the editing screen area. These can be turned off, but realistically, because the Component Browser is an essential part of the software operation, it needs to be kept on all the time.

On-screen working space is made even smaller because of two floating toolbars carrying wiring and drawing tools. The distinction between wiring and drawing tools is important, and obvious – except for the icons. In particular, because both line types have similar default colours, it is easy to inadvertently select a drawing rather than the wiring tool, and hence fail to connect up the components electrically.

Capture works as follows. After selecting the component

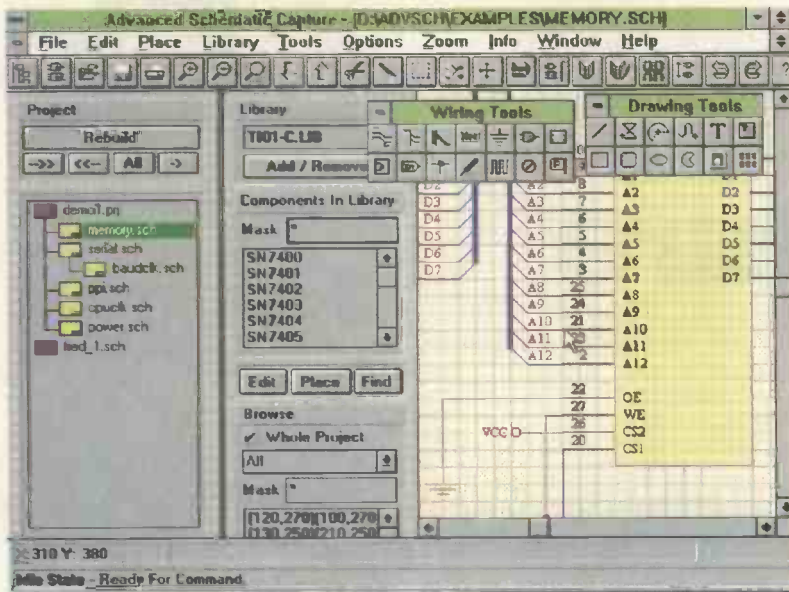


*The Normal operating screen! Note that this picture is captured in 640x480 vga format and the actual editing screen size increases with higher resolution formats.*

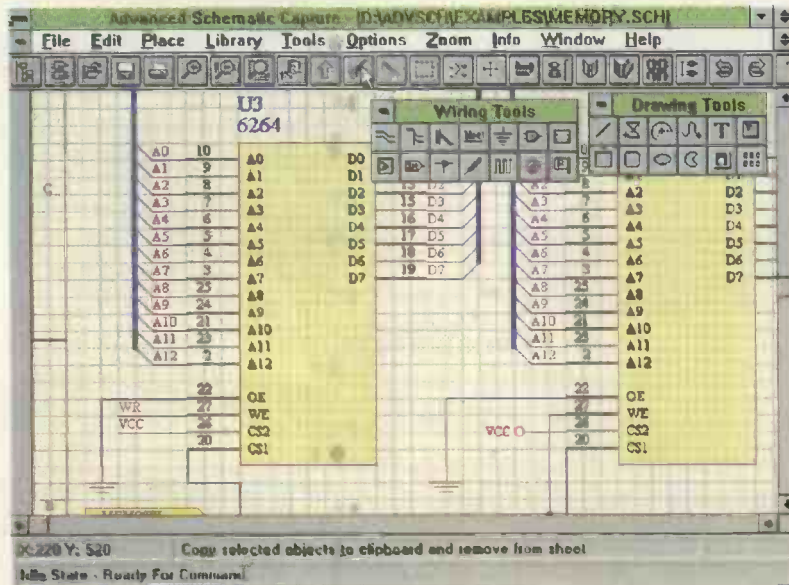
browser, the user selects which of the standard libraries to use via the Windows 'add feature' method. Back at the browser, any of the libraries in the selection list can be chosen. Once a library is chosen a list of components from that library is displayed. A specific component may then be selected and moved onto the drawing sheet.

This format of selection and placement seemed to work well, although the method did have weaknesses. In particular, if a multiple element component is selected, for example a 4-by-2-input nand gate, the placement system described above always places the first gate of the four, and you need to undertake a specific subsequent task to edit the gate identifiers or use the toggle part number icon to select any of the remaining three gates.

Editing facilities work well with the Windows clipboard, allowing selected items to be moved to the clipboard and then pasted to a new sheet. If the items are copied to the



Zoom in and the placement grid is clear.



There is much more room if the project manager and component browser are off.

clipboard then pasted back into the same drawing, no prompt or correction is made for the duplicated identifiers. Again using the clipboard, items clipped can be moved to other applications in Windows'.WMF' format – a nice touch for desktop publishing of technical manuals.

Moving around the sheet is somewhat awkward. This is mainly because the automatic panning is rather limited and only becomes available once a editing function is selected. The alternative is to rely on Windows scroll bars.

There are several files that can be generated from the schematic. There is a bill of materials, in tabular and comma separated variable form for spreadsheet or database use. There is also netlist output for interfacing to the pcb cad package, which may be output in any one of over 30 different formats.

Most important is the electrical rules check, or erc. This feature reads through the schematic database, generating a

list of rule violations. Examples include multiple components with the same identifier, unconnected lines and floating input pins.

Rules for the erc are set in a user programmable matrix of errors and warnings. As an example, connecting output pins together would normally be an error but leaving input pins unconnected may be considered warning. The designation of pin type is set in the library edit facility.

### Project control

Facilities within Advanced Schematic for project control are excellent and intuitive. Any number of sheets in a project hierarchy can be connected, and then whole projects loaded automatically. Each sheet is available at a click, which moves the selected sheet to the top window of a cascaded window stack.

Selecting the Library Editor from the Schematic Editor library menu results in a program running in another window which looks very similar to the schematic editor. However it automatically loads and decodes the currently selected library in the Library Browser.

As well as adding bit maps in any one of a variety of forms from '.WMF' and '.PCX' through to PostScript, the editor provides all the normal vector drawing facilities. The list of standard libraries is impressive, with a total of 76 libraries in all amounting to over 12,000 components taking over 12M-byte of disk space.

### Compatibility

A level of compatibility is maintained with the earlier Protel dos based schematic program, with some of the libraries arranged in a similar multiple vendor form.

Files generated by the earlier dos product are loaded by the editor, but a warning is provided that some components are converted from a bitmap form to vector form. In practice this did not seem to cause any problems and existing designs loaded without incident.

Electrical rule checking of the new software is better than that of the dos product. This can result in errors being reported in dos-based schematic designs which had passed the equivalent report facility in the old product.

When the schematic editor and the companion *Advanced PCB* editor are open at the same time, it is possible to cross probe – that is, select a part in the schematic and then jump automatically to the corresponding pcb component. This works in the reverse direction, perhaps suggesting that these two products might have been sold as one.

Back annotation from the pcb to the schematic, sometimes called the 'was-is' function, is supported. Forward annotation, where changes in the schematic are transferred to the pcb, is also provided. In this case, annotation reflects all netlist changes through removal of obsolete tracks and component footprints – dangerous!

*Advanced Schematic* has routes to interact with other programs. There is, as you might expect, the direct access icon to the *Advanced PCB* product, but direct execution of analogue, digital or mixed signal simulators is also possible. However, these are not supplied with the package and the level of support is little more than that of launching another dos or Windows program.

One exception to this is support for the analogue simulator, *S*. The software produces *Spice* compatible netlists, together with an ascii text input facility to add other *Spice* commands to the *Spice* control. These might be, for example, generator frequency or simulation parameters.

Other than *Spice*, the *Advanced Schematic* outputs for the somewhat obscure *EEsof* and *Touchstone* simulators.



# Advanced PCB 2

This is an upgraded version of the Windows-based integrated pcb layout program that Protel released two years ago. In addition to updating the package, Protel has also integrated *Advanced PCB 2* with *Advanced Schematic 2*.

Compared with the earlier Protel for Windows, this new package has 123 new functions and features. Although some of these are little more than corrections of problems with the earlier version, some of them are valuable. There is a split plane feature which allows a net to be assigned to one or more copper planes for example, and a preview-mode display allowing quick scanning between layers, displaying only one at a time.

The package is supplied with comprehensive user and reference manuals, an *Environment Guide* and a parallel port dongle. Installation follows the normal Windows procedure, involving a 'set-up' program which unpacks the files and installs its own group in file manager. It also requires modification of `autoexec.bat`.

Both manuals are well produced and include a command reference and user guide. However the package is straightforward to learn and use, so the manuals are only of importance should you run into problems. The level of detail in the manuals is commendable – extending even as far as providing the exact format of the `pcb-file` database. Stored in `ascii` form, the database could be edited by any word processor.

On initial start up, you are taken to an interrogation screen where you are prompted for access codes. These are codes which unlock specific features of the software. The review version had an eight-digit code for each of four modules, namely 'PCB', 'Advanced PCB', 'Advanced Route' and 'Advanced Place'. How advanced all these advanced features are remains to be seen.

Dimensional limits on pcb size are 100 by 100in, while positional resolution is 0.001in. Even with toggling between imperial and metric units, the system maintains an accuracy of 0.005in. It supports up to 16 signal layers, 4 internal power planes, 4 mechanical assembly layers, 2 silkscreen overlays, 2 resist masks, 2 paste masks, drill guide, drill drawing, multi-layer and drc error layers – 34 in all!

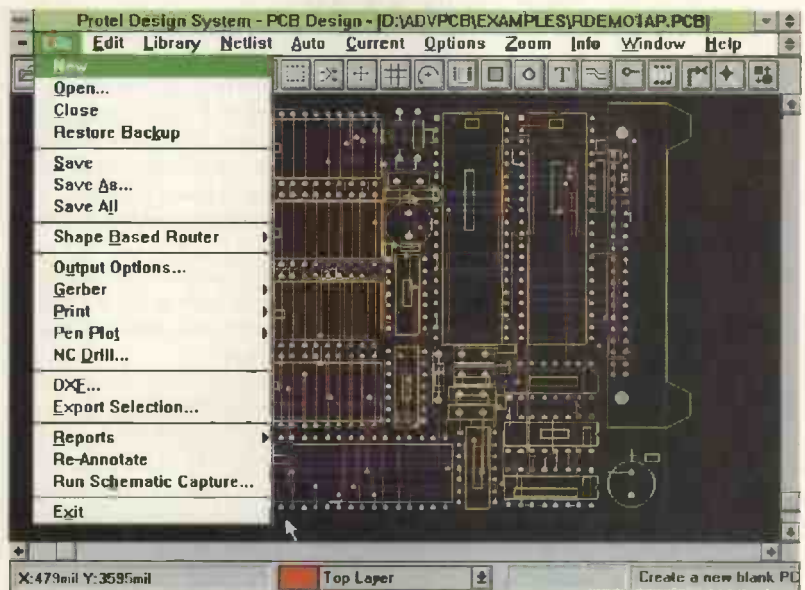
## Editing

Without further delay, and without reading the manuals, straight into the editor; load a file, Windows style, and start work. Moving around the pcb is done with the mouse, cursor keys or scroll bars. Zoom level is controlled via page up/down keys, the zoom toolbar, which is a window zoom function, or the zoom menu, from which any zoom can be set.

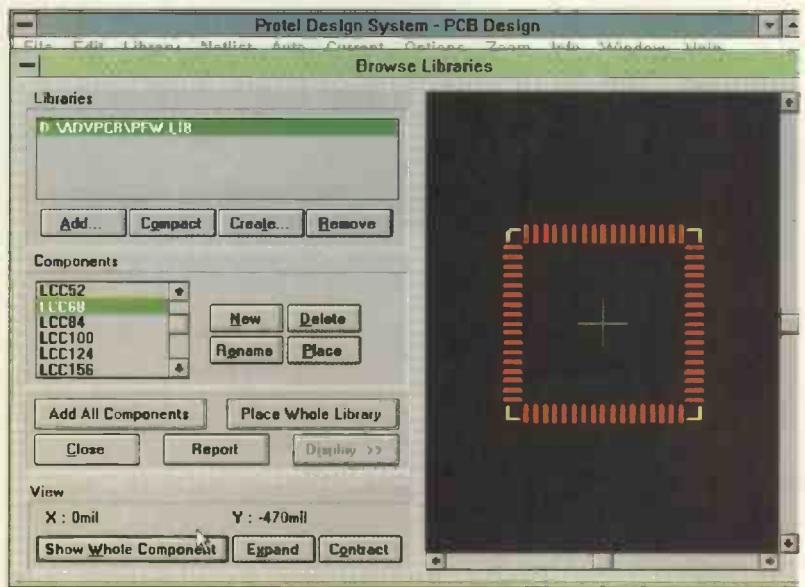
Commands can be executed from Windows pull down menus, but experienced users will find using two key sequence mnemonic hot keys much quicker. Pressing 'PA' for example places an arc. Pressing the Q key at any time toggles between metric and imperial units.

There are hot-key shortcuts for automatic pan and zoom. If you are using auto pan, for example, while dragging a component, holding down the shift key will pan the display at four times the normal rate. When using page-up and page-down to zoom, holding down the shift key causes slow zooming at 0.1 of the normal rate.

Interconnection starts with the `pcb netlist` generated by schematic capture. This defines the set of `pcb footprints` and the connectivity between nodes. Once the components



Advanced PCB's conventional windows editing environment.



Pattern selection from library by name and preview.

are placed, a rat's nest shows what needs to be connected and as the nodes are connected, so the rat's nest is removed. Once all the node connections are complete, the engineering rule check evaluates whether nets are complete and separate from one another.

Component placement is usually the key to a good pcb, making it easy to route and optimising it electrically. The strategy for auto-placement facility in *Advanced PCB* is not specified, but it is usual for optimisation to be based on total net length and real estate use. The facility worked well, if rather slowly, but using local auto-placement, quicker placement of specific areas can be achieved.

The autorouter can be set for a wide variety of routing strategies and passes, including pre-routes, `smd stringer` and fanout, memory routes and line probe. A maze router

and shape router can be selected. Performance of each of the facilities does depend upon the pcb type and density, but the overriding impressions are of very slow progress combined with excellent final results.

### Speed – or the lack of it

For any pcb layout package, it is essential that the redraw speed is fast. When you are trying to visualise how to route or place an item, you do not want to have to wait for the system to redraw. I tried *Advanced PCB* with a logic board of about 25 ICs and the redraw time was about 2-3 seconds on a 33MHz 486DX PC. This was significantly worse than the redraw time using the earlier DOS based *Autotrax* product. This made it clear why the Preview Mode display had been implemented!

Autorouting and placement are other areas where the speed problem prevails. If it takes an hour to try and route a few dozen routes – and fail to route about half of them – then productivity is certain to be poor.

*Advanced PCB* retains the same review and report structure as its predecessors. Although functional, some competing products provide on-line design-rule checks which can stop you doing something silly at the time. The design-rule check function was very slow compared with the old DOS based *Autotrax* – probably taking twice as long to do the same job.

There is a wide variety of component libraries, and as each library may have hundreds of components the new library search facility is very welcome.

The component outline library provides data on pad size and placement for a wide variety of component footprints totalling over 300. There are options available to generate your own library components, or indeed modify those provided. This is all achieved within the program library

## SYSTEM REQUIREMENTS

### *Advanced PCB 2:*

Windows 3.1 in standard mode with a 286 or better processor and at least 1M-byte ram.

*Advanced PCB* requires at least 4M-byte of ram with Windows 386 enhanced-mode recommended. Will work with a 386 with maths coprocessor, but a 486 processor is recommended.

MS DOS 5.0 or later.

*Advanced PCB* needs a minimum display resolution of 800x600.

Larger screens are recommended.

Output to a Windows supported pen plotter or printer is provided plus separate direct HPGL output. Gerber format photoplotter output is also possible.

### *Advanced Schematic 2:*

Windows 3.1. 386 processor minimum, 486 and svga video, i.e. 800 by 600, preferable. Larger screens are recommended. System will work with standard vga.

20M-byte hard disk space plus 8M-byte ram.

Output to a Windows supported pen plotter or printer.

Separate direct HPGL support. Gerber format photoplotter output.

## SUPPLIER DETAILS AND PRICE

Premier EDA Solutions, 133 Cardiff Road, Reading, Berkshire RG1 8ES. Tel 0734 57 44 44, fax 0734 599 519. Prices for the Protel packages: *Professional PCB* £695, *Advanced PCB* £1250, *Advanced Route* £695, *Advanced Placement* £695 and *Advanced Schematic 2* £695. The productivity pack reviewed is priced at £2795. There is a competitive upgrade scheme plus educational and volume discounts.

## CELL VERSUS SHAPE-BASED ROUTING

Most autorouters are grid-based routers using a map of grid cells to define every available cell on the pcb. For tight tracking, a small grid size is required and the memory requirements escalate alarmingly. A four layer pcb on a 0.001in grid only 5 by 5in with one byte per cell, for example, requires 100M-byte of memory. Although the day when a standard PC has this much memory may not be too far off, shape-based routing offers high resolution routing by only checking pcb objects while routing.

Protel's *Advanced SB Route* is an optional shape-based autorouter. The benefits of the shape-based router is that it describes the routing problem more precisely and in much less memory than a grid router. Applications where shape-based routing will score are off-grid metric placements, fine-pitch smds or staggered pga objects, where high resolution is required.

editor. Each 'component' may then be loaded to the pcb in the same way as any other.

Engineering change order, or eco, is a new Protel function. Following closely the PADS pcb system, it checks the pcb database for changes made during routing and produces a file which can be read into the schematic.

When the schematic editor and the companion *Advanced PCB* editor are open at the same time, it is possible to cross probe – that is, select a part on the pcb and then jump automatically to the corresponding pcb component on the schematic.

## Conclusions

*Advanced Schematic 2* is a truly excellent electronic cad tool. Although it has some weaknesses, these can be spotted and overcome in the normal use of the product to provide an electrically consistent schematic.

The ability to link to the simulation products is perhaps rather overstated, because it is only the *Spice* interface that seems to be properly supported. Many of the so called 'tool' facilities are just as easy to launch by task switching to program manager – an example of a facile menu option is that of launching the windows clock!

With a full Windows help system, you should be able to navigate through the program almost without reference to the documentation.

Fast selection of library components and a really good project orientated sheet hierarchy offer great user productivity, but this can only be achieved using the high resolution screen. A standard vga screen will operate – but is barely usable.

At less than £700 the package is competitively priced, and offers users the opportunity to truly upgrade their dos products to a product with much greater power and functionality. With a high resolution screen and fast processor the functionality and performance is equivalent to the best workstation products.

Although this review was carried out on a 33MHz 486DX PC with 8M-byte of ram, all the functions on the latest version of *Advanced PCB 2* ran very slowly. This is sad, because the software looks good and handles well, but without a 100MHz Pentium, it could bring on a case of severe frustration.

*Advanced PCB* offers a workstation level of functionality, but without the best PC processor speed and extended memory size it cannot deliver sufficient speed for good user productivity. ■



# Forget everything you KNOW about EPROM EMULATORS.

Debugging takes up no ROM space and requires no mods to code. Debug 100% full ROMs. Code runs 100% full speed.

68000  
80C166  
8031, 80537  
families  
Z80  
6303  
6809  
68HC11  
M740  
65C816  
and more

# Em4



**Crash Barrier Ltd**  
18 Oxford Street  
Wellingborough  
Northants  
NN8 4HY  
Tel: (0933) 224366  
Fax: (0933) 441877



Call or fax us for full data

- PC Printer port: 200Kbyte/Sec
- Emulates 16Kbit-16Mbit, 8 & 16-bit, 24/28/32/36/40/42-pin ROMs and EPROMs in one unit.
- BackChannel comms links
- Shadow Memory, Hardware Instruction-Injection for breakpoints, Breakpoint-per-address, Single-step, see/edit RAM/ROM/Regs, true Source-Level Debug, any MPU just from ROM sockets.
- from £695

# METAi New Features



**MORE 80**  
THAN  
**Processor families**  
in one Assembler System

- **Incremental Linking**; allows linking of object modules to form a new, composite OBJ file that can in turn be linked - improves modularity and link speed in large programs
- **One-pass Assembly** - takes half the time of two-pass assemblers, with no drawbacks - compatible with all directives
- **Assembler now accepts source files of any size**, caching in 16K chunks
  - **Assembler can generate 1Mbyte per segment**, up from 64K, up to 768 segments per link in up to 512 Object modules
  - **Assembler can accept macros and repeat/until loops of any size**
  - **Environment variables aid network use** - define default paths
- **Linker accepts LOCATOR file** to allow complex bank mapping schemes to be catered for automatically; adjusts code position in output file without changing target-system addresses
- **New Debugger Source-Level display** - 'folds' macro, include file and repeat/until loop bodies to give a 'tree' display; you can individually unfold items to retain a 'high level' view of your code, without getting swamped by the details of inner macro levels
- **ASSUME support deals with moveable base-page addressing modes**
  - **New transient symbols** - exist only until next non-transient
- **New CONTAINS directive** allows sub-classes to be arranged within a container class, excellent for arranging code blocks within banks
- Both Assembler and Linker use new **Symbol table** techniques that increase speed and remove constraints - typ. 320K for the Assembler

**From £445 Existing** users can get new manual and software for £35+£6.95 carr & VAT

CIRCLE NO. 116 ON REPLY CARD

## THE COMPLETE EMC EMISSIONS TEST KIT

All you need for effective pre-qualification EMC testing



The EMC regulations will be in force by the end of 1995! Pre-qualification testing has been acknowledged as a sensible and effective strategy for reducing timescales and costs involved with compliance. The RF-Kxx range of test kits provides all you need to test for all RF emissions, conducted and radiated, over the range 10KHz to 500MHz.

### Specific features include:

- Compliance to relevant CISPR specifications
- PC interface and software
- Precise frequency analysis
- Comparison against limits

### All kits include:

- Powerful RF Spectrum Analyser
- Broadband pre-amplifier
- Near field probe set (E&H)
- Far field antenna and stand
- All necessary cables
- Definitive text book - EMC for Designers

### Options:

- LISN for mains conducted measurement
- Serial link and software for PC

### The complete kit for:

- Checking existing products
- Refining circuit and screening design
- Location of hot spots and leaks
- Monitoring of problem frequencies
- Pass the formal test first time round
- Documenting results for Technical files
- Monitoring production performance

Prices for complete kits start from under £2000

RING FOR COMPLETE DETAILS LAPLACE INSTRUMENTS LTD TEL: 0692 500777 FAX: 0692 406177



CIRCLE NO. 117 ON REPLY CARD

# Audio design leaps forward?

*Designers have long recognised the theoretical advantages of combining feed-forward error correction with feedback. But in his design for a feed-forward audio power amp Giovanni Stochino looks to have succeeded in putting theory into practice.*

Since its invention by H S Black<sup>1</sup> in the 1920s feed-forward error correction has found practical application in radio frequency and microwave amplifiers<sup>2</sup>. But it has never been used, in Black's form, in audio power amplifiers<sup>3</sup>. The reason is probably the inherent difficulty in accurately and efficiently applying Black's feed-forward principle to audio power amplifiers over the full audio frequency range.

But a newly-developed circuit technique could do just that, and, within specified limits, put Black's true feed-forward principle to work in high power audio amplifiers.

Experimental results demonstrate the effectiveness of the proposed technique, but first, a look at some of the underlying theory.

## Feed-forward or feedback?

The general input-output relationship of a power amplifier, before applying correction, can be written as  $V_p = V_i G_p + E_p$ .  $G_p$  is the volt-

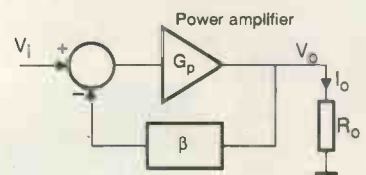
age gain, generally a function of frequency and load impedance, and  $E_p$  is the error component that includes the amplifier's non-linear distortion and noise.  $E_p$  depends on input voltage and load impedance, and on frequency.

When negative feedback is applied (Fig. 1), the input-output relationship of the corrected amplifier becomes  $V_o = A_{cl} V_i + E_{fb}$ .  $A_{cl}$  is the closed loop voltage gain, substantially defined by the feedback network, and  $E_{fb}$  is the residual error component after feedback correction.

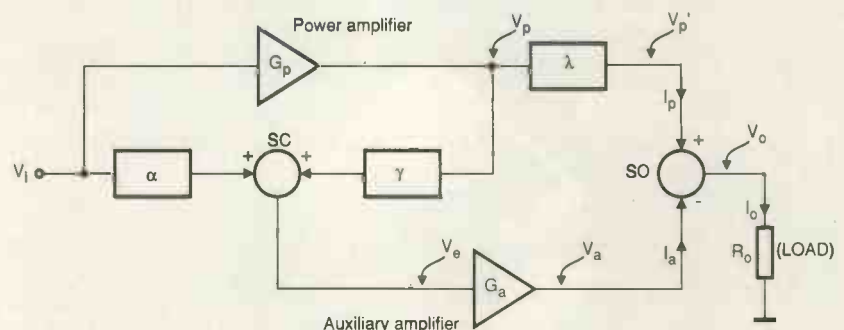
Analysis shows that distortion can never be completely nulled by negative feedback — though feedback is effective in reducing distortion as long as there is enough gain within the feedback loop.

Feed-forward is based on a different mechanism of error correction. The basic scheme (Fig. 2) incorporates a criterion network ( $\alpha$ ,  $\gamma$  and SC) to determine, isolate and extract power amplifier error; an auxiliary amplifier AA (low power requirement, low distortion

**Fig. 1. Basic elements of a feedback amplifier. Analysis shows that distortion can never be completely nulled with this configuration.**



**Fig. 2. Principles behind feed-forward. In this configuration, power amplifier error is extracted, determined and isolated via a criterion network comprising  $\alpha$ ,  $\gamma$  and SC.**





and low noise compared with the power amplifier, PA) to provide a buffered copy of  $E_p$ ; and output summing network  $SO$ . In  $SO$  the error component of PA and its copy available at the output of AA cancel out to provide a distortion-free output voltage on load  $R_0$ . Phase-amplitude equaliser network  $\lambda$  is added to the basic scheme to improve the error-correction mechanism at high frequency.

The scheme should include a few delay lines to compensate for amplifier propagation delay and connections. But their influence is negligible in the audio frequency range.

Simple analysis of the diagram gives:

$$V_0 = V_p' - V_a$$

$$= V_i G_p \lambda - G_a V_i (\alpha + \gamma G_p) + E_p (\lambda - \gamma G_a) + E_a$$

where  $E_a$  is the error component (distortion plus noise) produced by the auxiliary amplifier. Proper operation of the feed-forward technique requires that  $E_a \ll E_p$  so the effective output error is  $E_{ff} = E_a + E_p/\rho$ . Term  $\rho = 1/(\lambda - \gamma G_a)$  can be defined as the distortion rejection factor of the feed-forward amplifier and describes the effectiveness of feed-forward in removing distortion in the power amplifier.  $E_{ff}$  reduces to its lowest value of  $E_a$  when  $\rho = \infty$ , that is when  $\gamma G_a = \lambda$ , and shows the potential of the feed-forward mechanism to completely null distortion  $E_p$  in the power amplifier.

The further condition  $\gamma G_p = -\alpha$  should be satisfied to nullify the component  $V_e^* = V_e(V_i)$  (see panel p. 822 for definition of  $V_e^*$ ) at the input of the auxiliary amplifier. This would minimise both  $E_a$  and power handling requirements for the auxiliary amplifier. The mathematics implies that when  $\gamma > 0, G_p$  and  $\alpha$  have opposite signs.

**Feed-forward more promising?**

Distortion  $E_{fb}$  of a feedback amplifier can never be nulled, but it can be substantially reduced in the range of frequency and input voltage, where the feedback factor is much greater than 1.

As a technique, it is less effective at the highest frequency of the audio range and in the crossover region of class AB amplifiers, where the feedback factor can be low and deviation from linearity is high<sup>4</sup>.

On the other hand, negative feedback amplifier configurations are very simple and require no matching of components (Fig. 3).

Feed-forward error correction is much more complex. But better distortion results are possible. In theory, the error of the whole power amplifier can be reduced to that of the auxiliary amplifier alone, even at high frequencies and in the crossover region. The advantage is that the auxiliary amplifier needs to handle only moderate currents and voltages. So it can be designed to provide much lower distortion (for instance it can be operated in class A) than the power amplifier, and very low distortion can be achieved.

Neither feedback nor feed-forward error correction can completely null the output error of a power amplifier. But feed-forward is more promising, virtually nulling distortion of the

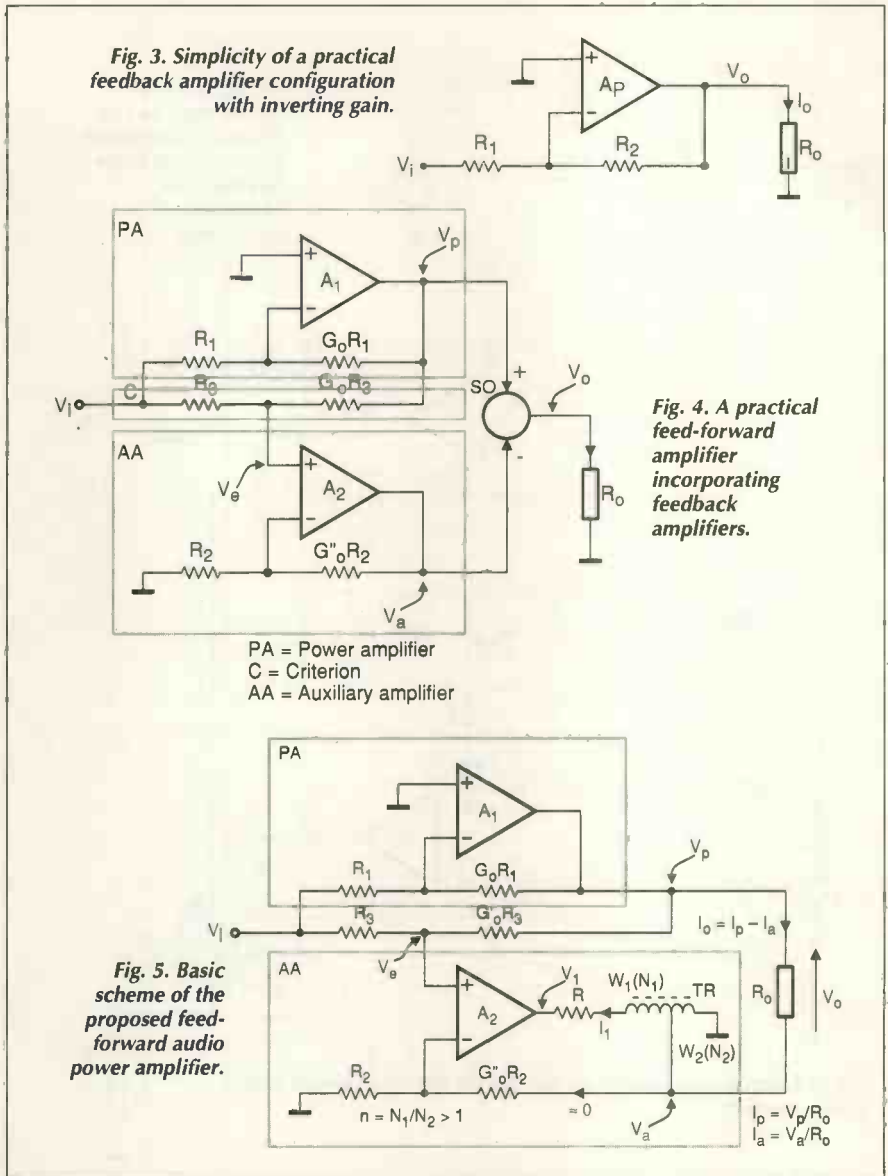


Fig. 3. Simplicity of a practical feedback amplifier configuration with inverting gain.

Fig. 4. A practical feed-forward amplifier incorporating feedback amplifiers.

Fig. 5. Basic scheme of the proposed feed-forward audio power amplifier.

PA = Power amplifier  
C = Criterion  
AA = Auxiliary amplifier

power amplifier, leaving only the low residual error of the auxiliary amplifier over the load.

**Combining feedback and feed-forward**

Tight matching of parameters in the feed-forward scheme (Fig. 2) can be achieved, simply and steadily, by using negative feedback. The strategy helps precise definition of gain in both the power amplifier and the auxiliary amplifier – provided the open loop gain of both amplifiers is high in the audio frequency range. So feedback and feed-forward techniques can be profitably combined in a true low-distortion audio power amplifiers. In a practical application (Fig. 4), the power amplifier and auxiliary amplifier have the gains defined by their respective feedback networks:  $G_p = V_p/V_i \cong -G_0$  and  $G_a = V_a/V_e \cong (1 + G_0'')$  provided  $A_1/G_0 \gg 1$  and  $A_2/G_0'' \gg 1$ . But there is also  $\gamma = 1/(1 + G_0')$ ,  $\lambda = 1$  and  $\alpha = G_0'/(1 + G_0')$ . As a result,  $G_0'' = G_0$  and  $G_0' = G_0$ .

The scheme is a practical way of assuring that the fundamental conditions for proper operation of feed-forward technique are always satisfied. But the problem remains in

implementing the output summing network – probably the most difficult obstacle in the basic feed-forward error correction scheme.

The simplest and most intuitive way of realising this summing network is where corrective voltage  $V_a$  is directly transferred into the load's loop. Voltage  $V_0$  across the load is equal to  $V_p - V_a = -G_0 V_i + E_p - E_p + E_a = -G_0 V_i + E_a$ , which is consistent with feed-forward theory.

But if, in this scheme, the auxiliary amplifier has to sustain the full load current, the assumption that the auxiliary amplifier is a low-power, low-distortion (prospectively class A) amplifier is no longer valid.

As a result, we can not assume that  $E_a \ll E_p$ , and consequently the inherent advantage of the feed-forward technique disappears. This is why the simple feed-forward configuration has never been used in power amplifiers<sup>3</sup>.

It also explains why, though the advantages of the feed-forward technique, in conjunction with feedback, are generally recognised, Black's feed-forward error correction technique has found only limited application by audio designers.

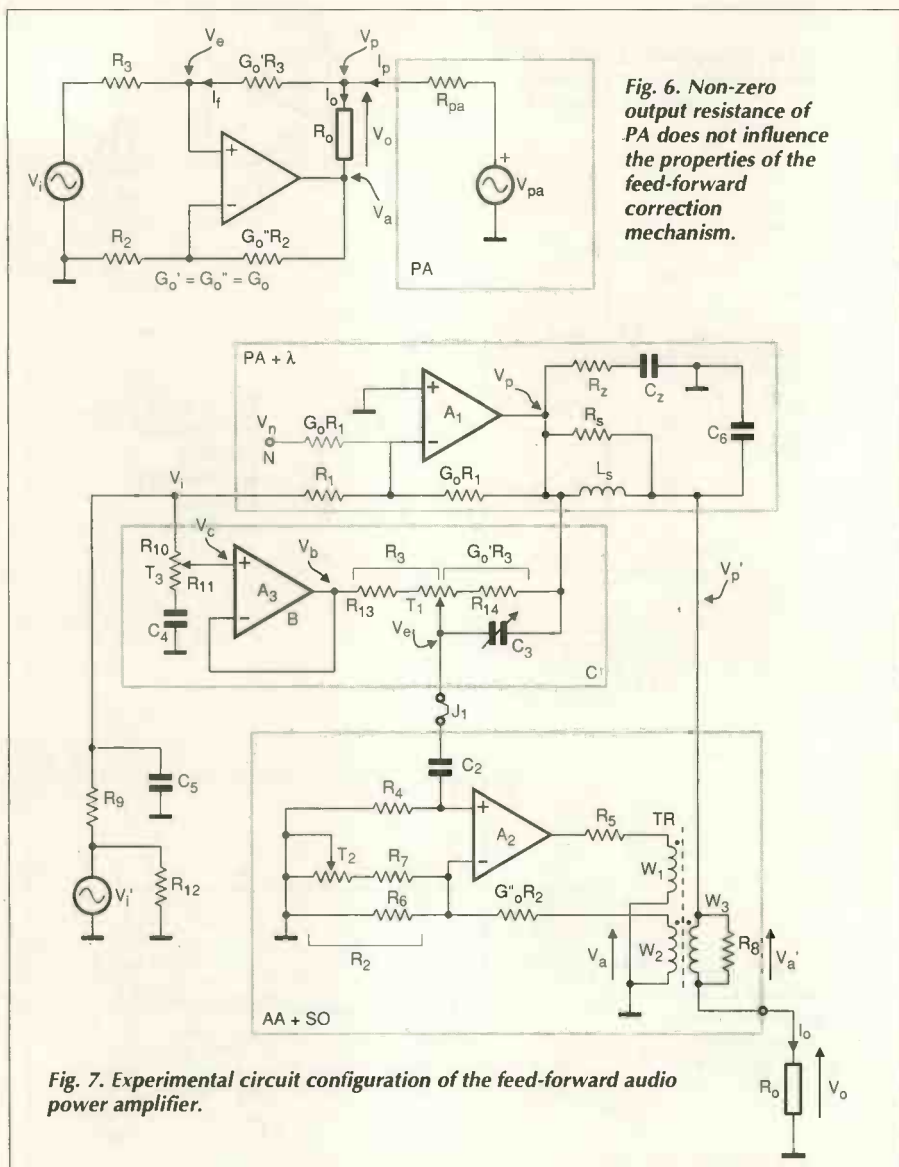


Fig. 6. Non-zero output resistance of PA does not influence the properties of the feed-forward correction mechanism.

Fig. 7. Experimental circuit configuration of the feed-forward audio power amplifier.

Feed-forward error correction (always intra-loop) is sometimes used in audio power amplifiers<sup>5, 6</sup>, but Black's basic scheme has yet to be incorporated into audio power amplifier design.

**A feed-forward power amplifier that works**

We have seen that, in the feed-forward scheme (Figs. 2, 4), the most critical part to be implemented in audio applications is the output summing network (SO). Here the power signal  $V_p$  coming from the power amplifier and low level corrective signal  $V_a$  produced by the auxiliary amplifier have to combine without undesired interaction (ie cross-modulation, frequency instability, gain impairment) to provide a distortion-free output.

What is more, this combination must be performed efficiently without requiring much power from the auxiliary amplifier, and must not be affected by impedance-variations of loads – even loads as difficult as loudspeakers.

In amplifiers for hf use, such problems are less critical. Appropriate networks can be used to implement the output summing function,

due mainly to the favourable frequency range and fixed system impedance (50 $\Omega$ ).

But audio applications span an unfavourable frequency range and imply complex and unpredictable load impedances. As a result, circuit techniques commonly used in radio frequency and microwave feed-forward power amplifiers are not practical, and different solutions have to be found.

An effective approach (Fig. 5<sup>7</sup>) has PA as the power amplifier to be corrected (usually class AB), and AA as the auxiliary amplifier. AA should be operated in class A for the best performance and incorporates transformer TR in its feedback loop. (Resistor R also includes the resistance of winding  $W_1$  and the output resistance of  $A_2$ .)

The unique role of TR is to provide both the wide-band impedance matching of the auxiliary amplifier to  $R_o$  and the power-efficient means for injecting the corrective signal  $V_a$  into the load's loop.

Transformers are usually avoided in solid state audio power amplifiers, as they are expensive, bulky, band-limited and not suited for very low distortion applications. But when

used in unconventional ways, as in this case, their unique properties can prove useful.

Putting transformer TR in the feedback loop of the auxiliary amplifier has two very important effects. The flux produced in the magnetic core of TR by the power component of the load current is automatically annulled by the feedback that forces voltage  $V_a$  to be insensitive to power component variation. So no restrictions are imposed on transformer size and core material by the amount of power that the power amplifier transfers into the load. In most cases a small transformer can be used.

Open loop output impedance of the auxiliary amplifier can also be extremely low (a few m $\Omega$ ) in the full audio frequency range and above. The consequence is that undesired interactions and cross-modulations between power amplifier and auxiliary amplifier, as well as the sensitivity of the auxiliary amplifier to load impedance variations, are strongly reduced. A further benefit is that the primary winding of TR is driven, virtually, by a voltage source, since R tends to zero. This widens the frequency bandwidth of TR, whose practical low frequency corner  $f_0$  turns out to be as low as a few Hz, even if a small ferrite core is used to improve its bandwidth and linearity.

**Transformer operational requirements**

The function of the transformer – to permit injection of the corrective current into the load without interaction with the main current component – is performed by cancelling the core flux generated by the main current component.

This flux neutralisation is carried out by the coercive action of the auxiliary amplifier's feedback loop and is effective as long as the current and voltage available at the output of  $A_2$  are adequate and the loop gain remains high. The only effective flux in the transformer core is therefore produced by the corrective voltage  $V_a$ .

For frequency  $f > f_0$ , the peak flux density  $B_p$  and the peak voltage  $V_{ap}$  are linked by  $2\pi f B_m S_e N_2$  where  $S_e$  is the effective cross-sectional area of the transformer core. So the amount of corrective voltage  $V_{ap}$  that can be provided to the load is limited by the core geometry, through  $S_e$ , and the core material, through  $B_s$  (ie the saturation flux density), since it must always be  $B_p \leq B_s$ . The amount of available corrective voltage can also be seen to increase in direct proportion to frequency.

As an example, take a toroidal ferrite core with  $S_e$  at 100mm<sup>2</sup> and  $B_s$  at 200mT. If  $N_2$  is 20,  $V_{ap}$  is 50mV at 20Hz and  $V_{ap}$  is 5V at 2kHz. Compared to an output of 100W/8 $\Omega$ , they represent peak correctable errors of 0.12% and 8.7% respectively.

Performance matches well with that of class AB audio power amplifiers, exhibiting non-linear distortion that rises with increasing frequency, and extends normally, say, from 0.01% to 1% in the audio frequency range.

**Amplifier requirements**

Class A operation is mandatory for amplifier  $A_2$  to achieve the lowest distortion with low level error signals. High gain and low noise



# A Selection from Current Inventory - call today to view

## SURFACE MOUNT

### DYNAPERT Pick and Place

#### MPS111

- 2000cph test rate
- 457 x 457mm working area
- Adhesive dispensing unit
- Systems accuracy: +/-0.2mm
- Self teach programming
- 30 or 60 way feeder capacity

#### MPS318\*

- 4000cph test rate
- 457 x 457mm working area
- Adhesive dispensing unit
- Systems accuracy: +/-0.2mm
- 60 way feeder capacity

#### MPS318HR\*

As the MPS318 with higher resolution Theta Drive (0.1°)

\*Options available for MPS318/HR

- Fiducial correction,
- Manual or autochuck
- Front and rear cropper
- Feeder compaction
- CCTV system for programme ease
- Pattern recognition
- 100 way feeder capacity

#### MPS500

- 6000cph test rate
- 457 x 356mm working area
- Adhesive dispenser
- Systems accuracy: +/-0.1mm
- 120 way feeder capacity
- Feeder compaction
- In-line auto chuck

### MPS525

Same specification as MPS500, but includes flying probe pattern recognition. 200 way feeder capacity.

### MPS2500

- 13000cph test rate
- 610 x 457mm working area
- System accuracy: +/-0.1mm
- 0805 chip to PLCC84
- Linear or carousel feeder carriage

### Magazine Board Loaders, Unloaders and Inverters available

#### OKANO OCM 8400IIL

- 4500cph test rate
- 460 x 410mm working area
- 60 feeder capacity

#### ISMECA 350 19 1151

- Bad board detection,
- Feeder pack

### SMT Production Lines

- Sanyo
- Panasonic MK1B
- Siemens HS180

Phone for Details

## SCREEN PRINTERS

### DEK 240 Manual

- 254 x 203mm print area
- Print stroke from 25mm upwards

### DEK 245 Semi-Automatic

- 254 x 203mm print area
- Print stroke: Half 160mm/ Full 290mm
- Print registration: +/- 25 microns

### DEK 247 Semi-Automatic

- 304 x 304mm print area
- Electronic control of print head
- Print registration: +/- 25 microns

### DEK 255 Pass Thru Automatic

- Motorised automatic print cycle
- Screen adjustment: X,Y +/-10mm

### DYNAPERT MPM ASP-24 Automatic

- 500 x 500mm print area
- Stand alone or inline

## REFLOW OVENS

### MCBT 6820 Belt type hot platen

- SURF UV/IR adhesive curing oven
- HERAEUS CM-V/24-IR/T21-PC adhesive curing oven
- UNIVERSAL 4813C curing and reflow
- IEMME IM750 infrared reflow

## ENVIRONMENTAL OVENS

- MONFORD: -70c to +200c. Liq Nit
- GALLENKAMP: Amb to +60. Humid
- HERAEUS: Ambient to 250c
- HERAEUS: Vacuum. +40 to +180

## THRU-HOLE

### Panasonic

Complete Panasonic radial and axial line. Consisting of: Radial RH6 • Axial AV Plus loaders/unloaders. Phone for details

#### AMISTAR A16448

- Axial Lead Component inserter
- Sequencer/Inserter
- VCD Head
- Component Verifier
- 64 fixed reels/48 Cartridges
- AL300 Cartridge Loader

#### AMISTAR C13000:

- Dip socket inserter

#### TDK VCH

- Upgraded to the VC5 insertion head. Complete line. Phone for details

#### ROBIN AMBOTECH

- Automatic axial radial machine

#### MARCONI 510 AUTO

Board Test System fully configured Plus latest firmware and software upgrades.

#### HEEB LIGHT GUIDED ASSEMBLY

- For SMT or leaded components
- Microprocessor controlled
- Quantity available

## ELECTROVERT CENTURY 2000S WAVE SOLDERER

High Performance Micro Processor Wave Solder Machine with auto solder wire feed replenishment

## HUGHES 2460-II-TAB BONDER

High speed single point tape automated bonder (TAB).

## TEST EQUIPMENT

### Signal Analysers:

- HP 3582A Dynamic signal analyser 0.02Hz-25.5kHz
- TEK AM503S Current probe amplifier system

### Signal Sources:

- HP 8640B 0.5 to 512MHz AM FM PM Signal gen
- HP8662A 10kHz to 1280MHz signal/sweep gen
- HP3335A synthesizer/level generator 200Hz to 81MHz

### Oscilloscopes:

- TEK 2445150MHz 4 channel
- TEK 2201DSO 10MHz Digital storage

- TEK 222 Hand-held battery portable 10MHz DSO

### Audio/TV Test:

- Abacus ARTA600 Audio real time analyser
- System video 2461 Gencoder

# Alternative SURFACE MOUNT DISTRIBUTION SPECIALISTS

TEL: 071-284 4074

FAX: 071-267 7363

Alternative Distribution (UK) Ltd., 146 Camden Street, London NW1 9PF England. Tel +44 71 284 4074

All Trademarks acknowledged

CIRCLE NO. 118 ON REPLY CARD

# KESTREL ELECTRONIC COMPONENTS LTD

- ☆ All items guaranteed to manufacturers' spec.
- ☆ Many other items available.

'Exclusive of V.A.T. and post and package'

	1+	100+		1+	100+
<b>EPROMS</b>			<b>STATIC RAMS</b>		
27C64-150	2.30	1.68	62256LP-10	3.00	2.25
27256-25	2.20	1.85	6264LP-10	1.85	2.28
27C256-15	2.50	2.20	6522P	2.40	1.80
27C512-15	3.00	2.40	65C02P2	2.90	2.38
27C010-15	5.60	3.70	65C21P2	2.90	2.50
27C020-15	6.20	4.30	65C22P2	2.80	2.30
27C040-15	9.60	7.00	MC146818AP	2.20	1.65
MAX232	1.35	0.95	MM58274CN	4.90	3.98
D8748H	4.20	3.40	SN75176BP	1.60	0.80
D8749H	4.40	3.50	Z80A CPU	1.50	1.00
80C31-12	2.60	1.80	Z80A CTC	1.30	0.85
80C85A	2.60	1.80	Z80A DART	2.10	1.40
82C55-8MEG	1.95	1.58	1488P/1489P	0.32	0.25

74LS, 74HC, 74HCT Series available

Phone for full price list

All memory prices are fluctuating daily, please phone to confirm prices

178 Brighton Road,  
Purley, Surrey CR8 4HA

Tel: 081-668 7522. Fax: 081-668 4190.

CIRCLE NO. 119 ON REPLY CARD

# JPG Electronics

Inverter toroidal transformers 225VA 10.5-0-10.5 primary 0-260-285 secondary.....£29.95  
LEDs 3mm or 5mm, red or green.....6p each  
Yellow.....11p each  
High intensity red, green or yellow 5mm.....30p each  
Cable ties, 1p each, £5.95 per 1000, £49.50 per 10,000  
High quality photo resist copper clad epoxy glass boards  
Dimensions single sided double sided  
3x4 inches £1.09 £1.23  
4x8 inches £2.75 £2.99  
6x12 inches £6.20  
12x12 inches £12.25  
Rechargeable batteries  
AA 500mAh.....£0.99  
AA 700mAh.....£1.75  
C 2AH with solder tags.....£3.60  
D 4AH with solder tags.....£4.95  
1/2 AA with solder tags.....£2.50  
AA A (HP16) 1/5 AA with tags (Phillips CTV).....£1.95  
180mAh.....£1.75  
Standard charger charges 4 AA cells in 5 hours or 4Cs or Ds in 12-14 hours + 18PP3 (1, 2, 3 or 6 cells may be charged at a time).....£5.95  
High power charger as above but charges the Cs and Ds in 5 hours. AAs, Cs and Ds must be charged in 2s or 6s.....£10.95  
Nickel Metal Hydride AA cells high capacity with no memory. 1000mAh £3.85 1200mAh £4.40  
Special offers, please check for availability.  
45 x 16mm dia 12v.....£1.45  
Stick of 4 171mmx16mm dia with red & black leads 4.8v.....£5.95  
Computer grade capacitors with screw terminals  
87000uf 20v.....£2.50  
87000uf 10v.....£1.95 68000uf 15v.....£2.95 10000uf 16v.....£1.50 58000uf 60v.....£4.95  
7 segment common anode led display 12mm.....£0.45  
LM2931A 5.0 low drop out 5v regulator T0220 package.....£0.85  
7812 and 7912 12v 1A regulators.....£26.00 per 100  
LM337K T03 case variable regulator.....£1.95 (£1.44 100+)  
GaAs FET low leakage current 58873.....£12.95 each (£9.95 10+, £7.95 100+)  
BS250 P channel mosfet.....£0.45 BC559 transistor.....£3.95 per 100  
74LS05 hex inverter £10.00 per 100 Used 8748 Microcontroller.....£3.50  
SL952 UHF Limiting amplifier LC 16 surface mounting package with data sheet.....£1.95  
A M 27 S 0 2.....£1.25 each 90p 100+ GD4007UB.....£1.00 (6p, 1000+)

Sinclair light gun terminated with a jack plug and PP3 clip gives a signal when pointed at 50Hz flickering light with output wave form chart.....£3.95  
DC-DC converter Reliability model V12P5 12v in 5v 200ma out 300v input to output isolation with data.....£4.95 each or pack of 10.....£39.50  
Hour counter used 7 digit 240vac 50 Hz.....£1.45  
QWERTY keyboard 58 key good quality switches new.....£5.00  
Airpax A8280S-C large stepping motor 14v 7.5 step 27ohm 68mm dia body 6.3mm shaft.....£8.95 or £200.00 for a box of 50  
Polyester capacitors box type 22.5mm lead pitch 0.9uf 250vdc 18p each 14p.....100+ 9p.....1000+ 1uf 250vdc.....20p each 15p.....100+ 10p.....1000+ 2.2uf 250vdc (27.5mm pitch).....30p each 20p 100+ 15p.....1000+  
3.3uf 100vdc.....30p each 20p.....100+ 15p.....1000+ 1uf 50v bipolar electrolytic axial leads.....15p each 7.5p.....1000+  
0.22uf 250v polyester axial leads.....15p each 7.5p 100+  
Polypropylene luf 400vdc (Wima MKP10) 27.5mm pitch 32x29x17mm case 75p each 60p 100+  
Phillips 123 series solid aluminium axial leads - 33uf 10v & 2.2uf 40v.....40p each 25p 100+  
Phillips 108 series 220v 63v axial.....50p each 15p.....1000+  
Multilayer AVX ceramic capacitors all 5mm pitch 100v 100pf, 150pf, 220pf, 10,000pf (10n).....10p each 5p.....100+ 5.5p.....1000+  
500pf compression trimmer.....60p 40 uf 370vac motor start capacitor (dielectric type containing no PCBs).....£5.95 or £49.50 for 10  
Wetvyn W25 9W 120ohm.....35p each 20p 100+  
680 ohm 2W metal film resistor 4p 100+ 2p 1000+  
Solid carbon resistors very low inductance ideal for RF circuits - 270hm 2W, 680hm 2W.....25p each 15p each 100+  
We have a range of 0.25w 0.5w 1w and 2w solid carbon resistors, please send SAE for list  
P.C. 400W PSU (Intel part 201035-001) with standard motherboard and 5 disk drive connectors, fans and mains inlet/outlet connectors on back and switch on the side (top for tower case) dims 212x149x149mm excluding switch. £26.00 each £138.00 for 6  
MX180 Digital multimeter 17 ranges 1000vdc 750vac 2Mohm 200mA transistor Hfc 9v and 1.5v battery test.....£12.95  
AMD 2726-3 EProms.....£2.00 each £1.25 100+  
DIP switch 3PC0 12 pin (ERC SDC-3-023).....60p each 40p.....100+  
Disk drive boxes for 5.25 disk drive with room for a power supply, light grey plastic, 67x268x247mm.....£7.95 £49.50 for 10  
Hand held ultrasonic remote control.....£3.95  
CV2486 gas relay, 30x10mm dia with 3 wire terminals, will also work as a neon light.....20p each £7.50 per 100  
A23 12v battery for car alarms or lighters.....75p each £50.00 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 (0246) 211202 Callers welcome

CIRCLE NO. 120 ON REPLY CARD



are also recommended, as is low output offset voltage to stop any noticeable direct current flowing into the transformer winding.

Other requirements are wide bandwidth and high slew rate so that the correction capability of the auxiliary amplifier is extended to the highest harmonics of audio signals.

Output voltage and current handling capabilities of the auxiliary amplifier are dictated by the peak values of load current and corrective voltage:  $V_i \approx nV_{ap}$  and  $I_i \approx I_{op}/n$  where  $n = N_1/N_2$  is the turns ratio and  $is \gg 1$ . The turns ratio is used to trade-off voltage for current to reach the best level of performance of  $A_2$  with a reasonable power consumption. For example,  $I_{op} = 8A$ ,  $V_{ap} = 0.5V$  and  $n = 40$  gives  $V_i = 20V$  and  $I_i = 0.2A$ . Therefore,  $A_2$  can be powered from  $\pm 25V$  and its output stage biased at 0.2A for class A operation.

Only 10W of power is consumed by the auxiliary amplifier – a reasonable and worthy amount if compared with the 256W of undistorted audio power furnished to an  $8\Omega$  load.

**Auxiliary considerations**

An important, yet often overlooked, characteristic of feed-forward schemes based upon Black's principle, is that the voltage across the load is not defined by the power amplifier, but by the auxiliary amplifier only. In other words  $V_0$  is not theoretically dependent on power amplifier parameters (output impedance, gain, linearity etc). Power amplifier output could even be completely uncorrelated with  $V_i$ , and power amplifier output impedance could be high and non-linear without affecting the output voltage value ( $V_0 = -G_0V_i$  in Fig. 5).

We can also deduce, mathematically, that  $V_a = V_iG_0 + V_p$  and  $V_0 = V_p - V_iG_0 - V_p = -V_iG_0$  to show that output voltage is always equal to the desired value, regardless of the power amplifier output voltage  $V_p$ . So any deviation of  $V_p$  from its ideal value affects the output of the auxiliary amplifier but not output voltage  $V_0$ .

We reach the same conclusion if we take into account the non-zero output impedance of the power amplifier Fig. 6 – particularly important in the crossover and clipping regions, where comparatively high values of output impedance can be experienced.

Assume  $G_0R_3 \gg R_{pa}$ . In this case we have  $I_f \ll I_p$  so  $I_p \approx I_0$  and the node voltages are:

$$V_p = (V_{pa} - V_a) / (R_0 + R_{pa}) + V_a,$$

and,

$$V_a = V_{pa} + G_0V_i.$$

Solving simultaneously, substituting and assuming in normal operation that  $V_{pa} = -G_0V_i + E_p$ , we have:

$$V_p = -G_0V_i(1 - R_{pa}/R_0) + E_p$$

and

$$V_a = G_0V_iR_{pa}/R_0 + E_p$$

You can see that the auxiliary amplifier has to contribute a certain amount of signal voltage to the load in addition to the copy of the error voltage  $E_p$ . This amount is proportional to the ratio  $R_{pa}/R_0$ .

Power amplifiers with poorly biased class AB output stages can actually have closed loop-output impedances comparable with load impedance, at least in the crossover region. In such cases, the auxiliary amplifier contribution to the output signal voltage in the crossover region can prove significant.

Clearly, the role of forcing the desired voltage across the load is undertaken by the auxiliary amplifier.

In well-designed feed-forward amplifiers, the power amplifier provides the power to the load, while the auxiliary amplifier is limited to providing accuracy and precision only. Nevertheless, should the power amplifier fail to do its job (for instance due to crossover mechanism), the auxiliary amplifier would be forced to provide power as well as precision. Obviously, the auxiliary amplifier is designed to provide only a limited amount of precise corrective voltage.

It is worth noting that the auxiliary amplifier is always stable because even with the worst-case positive feedback factor ( $R_{pa} = \infty$ ),

$$F_p = R_3 / [R_3(1 + G_0') + R_0]$$

of the auxiliary amplifier.

Extremely low open loop output impedance means the auxiliary amplifier's closed loop gain and distortion performance are insensitive to load impedance variations.

Wide bandwidth achievable for the low power auxiliary amplifier also allows a large reduction of the highest harmonics of audio signals.

Error correction technique (Fig. 5) can be applied to all power amplifier circuit configurations, with inverting as well as non-inverting gain.

**Magnetic flux cancellation**

This diagram helps analyse the mechanism of magnetic flux cancellation  $\Phi(V_i)$  in the transformer core, due to main signal current  $I_p = V_p/R_0 \approx -G_0V_i/R_0$ . It is operated by the auxiliary amplifier.

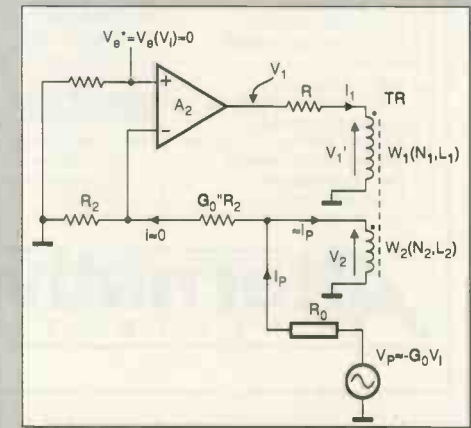
$$\Phi(V_i) \equiv V_2(V_i) / (2\pi f N_2)$$

$$V_2(V_i) \equiv -G_0V_i \frac{R}{n^2R_0} \cdot \frac{1}{\{1 + A_2/[n(1 + G_0'')]\}}$$

From this,

$$\lim V_2(V_i) = \Phi(V_i) = 0$$

$$(A_2 \rightarrow \infty \text{ and/or } R \rightarrow 0)$$



is always lower than the negative feedback factor  $F_n = R_2/[R_2(1 + G_0'')]$  when  $G_0' = G_0''$ .

**Practical circuit**

In a practical circuit implementation (Fig. 7), the first-order error due to the finite gain-bandwidth product of the amplifiers can be taken into account and compensated for.

Transformer TR is modified to provide error correction to a grounded load and its secondary windings  $W_2$  and  $W_3$  are close-coupled to assure that  $V_a' = V_a$ . Follower B buffers the input voltage source and the phase-amplitude-equaliser ( $R_{10}$ ,  $R_{11}$  and  $C_4$ ) from the criterion network.  $R_g$  and  $C_5$  form an input low-pass filter cutting off input frequencies above 100kHz. Decoupling  $C_2$  avoids undesired dc operation with the auxiliary amplifier. Trimmers  $T_1$ ,  $T_2$  and  $T_3$  facilitate calibration of the complete amplifier and help achieve the best distortion performance.

In analysing the circuit, the effects of  $C_2$  on the output voltage can be neglected, with  $C_2$  assumed to be  $\infty$ .

In the Zobel network ( $R_z$ ,  $C_z$ ,  $R_s$  and  $L_s$ ) commonly used at the output of class AB audio power amplifiers,  $R_s$  and  $L_s$  in conjunction with  $C_6$  implement the  $\lambda$  amplitude-phase equalisation network (Fig. 2).

As well as its normal role of separating the power amplifier from the load at frequencies far above the audio range, this network also limits positive feedback around the auxiliary amplifier at the highest frequencies, improving

**Turning Black's feed-forward principle into practice**

Load impedance 'seen' by amplifier  $A_2$  is high enough to allow true low distortion operation of the auxiliary amplifier.

Auxiliary amplifier has to process only small error components, and being class A operated, its percent error contribution to load current is extremely low.

There is no appreciable common-mode-induced distortion because component  $V_e^* = V_e(V_i)$  is virtually zero.

Transformer distortion, if any, is reduced in proportion to the loop gain



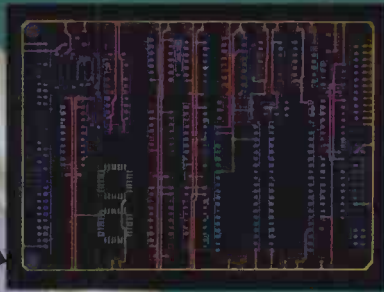
# FROM CONCEPT TO ARTWORK IN 1 DAY



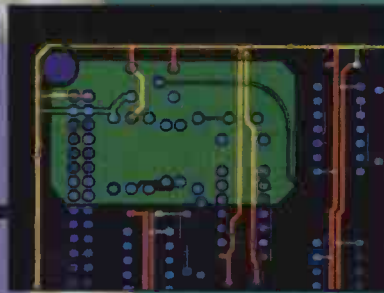
Your design ideas are quickly captured using the ULTIcap schematic design Tool. ULTIcap uses REAL-TIME checks to prevent logic errors. Schematic editing is painless; simply click your start and end points and ULTIcap automatically wires them for you. ULTIcap's auto 'snap to pin and auto junction features ensure your netlist is complete, thereby relieving you of tedious netlist checking.



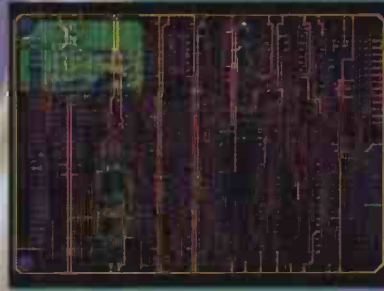
ULTIshell, the integrated user interface, makes sure all your design information is transferred correctly from ULTIcap to ULTIboard. Good manual placement tools are vital to the progress of your design, therefore ULTIboard gives you a powerful suite of REAL-TIME functions such as, FORCE VECTORS, RATS NEST RECONNECT and DENSITY HISTOGRAMS. Pin and gate swapping allows you to further optimise your layout.



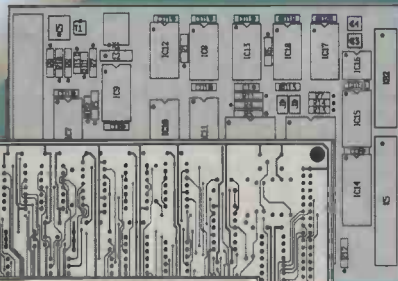
Now you can quickly route your critical tracks. ULTIboard's REAL-TIME DESIGN RULE CHECK will not allow you to make illegal connections or violate your design rules. ULTIboard's powerful TRACE SHOVE, and REROUTE-WHILE-MOVE algorithms guarantee that any manual track editing is flawless. Blind and buried vias and surface mount designs are fully supported.



If you need partial ground planes, then with the Dos extended board systems you can automatically create copper polygons simply by drawing the outline. The polygon is then filled with copper of the desired net, all correct pins are connected to the polygon with thermal relief connections and user defined gaps are respected around all other pads and tracks.



ULTIboard's autorouter allows you to control which parts of your board are autorouted, either selected nets, or a component, or a window of the board, or the whole board. ULTIboard's intelligent router uses copper sharing techniques to minimise route lengths. Automatic via minimisation reduces the number of vias to decrease production costs. The autorouter will handle up to 32 layers, as well as single sided routing.



ULTIboard's backannotation automatically updates your ULTIcap schematic with any pin and gate swaps or component renumbering. Finally, your design is post processed to generate pen / photo plots, dot matrix/laser or postscript prints and custom drill files.

**CIRCLE NO. 121 ON REPLY CARD**

## NEW

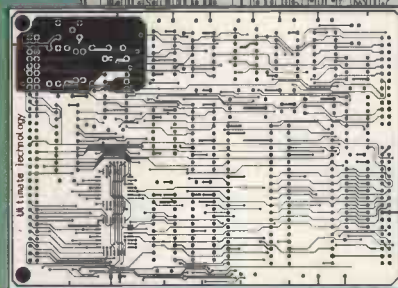
ULTIboard/ULTIcap evaluation system:

- all features of the bigger versions
- full set of manuals
- design capacity 500 pins

Price incl. S & H, excl. VAT:

### £95

Purchase price is 100% credited when upgrading to a bigger version. • Also suitable for study & hobby



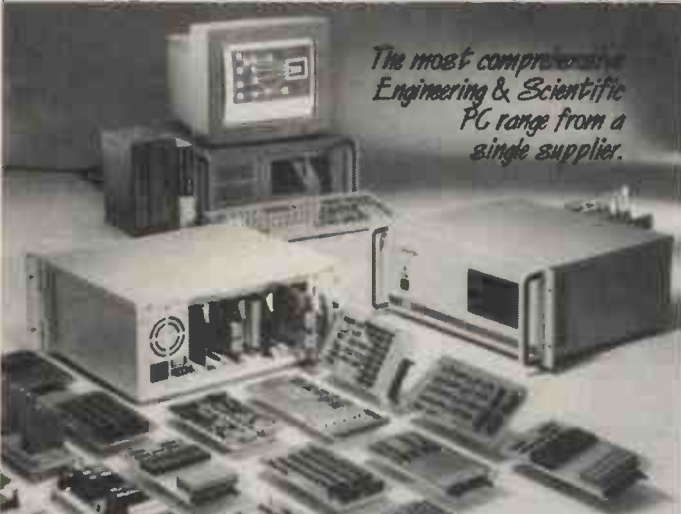
ULTIboard PCB Design/ULTIcap Schematic Design Systems are available in low-cost DOS versions, fully compatible with and upgradable to the 16 and 32 bit DOS-extended and UNIX versions, featuring unlimited design capacity.

*The European quality alternative*

## ULTICAP + ULTIBOARD = MAXIMUM PRODUCTIVITY







*The most comprehensive  
Engineering & Scientific  
PC range from a  
single supplier.*

Metular A/D, D/A, Di I/O T... Card	4.5 Digit DMM V/A/R Card	8 Chan A/D, D/A, Di I/O, Timer Card
Labtech Notebook & Control Software	3 Axis Stepper Motor Controller Card	Slot PC Bus Chassis with PSU
IEEE-488 (GPIB) Instrument Interface	8 Port Intelligent/Buffered RS232 I/O	PC Lab Data Acquisition & Control Cards
Remote Data Acquisition Modules	Windows Acquisition Control Chassis	Solid State RAM, EPROM Disk Cards
286/386/486 CPU's & Backplanes	16 Chan Relay Switch	8 Slot Card Cage & PC Bus Backplane
Solid State Memory Disk & Card	RS232/422/485 Communications Cards	Signal Conditioning & Amplifier Modules
PC-Bus Slot Extenders (8/16 Bit)	3 Slot Micro-Box PC Bus Chassis	Relay Switch & Isolated Dig I/O

**Plus MUCH more ...**

Please CALL for your FREE copy of our latest Catalogue  
OEM, Dealer & Educational Enquiries Welcome



Integrated Measurement Systems Ltd.  
305-308 Solent Business Centre,  
Millbrook Rd West  
Southampton SO1 0HW, HAMPSHIRE

Tel: (0703) 771143 Fax: (0703) 704301

ADVANTECH.  
UK Distributor

Designers & Suppliers of Measurement, Test & Control Systems & Software

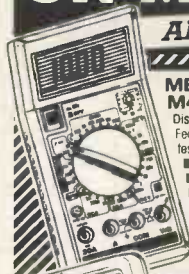
CIRCLE NO. 129 ON REPLY CARD

**FANTASTIC SAVINGS  
ON METERS  
AND MORE !!!**

ALL PRICES INCLUDE VAT

**TEST METERS**

- Satellite Finder **£29.95**
- Easy to use kit **£29.95**
- Professional Satellite F/S meter **£89.95**
- LCR Meter ■ 3 1/2 Digit ■ 7 Cap ■ 6 Inductance ■ 7 resistance ranges **£62.95**
- Capacitance Meter ■ 3 1/2 Digit ■ 9 ranges ■ 18mm LCD display **£62.95**
- Digital Lux Meter ■ 5 ranges ■ 3 1/2 digit LCD ■ Data hold output terminal **£62.95**
- Sound Level Meter ■ 40 to 120 db ■ Two ranges **£46.95**
- Analogue Clamp Meter ■ 0/300 amps ■ AC 5 ranges ■ 0/750 VAC 0/75v DC ■ 0/200 K OHM **£32.95**
- Digital Clamp Meter ■ 3 1/2 Digit ■ 11 ranges Incl temperature ■ Data hold etc. **£56.95**



**METEX 4 1/2 DIGIT DMM  
M4630**

- 30 Range 4 1/2 Digit Display 17mm ■ 0.05% Accuracy.
- Features: ■ 5 range capacitance test ■ 5 ohms ranges to 20M
- Transistor and Diode Test
- Continuity LED and buzzer ■ Data hold switch ■ 5-ranges AC/DC Volts
- AC/DC current to 20 Amps
- With leads, battery, instructions and hard case

**£49.95**



**TL34 ■ 33 Range ■ 3 1/2 digit 24mm Large Display**

- Features: ■ 5 Capacitance ranges
- 6 - resistance ranges to 20M ohm
- Diode and transistor test ■ 5 AC/DC volts ranges Basic 0.5% accuracy.
- 5 ranges AC/DC current to 20Amps
- With leads, battery and instructions.

**£27.95**



**MX190**

- 19 Range 3 1/2 Digit
- Features: ■ AC/DC Volts (0.7%)
- 0-10 ADC current ■ 0/2K/2MEG ohmresistance ■ Diode test ■ Signal Injector function
- With leads, battery and instructions

**£13.95**

Full details send for instruments info pack (SAE 36p UK) Ref: TG

**BENCH INSTRUMENTS**

- Digital LED Capacitance autorange bench meter 0.1% **£93.00**
- LCR bridge **£126.00**
- 7 Digit frequency counter 10KHz to 200MHz **£87.00**

**POWER SUPPLIES**

- \*Single meter \*Twin meter
- 0/24v dc 0/30amps **£874.00**
- 0/24v dc 0/50amps **£888.00**
- 0/30v dc 0/30amps **£140.00**
- Twin version **£260.00**
- 5-15v dc 0/4 amps **£52.95**
- 0/30v DC 0/2x Amps digital display **£99.95**

**SIGNAL SOURCES 220/240V AC**

- 6 Range RF Gen 100 KHZ to 150 MHz (350MHz Harmonics) **£122.00**
- 5 - range Audio Gen 10Hz to 1 MHz Sine/square **£119.00**
- 0.5Hz to 500KHz Function Gen Sine/Sq/Triang **£124.00**

ALL PRICES INCLUDE VAT  
OPEN 6 DAYS A WEEK

**HENRY'S**  
AUDIO ELECTRONICS  
(Reg. Prop. Cubegate Ltd)

404 Edgware Rd, London W2 1ED  
Tel: 071-724 3564/071-258 1831  
Fax: 071-724 0322  
Discounts for quantity and education



CIRCLE NO. 130 ON REPLY CARD



**Chelmer Valve Company**

**Worldwide supplier  
with 30 years experience**

- **Electron tubes: Transmitting, Industrial, Microwave, Audio, Receiving, Display, etc, etc.**
- **For Maintenance, Spares or Production.**
- **Semiconductors: Transistors, Thyristors, Diodes, RF, Power I/C's, etc.**
- **We have one of the largest stocks in the U.K.**

**★ TRY US! ★**

FAX, PHONE, POST OR TELEX YOUR REQUIREMENTS  
**130 NEW LONDON ROAD, CHELMSFORD,  
ESSEX CM2 0RG, ENGLAND**

Telephone: (0245) 355296/265865  
Telex: 995398 SEEVEE G Fax: (0245) 490064

CIRCLE NO. 131 ON REPLY CARD

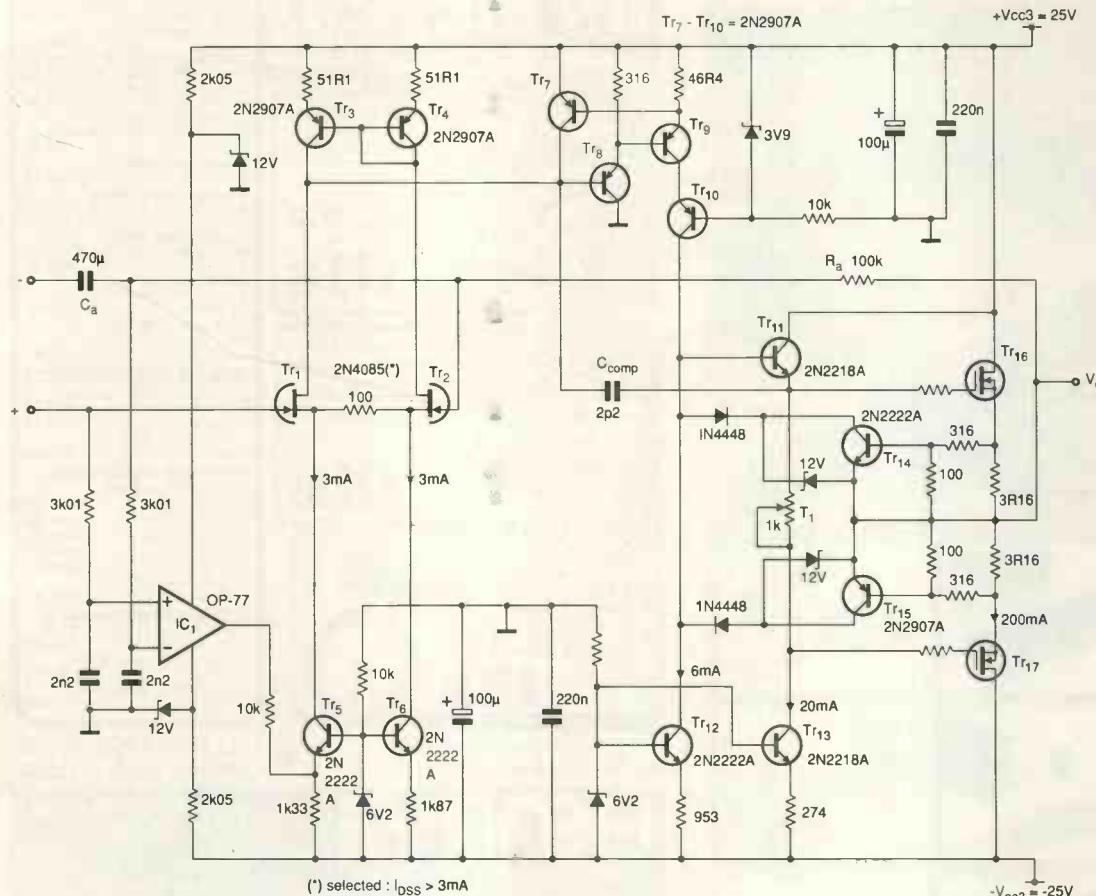


Fig. 9. Power output requirement for the auxiliary operational amplifier,  $A_2$ , is lower. In class A, output is  $\pm 200\text{mA}$  while in class AB it rises to  $\pm 800\text{mA}$ .

stage, biased by adjusting trimmer  $T_1$  at 200mA for class A operation in normal working conditions. But it can operate in class AB operation, when  $A_2$  is forced to sink or source higher currents, due to variations in load impedance or clipping for example.

The circuit is a combination of a high-speed, high dynamic-range amplifiers ( $Tr_{1-17}$ ) and a precision integrated op-amp  $IC_1$ . The main task of  $IC_1$  is, with the help of coupling capacitor  $C_a$  and feedback resistor  $R_a$ , to keep the offset voltage below a few hundred millivolts and to increase the low frequency open loop gain of the overall amplifier.

$IC_1$  also helps reduce the low-frequency voltage noise ( $1/f$  noise) associated with jfet pair  $Tr_{1,2}$ .

**Main characteristics – buffer**

TDH with 1V/600Ω	
from 20Hz to 20kHz	≤0.0005
–3dB small-signal bandwidth	≅15MHz
Voltage noise density	≅1nV/√Hz
Slew rate	≅±20V/μs

**Buffering**

Buffer  $B$  of Fig. 10 consists of an op-amp voltage follower and makes use of a high-performance integrated operational amplifier, featuring low noise and very low distortion.

**Transformer**

Transformer  $TR$ 's core is a small toroid – 23mm external diameter, 14mm internal diam-

**Complete auxiliary amplifier and transformer characteristics**

Voltage gain	≅18.1
Gain-bandwidth product	≅10MHz
Slew rate	≅±17V/μs
Thd+noise	
@5kHz	≅0.01%
Thd, $V_a=0.5V/1\Omega$	
@50kHz	≅0.05%

eter and 7mm high. Its cross-sectional area  $S_e$  is approximately 31mm<sup>2</sup>. The core material is Ferroxcube-grade 3E2, having a saturation flux density  $B_s$  of about 350mT, and a useful linear range of  $\pm 200\text{mT}$ . Turns ratio  $n$  is 30 ( $N_1=300, N_2=N_3=10$ ).

Secondary windings  $W_2$  and  $W_3$  are close-coupled with parallel and cross-coupled thick

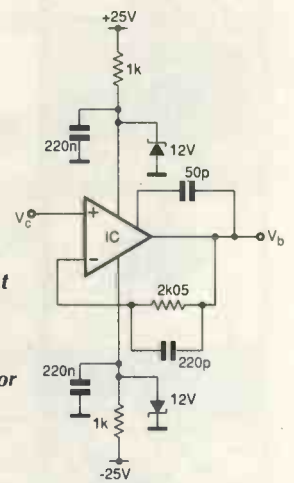


Fig. 10. Buffer  $B$ . At frequencies from 20Hz to 20kHz, distortion of this design is less than or equal to 0.0005%.

wires and all windings are uniformly wound along the core length. When driving the primary winding with a source resistance of 5Ω, the –3dB small signal bandwidth of the transformer extends from 5Hz to about 13MHz.

**Amplifier calibration**

Amplifier calibration has been performed with a load of 8Ω in parallel with 0.2μF using the following procedure.

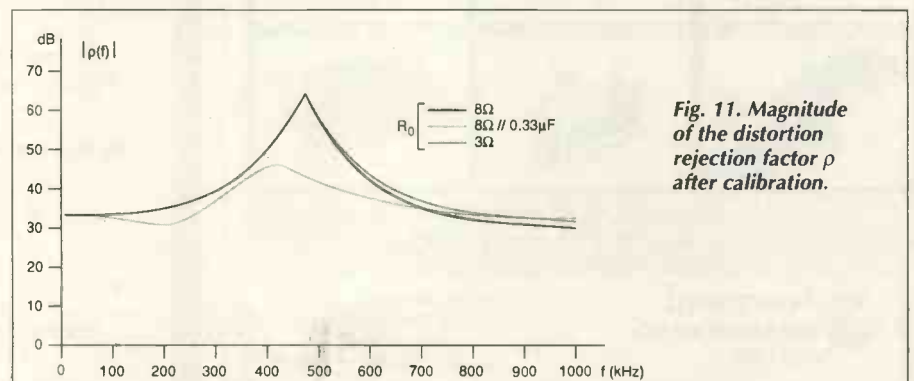


Fig. 11. Magnitude of the distortion rejection factor  $\rho$  after calibration.



Step 1: Jumper  $J_1$  is opened to isolate AA.

Step 2: Corner frequency of both PA and AA is measured and recorded ( $G_0'' \cong G_0 \cong 18.1$ ).

$$f_{c1} = p_1/2\pi \cong 422\text{kHz}$$

$$f_{c2} = p_2/2\pi \cong 650\text{kHz}$$

Step 3: Nominal value of  $C_3$  is determined with  $z_3 = p_2$ :

$$C_3 = 1/(G_0 R_3 p_2) \cong 13.5\text{pF}$$

Step 4: Nominal values of  $C_4$ ,  $R_{10}$  and  $R_{11}$  are found by applying  $p_0 = 1/C_4(R_{10} + R_{11})$  and  $z_0 = 1/C_4 R_{11}$  and using  $p_0 = p_1$  and  $z_0 = z_3$ . Since  $R_{10} + R_{11} = R_{T3} = 2\text{k}\Omega$  we obtain:

$$C_4 = 1/[(R_{10} + R_{11})p_1] \cong 188\text{pF}$$

$$R_{11} = 1/C_4 z_3 = 1/C_4 p_2 \cong 1.3\text{k}\Omega$$

Step 5: The aim is to meet the condition defined by  $\gamma G_a = \lambda$ . Signal  $V_i' = 100\text{mV}/3\text{kHz}$  is applied to the input and trimmer  $T_1$  is adjusted so that  $V_e^* = V_e(V_i)$  reaches a minimum. Then the frequency is increased to 100kHz and trimmer  $T_3$  is adjusted so that  $V_e^* = V_e(V_i)$  is again at a minimum.

Step 6: Connect jumper  $J_1$  and repeat step 5.

Step 7: Input of the amplifier is grounded and a forced error signal  $E_{pn}$  is produced at the output of PA by applying the input voltage  $V_n \cong 50\text{mV}$  (the amplitude of  $V_n$  must be kept below the limits set by  $V_{am} = 2\pi/B_m S_e N_2$ , as shown in Fig. 7. Since  $E_{pn} = E_n$ , this method maximises, in a wide frequency range (up to 1MHz), the distortion rejection factor  $\rho = 1/(\lambda - \gamma G_p)$  of the auxiliary amplifier.

Frequency of  $V_n$  is first set at 3kHz and trimmer  $T_2$  is adjusted so that the output voltage  $V_0(V_n)$  is at a minimum. Then, the frequency is increased to 300kHz and  $C_3$  is adjusted again to have maximum rejection. A network analyser would simplify amplifier calibration, allowing optimization of  $\pi$  in the 1kHz to 1MHz frequency range.

Step 8: Repeat step 5

**Measurement results**

Figure 11 shows the magnitude of the distortion rejection factor as a function of frequency,

achieved for the experimental prototypes which have been calibrated.

We see that  $\pi$  values extending from magnitudes of 30-60dB have been achieved in the wide frequency range 200Hz to 1MHz. Even better results can be expected with more care taken in layout and power distribution design. These values translate into an equivalent degree of reduction of the total harmonic distortion, thd, of the power amplifier, as demonstrated by test results (Figs. 12 and 13).

Two significant levels of the total bias current  $I_{bias}$  of the power amplifier mosfet output stage are taken into account. The first one,  $I_{bias} = 1\text{mA}$ , representing a very poor biasing level, helps prove the ability of the proposed technique to counter-balance the effects of the comparatively high output impedance of the power amplifier in the crossover region.

In addition, it shows the ability of feed-forward to reject high-order harmonics normally generated by poorly-biased output stages.

The second level,  $I_{bias} = 100\text{mA}$ , is closer to the normal level of biasing of power mosfet output stages and demonstrates the effectiveness of the proposed technique to correct small amounts of distortion.

Results (Figs. 12 and 13) show that the measured improvement ratio of about 30dB is in good agreement with the value of distortion rejection reported in Fig. 11, and gives clear evidence of the effectiveness of the proposed feed-forward technique.

Only the worst case ( $f = 20\text{kHz}$ ) thd+noise versus output level (volt peak-to-peak/8 $\Omega$  load) is reported. All other measurements taken at  $f < 10\text{kHz}$  are, after applying the error correction technique, very close to the instrumentation limits.

Effectiveness of the distortion rejection mechanism with audio programs, has also been simulated by superposing a white-noise voltage at the output of the power amplifier.

A white-noise level of  $V_n = 0.5\text{Vrms}$  was injected at input node N while the amplifier was delivering 20Vpk-pk to the load with  $f$  at 1kHz. Unfiltered noise appearing across the load was 32dB lower than that measured at the output of PA – a high level of rejection in agreement with theoretical expectations.

The final test report refers to the output noise levels of the amplifier, before and after correction. They are 0.79mV and 0.38mV, respectively. ■

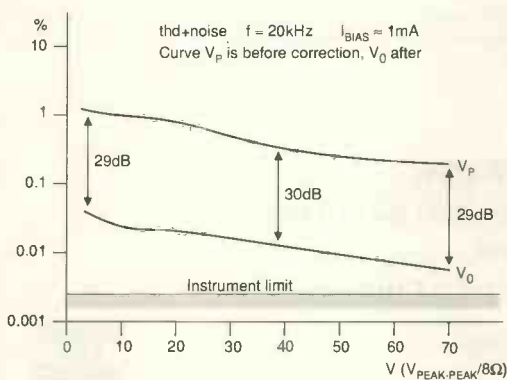
**Components**

These component values were used in the prototype. All resistors have 1% tolerance.

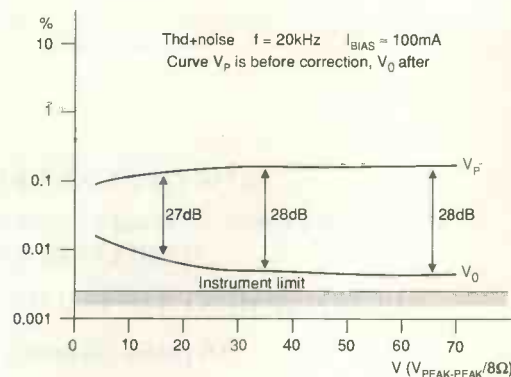
$R_1$	= 12.5k $\Omega$
$G_0 R_1$	= 226k $\Omega$
$G_0$	= 18.08
$R_2$	= 89.6 $\Omega$ (nom)
$G_0'' R_2$	= 1.62k $\Omega$
$R_4$	= 10k $\Omega$
$R_5$	= 5 $\Omega$
$R_6$	= 110 $\Omega$
$R_7$	= 332 $\Omega$
$R_8$	= 5.11 $\Omega$
$R_9$	= 1k $\Omega$
$R_{10}$	= 0.7k $\Omega$ (nom)
$R_{11}$	= 1.3k $\Omega$ (nom)
$R_{12}$	= 4.7k $\Omega$
$R_{13}$	= 909 $\Omega$
$R_{14}$	= 17.8k $\Omega$
$C_2$	= 1 $\mu\text{F}$
$C_3$	= 13.5pF (nom)
$C_4$	= 188pF (nom)
$C_6$	= 13.5nF
$T_1$	= 220 $\Omega$
$T_2$	= 1k $\Omega$
$T_3$	= 2k $\Omega$
$L_5$	= 1 $\mu\text{H}$
$R_5$	= 8 $\Omega$
$R_z$	= 10 $\Omega$
$C_z$	= 47nF

**References**

1. H S Black, *Translating System*, US Patent 1686792 (1928 Oct. 9).
2. H Seidel, H R Beurrier, and A N Friedman, *Error-Controlled High Power Linear Amplifier at VHF*, *Bell Sys Tech J*, Vol. 47, pp. 651-722 (1968 May-June).
3. J Vanderkooij, S P Lipshitz, *Feed-forward Error Correction in Power Amplifiers*, *J Audio Eng Soc*, Vol. 28, N 1/2, (1980 January/February).
4. D Self, *Distortion in Power Amplifier, 5: output stage*, *EW+WW*, Vol 99, No 1693, pp.1009-1014, (1993 December).
5. P J Walker, *Current Dumping Audio Amplifier*, *Wireless World*, Vol. 81, pp.560-562, (1975 December).
6. S Takahashi, S Tanaka, *Design and construction of a Feed-forward Error-Correction Amplifier*, *J Audio Eng Soc*, Vol. 29, No. 1/2, pp.31-37, (1981 January/February).
7. G Stochino, Italian Patent Application No RM93. A000611, (1993 September 10).



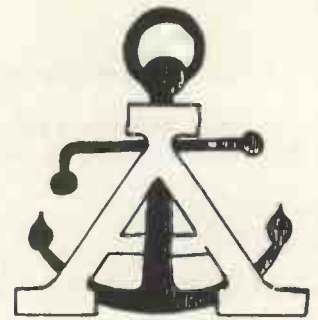
**Fig. 12. Total harmonic distortion + noise versus output level. Test conditions:  $I_{bias} = 1\text{mA}$ ,  $f = 20\text{kHz}$ .**



**Fig. 13. Total harmonic distortion + noise versus output level. Test conditions:  $I_{bias} = 100\text{mA}$ ,  $f = 20\text{kHz}$ .**



**ANCHOR SURPLUS LTD**  
**THE CATTLE MARKET**  
**NOTTINGHAM**  
**NG2 3GY**  
**TEL: (0602) 864902 & 864041**  
**FAX: (0602) 864667**



**HP 141T SPECTRUM  
 ANALYSER SYSTEMS**

- 141T+8552B+8553 (1Khz-110Mhz) .....£525
- 141T+8552B+8554 (100Khz-1250Mhz) £750
- 141T+8552B+8555A (10Mhz-18Ghz) ....£995
- PLUG IN's Available as Separates
- 8552B IF.....£250                      8553 RF.....£175
- 8554 RF.....£395                      8555A RF.....£595
- 141T Storage Mainframes .....£250

**ACCESSORIES**

- 8443A Tracking Generator Counter (110Mhz).....£300
- 8445B Tracking Pre-Selector .....£450
- 8445B Tracking Pre Selector with Digital Readout (opt 002-003).....£750

**ONE MONTH ONLY SPECIAL OFFERS**

GOULD 0S250A-S2 OSCILLOSCOPES  
 Dual Trace Cal to 10MHz. Use to 30MHz typ  
 Tested & Calibration Verified ONLY £99.00

**FARNELL DSG2M  
 SYNTHESISED SIGNAL  
 GENERATORS**  
 Precision generators from  
 0.001Hz to 110Khz  
 500ohm & 300ohm Outputs  
 Fitted IEEE (GPIB)  
 Range Sweep  
 Incl Manual  
**ONLY £125.00**

HEWLETT PACKARD 1600A  
 LOGIC STATE ANALYSERS  
 incl PODS...16bit...50MHz  
**ONLY £99.00**

HEWLETT PACKARD 1607A  
 LOGIC STATE ANALYSERS  
 incl PODS...16bit...50MHz  
**ONLY £79.00**

**Both 1600A & 1607A (32bits)  
 ONLY £149.00**

RACAL DANA 9904  
 UNIVERSAL COUNTER TIMERS  
 7 Digit LED Display  
 Measures Frequency...Period...  
 Interval etc etc  
 Calibration to 50MHZ  
 Typically OK to 85MHZ  
**FEW ONLY at £55.00**

MARCONI TF2603  
 RF MILLIVOLTMETERS  
 1mV to 300V fsd  
 to 1500Mhz  
 incl probe  
**ONLY £75.00**

AVO HF135  
 RF SIGNAL GENERATORS  
 100Khz to 240MHz  
 Int/Ext Mod  
**ONLY £75.00**

**NOW OPEN SEVEN DAYS A WEEK**

**Monday to Friday: 9.00 am to 6.00 pm    Saturday: 8.00 am to 4.00 pm**  
**SUNDAY: 10.00 am to 4.00 pm**

**ALL EQUIPMENT TESTED WITH VERIFIED CALIBRATION**

**All prices excluding VAT & carriage.**





# NEW WAVE MICROWAVES

## 7: mixers and signal conversion

**Microwave signals must be detected and demodulated to reveal their information. Mike Hosking describes components and circuits for this application.**

So far in this series, solid state devices encountered have been those associated with microwave signal generation and amplification. The complement to this is the extraction of information contained in the signal if any. Information may take the form of carrier frequency and power level together with any amplitude, frequency, phase, pulse or code modulation.

Other things may be important... attenuation, amplitude and pulse modulation and limiting. Phase shifting is also required, together with signal routing, as in multi-throw switches. For instance, phased array radars require electronic control of phase and amplitude to each element for beam shaping and steering; microwave receiver applications generally require input limiting for receiver protection; communication systems often use frequency or channel switching for frequency or time division multiplexing.

### Signal detection

Diodes are the mainstay of microwave signal detection. Two forms of circuit are commonly employed: the simple diode detector, Fig. 1a), or down-converter of Fig. 1b).

At the higher frequencies, the technology of the diode is different with much attention paid to reducing parasitic reactances associated with packaging and bond wires. Diode types include point contact, a chemically sharpened metallic whisker is brought into physical contact with the semiconductor; the backward diode, a pn junction which operates by tunnelling action. A bipolar transistor or fet junction itself may be used as the non-linear detection element. However, the most common form of microwave diode is the Schottky barrier device.

As operating frequencies increase into the microwave region, charge storage makes the pn junction less effective which limits switching speed. The Schottky diode is a metal-semiconductor junction (Fig. 2) made with either Si or GaAs. The junction area is defined by etching a small hole in the oxide passivation layer and depositing a metallic contact (in a choice of metals or alloys) on top of the hole. Bonded contact to the external circuitry is then made to the deposited metal.

With no external voltage applied to the junction, electrons in the n-type layer diffuse into the metal contact, leaving behind a space-charge, or depletion region containing positive charge. This fixed charge tends to inhibit the further flow of electrons until a threshold voltage is reached. This point, the built-in potential difference, is called the barrier height of the Schottky junction. Depending upon choice of metal and semiconductor, this barrier lies typically between 0.3V and 1V. Externally applied voltage beyond this causes the junction to behave as other rectifying junctions.

The key Schottky feature is the fact that the depletion region is highly insulating with virtually no minority carrier current (1pA or less). Thus, the junction stores negligible charge and can switch extremely rapidly between forward and reverse bias making it suitable for high frequency operation.

Simple diode detection finds use in instrumentation: for example, as part of the AGC in signal generators and as a sensor in the measurement of 's' parameters using a scalar network analyzer (Fig. 3).

Certain types of radar detection and surveillance receivers also use wideband diode detection for the reception and de-interleaving of complex pulse trains. In addition, as the detec-

\*Mike Hosking is a lecturer in telecommunications and microwaves at the University of Portsmouth.

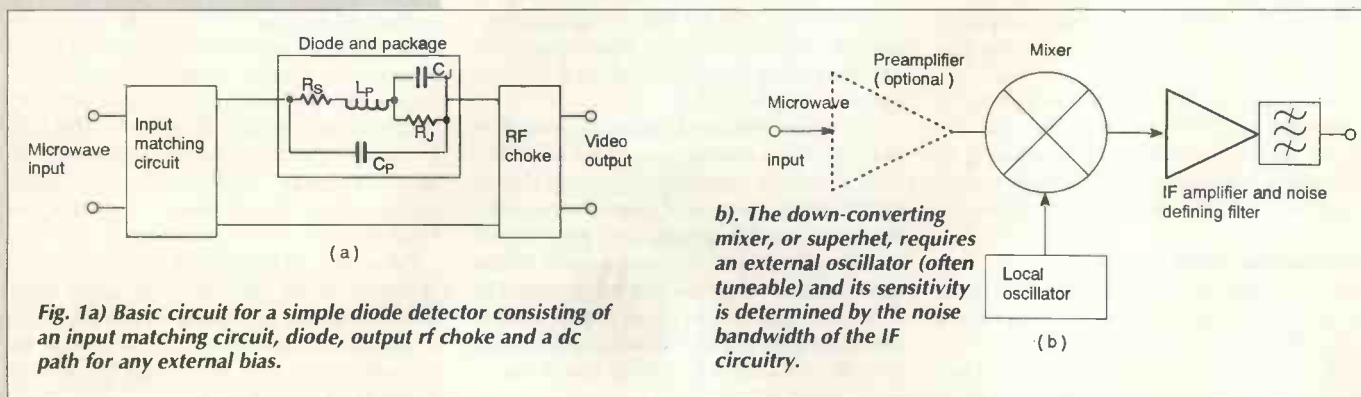


Fig. 1a) Basic circuit for a simple diode detector consisting of an input matching circuit, diode, output rf choke and a dc path for any external bias.

b). The down-converting mixer, or superhet, requires an external oscillator (often tuneable) and its sensitivity is determined by the noise bandwidth of the IF circuitry.

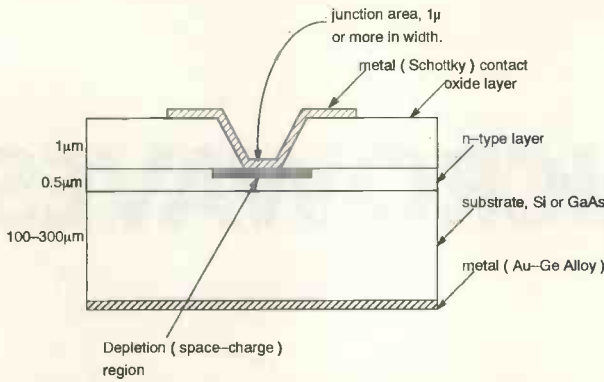


Fig. 2. The Schottky barrier diode is one of the main devices for microwave detectors and mixers, as its virtual absence of minority carriers results in negligible charge storage and fast response.

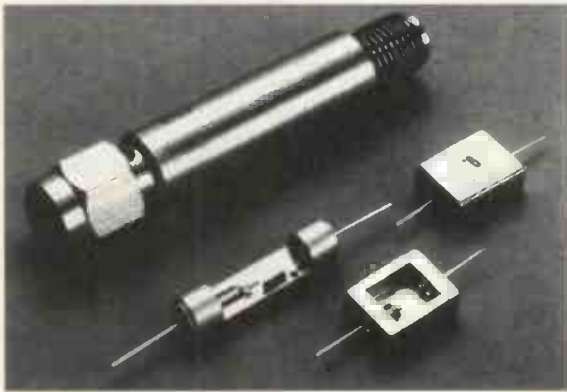


Fig. 4. A collection of diode detector circuit modules available to the microwave designer, already matched and with either standard connectors or with pins for 'drop-in' application. Courtesy of M/A Com Ltd.

tor output voltage is related to the microwave input power, a simple transfer calibration can yield a moderately accurate power meter, suitable for both peak and average power measurement.

Commercially available detectors with integral matching may cover an instantaneous bandwidth of 10MHz to 20GHz. Figure 4 shows a number of matched and packaged detectors suitable for direct circuit connection or as drop-in modules. A well designed diode and input matching circuit usually requires just an output rf bypass, with possibly a small dc bias and a video amplifier.

Detection sensitivity of the simple diode detector is typically several orders of magnitude less than that of a superheterodyne receiver; The limits are the barrier potential but, more so, the 1/f noise and any dc bias current noise.

From a system point of view, the detector is performing a rectifying function and, thus, the output only contains information relating to the amplitude of the microwave input signal. Frequency and phase information is lost.

**Detector specifications**

A point of great interest is the minimum input power level which can be detected to provide a useable output. This results in a parameter, unique to microwave applications, called the

tangential sensitivity (TSS). For circuits and devices operating at microwave frequencies, there exists a conceptual difference from their lower frequency counterparts in the treatment of voltage and current. These quantities have little physical significance at small wavelengths as they cannot be measured directly. Furthermore, being a function of position within the transmission line circuits, they have no unique value. Instead, circuit analysis is performed using electric and magnetic field distributions and the quantities actually measured are power and impedance. Also, as we saw earlier in the series, the situation is complicated further when a particular circuit element, active or passive, becomes a significant fraction of a wavelength in extent. Fig. 5 shows the test arrangement for the measurement of TSS: a microwave signal generator, on/off square wave modulation and variable signal amplitude control.

The output of the diode under test is taken to an oscilloscope display via a video amplifier. With no microwave signal present, the display will be just the amplified thermal noise from the test system but, as the signal amplitude is increased from zero, the square wave modulated output from the detector will appear. The TSS is defined as that input power level at which the peak noise level without the signal coincides with the lowest levels on the square

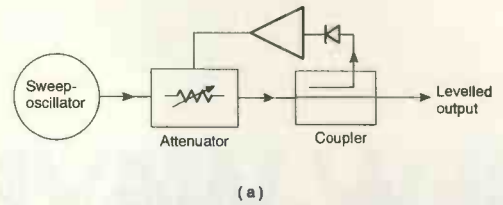
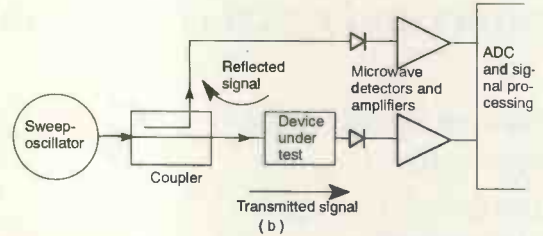


Fig. 3a. One typical application of the diode detector is as part of a levelling loop to sample the amplitude of the main signal so that fluctuations can be reduced.



b). The diode is also found as the wideband sensor in scalar network analysis where the incident, reflected and transmitted signals are used to determine a component's s-parameters.

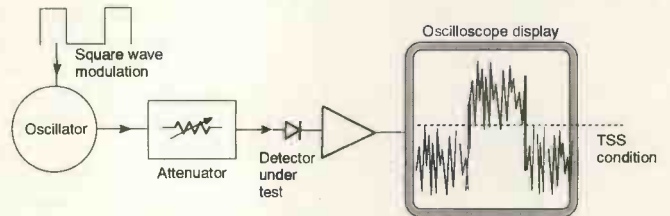


Fig. 5. Equipment used for the measurement of tangential sensitivity, determined by the coincidence of noise peaks on a pulse modulated signal.

wave pulse when the signal is present as indicated in Fig. 5.

Although this is a subjective measurement and operator dependant, it has been found to be repeatable to within about 1dB and is still the method most widely used by diode manufacturers for specifying the low-level sensitivity. The units of TSS are invariably quoted in dB, as a power level with respect to a 1mW reference; i.e. dBm. Values of -50 to -55dBm are typical for good detectors (<10<sup>-8</sup>W). For purposes of calculation consistency, the TSS is usually taken as an input rms signal to noise ratio of 2.5 (4dB) and this should also be referenced to the noise bandwidth and noise figure of the video amplifier.

A further parameter of interest is the actual voltage output from the detector, compared with the microwave power input. This is termed the voltage sensitivity and, while intrinsically having the units of volts per watt, is colloquially quoted in mV/µW. Typical, low power open circuit voltage sensitivities for silicon Schottky barrier and point contact diodes range from about 1mV/µW to 15mV/µW.

The actual achievable sensitivity is dependent on a further parameter: the output resistance of the diode (usually called the video resistance R<sub>v</sub>) and its associated loading by any external circuit resistance R<sub>L</sub>. For Si



## SYSTEM 200 DEVICE PROGRAMMER



**SYSTEM:** Programs 24,28,32 pin EPROMS, EEPROMS, FLASH and Emulators as standard, quickly, reliably and at low cost.

Expandable to cover virtually any programmable part including serial EEPROMs, PALs, GALs, EPLDs and microcontrollers, in many different packages.

**DESIGN:** Not a plug in card but connecting to the PC serial or parallel port; it comes complete with powerful yet easy to control software, cable and manual.

**SUPPORT:** UK design, manufacture and support. Same day dispatch, 12 month warranty. 10 day money back guarantee.



MQP ELECTRONICS Ltd.

Park Road Centre

Malmesbury, Wiltshire. SN16 0BX. UK  
TEL. 0666 825146 FAX. 0666 825141



### ASK FOR FREE INFORMATION PACK

IRELAND 1-2800395  
GERMANY 089/4602071  
NORWAY 0702-17890  
ITALY 02 92 10 35 54  
FRANCE 1 69 30 13 79  
SWEDEN 08 590 32185  
Also from ELECTROSPEED UK

CIRCLE NO. 124 ON REPLY CARD

# RADIO SOLUTIONS

low-power short-range  
licence-free radio for

TELEMETRY

SECURITY SYSTEMS

RF TAGGING

CLANs

RF DATA

COMMUNICATIONS



October 25th - 26th 1994  
National Motorcycle Museum  
Birmingham

## CONFERENCE & EXHIBITION

for anyone  
involved professionally  
in low power radio  
manufacturers, designers and users.

### TOPICS INCLUDE :

The licence-free bands  
Management of EMC  
Forthcoming legislation  
European harmonization  
Radio data terminals  
Antennas  
Road toll tags  
Radio Fieldbus in the process industry  
Communicating through rock  
Price/performance issues  
LPR in urban environments  
Environmental monitoring in museums  
& animal houses

### PLEASE SEND ME FULL DETAILS, CONFERENCE PROGRAMME AND FREE TICKETS TO THE EXHIBITION

Name \_\_\_\_\_ Position \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

Tel \_\_\_\_\_ Fax \_\_\_\_\_

SEND TO : LOW POWER RADIO ASSOCIATION  
The Old Vicarage, Haley Hill, Halifax, HX3 6DR.

OR CONTACT HOLLY McGILL NOW ON TEL : 0422 380397  
FAX : 0422 355604

CIRCLE NO. 125 ON REPLY CARD

## STEREO STABILIZER 5



- Rack mounting frequency shifter for howl reduction in public address and sound reinforcement.
- Mono version, box types and 5Hz fixed shift boards also available.

- ★ Broadcast Monitor Receiver 150kHz-30MHz.
- ★ Advanced Active Aerial 4kHz-30MHz.
- ★ Stereo Variable Emphasis Limiter 3.
- ★ 10-Outlet Audio Distribution Amplifier 4.
- ★ PPM10 In-vision PPM and chart recorder, also as expansion board for Acorn Computers.
- ★ Twin Twin PPM Rack and Box Units.
- ★ PPM5 hybrid, PPM9 microprocessor and PPM8 IEC/DIN -50/+6dB drives and movements.
- ★ Broadcast Stereo Coders.
- ★ Stereo Disc Amplifiers.
- ★ Peak Deviation Meter for FM broadcasting

### SURREY ELECTRONICS LTD

The Forge, Lucks Green, Cranleigh, GU6 7BG  
Telephone: 0483 275997. Fax: 276477.

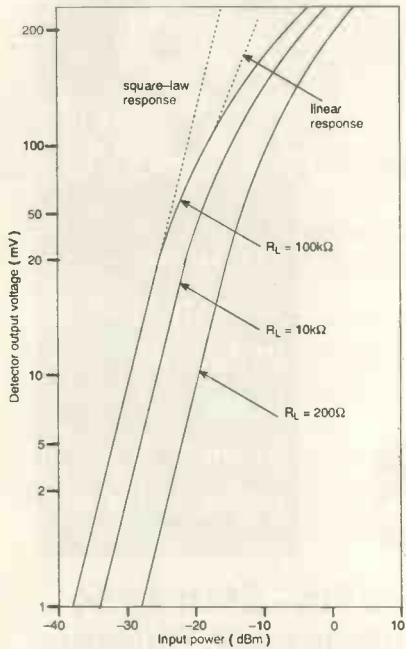


Fig. 6. The diode V/I characteristic passes from a square-law region to linear and into saturation with a forward voltage drop before conduction takes place. In the square-law region, the OUTPUT voltage is directly proportional to the INPUT power.

detector diodes,  $R_v$  is typically  $1k\Omega$  to several  $k\Omega$ , although higher values are possible at low microwave frequencies. Thus, the voltage sensitivity will be degraded by the factor and so, for maximum output,  $R_L$  must be high.

When detecting pulsed input signals, the fidelity of the pulse output depends upon the time constant set by the output resistance and capacitance. There is, thus, a trade-off which can be made: sacrificing voltage sensitivity with a small value of load resistance (say  $50\Omega$ ) in order to speed up the rise time.

Input power level also affects the diode parameters and Fig. 6 illustrates this for several values of load resistance. The main features of the curves are the three regions of different slope. Firstly, at low power levels typically less than a microwatt, the curve follows a square law, so that the output voltage becomes directly proportional to the output power. As the input power level rises, the detection law changes to linear and then starts to saturate. The video resistance and sensitivity properties also change so, for the circuit designer, different matching techniques must be used, depending upon whether the detector is to be optimised for high output, wideband, or flat response.

Mixing

Radar and communications systems require the ability to receive signals much lower in

amplitude than those which can be detected with a simple diode. A level of one picowatt ( $10^{-12}W$ ) is not uncommon. For these systems, the process employed uses a separate local oscillator for carrier injection into the mixer circuit. Within the context of this article, the key component is the Schottky barrier diode again, although optimised for the frequency conversion rather than simple detection.

The mixing process combines the microwave input signal with the local oscillator (lo), at the terminals of one or more diodes. The lo signal is normally orders of magnitude larger (about 1mw per diode) than the microwave input and serves to switch the diode(s) between conducting and non-conducting states during each cycle.

This action is analogous to a sampling process and results in the non-linear V-I characteristic of the diode generating a theoretically infinite series of harmonics and sidebands of the lo and input signals. In the down-converting mixer, only one of these outputs is required: the difference frequency between the microwave input and the lo (intermediate frequency, IF). Other components generated in the mixing process, shown graphically in Fig. 7, are a dc level caused by rectification of the lo signal, together with the sum frequency (or upper sideband) of the two inputs. All of these are rejected by filtering.

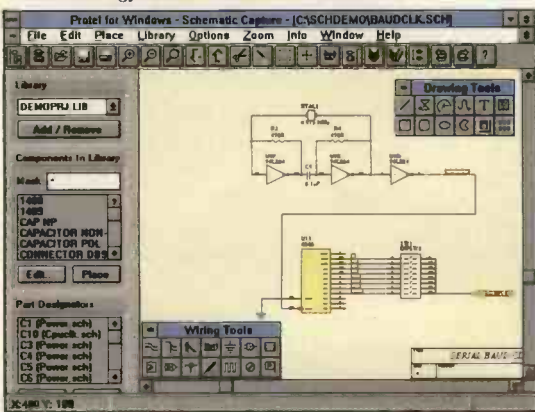
Intermediate frequencies of several hundred

Protel Technology

# Leading the way in Windows EDA

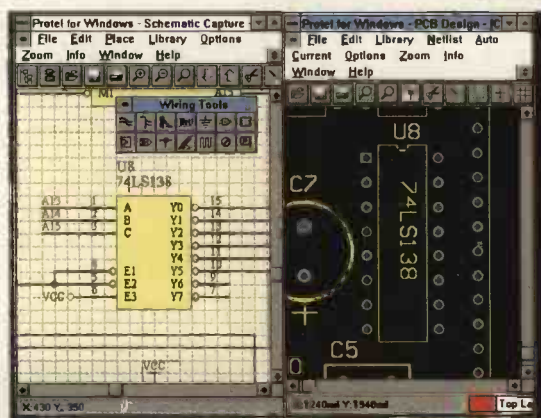
Why wait for Windows EDA

Protel for Windows - First in Windows EDA



Advanced Schematic 2.0

- ◆ Heads up guided wiring.
- ◆ Pop up library editor/manager.
- ◆ 15,000+ component library with graphical browsing.
- ◆ Easy navigation through complex hierarchical designs with our Project Manager.
- ◆ Font management system.
- ◆ Forward and backward annotation between schematic and PCB (ECO).
- ◆ Bidirectional cross-probing between schematic and PCB.
- ◆ SPICE simulation support.
- ◆ EEsof simulation support.
- ◆ EDIF netlist output.
- ◆ Full support for loading 32-bit OrCAD SDT 386+ file format.



Advanced PCB 2.0

- ◆ 32-bit, 0.000001" resolution.
- ◆ Unlimited database size.
- ◆ Fully editable copper pour.
- ◆ On-line design rule checking.
- ◆ Forward and backward annotation between schematic and PCB (ECO).
- ◆ Bidirectional cross-probing between schematic and PCB.
- ◆ Direct loading of Gerber, PADS, PCAD & Tango file formats.
- ◆ Optional integration to Cooper & Chyan's SPECCTRA autorouter.

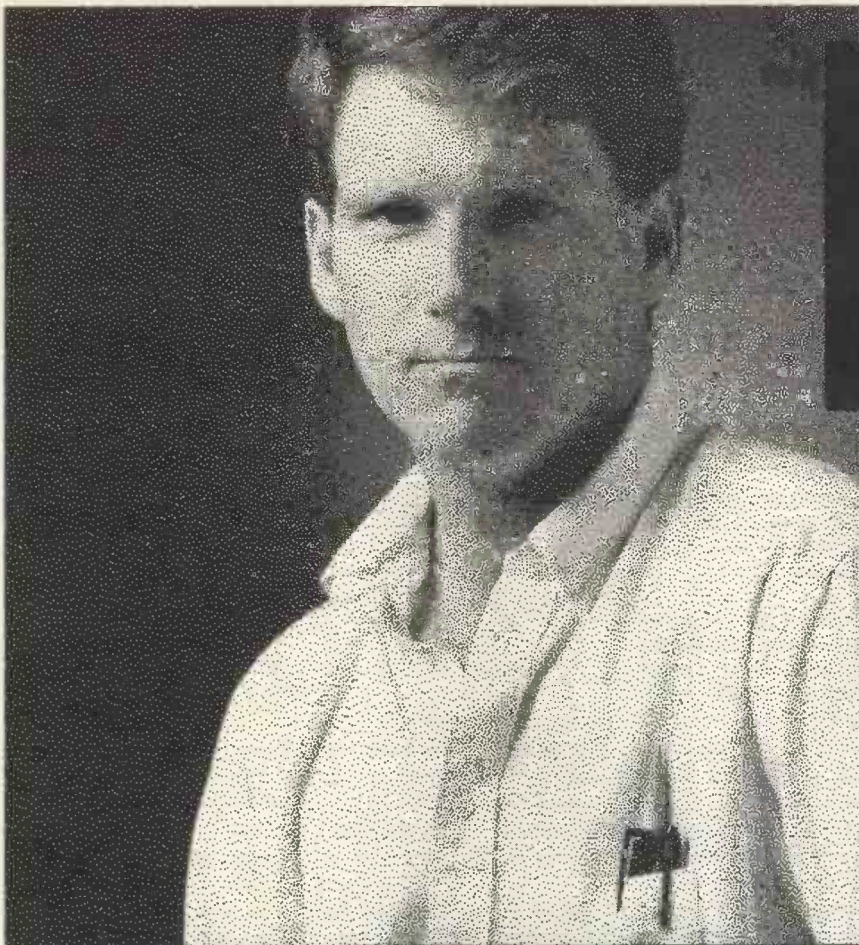
To find out more about Protel for Windows please contact us at...

Premier EDA Solutions Ltd,  
133 Cardiff Road,  
Reading,  
Berks.  
RG1 8ES.

**Premier**  
EDA Solutions  
Tel: 0734 589 898.  
Fax: 0734 599 519.



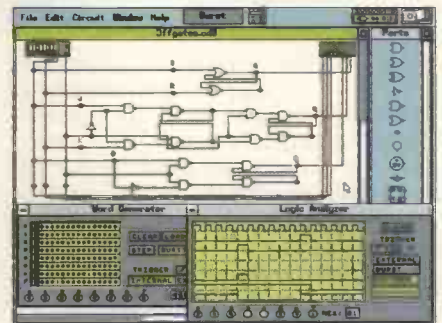




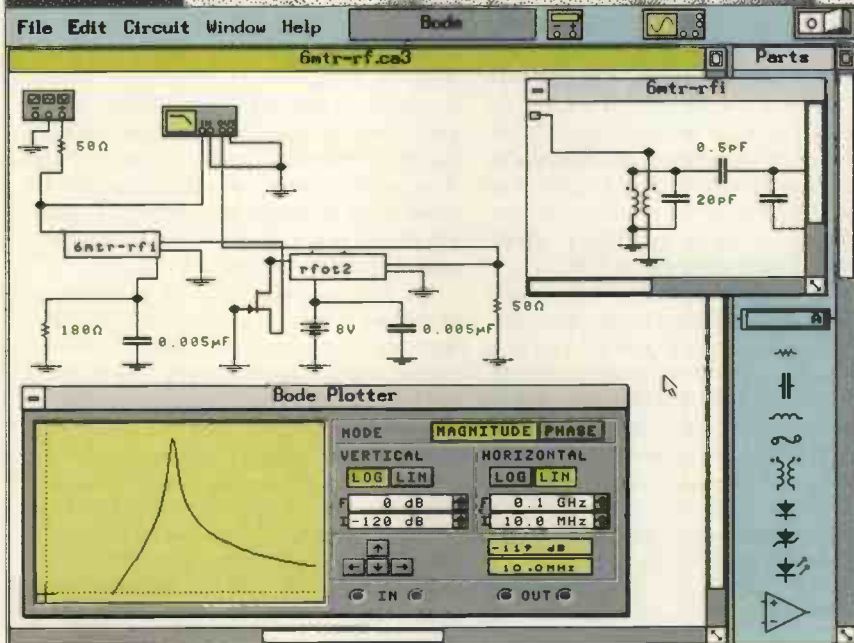
“Electronics Workbench is the best simulator to design and verify circuits.”

Gordon MacDonald  
Production Engineer Technician

Electronics Workbench is a highly productive bench where you design and verify circuits in a fraction of the time. Connections are always perfect. Wires route themselves. And the simulated components and test instruments work just like the real thing.



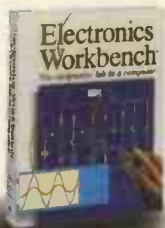
Digital Module: Analyzing a logic circuit.



Analog Module: Tuning an RF front end.

It's faster than building with actual components because you change connections and component values instantly. And since the simulated components are free, you don't need to replace burnt-out parts or keep an extensive inventory. The result: You save precious time and money. Guaranteed!

The standard for simplicity and power for over six years, Electronics Workbench is the most popular tool of its kind. It has gained worldwide acclaim as the ideal complement to any test bench. Fact: Over 90% of our customers recommend it to their friends and colleagues.



**FREE**  
Model Set  
Library

# Electronics Workbench®

The electronics lab in a computer™

## Call: 44 0203 233216

Robinson Marshall (Europe) PLC  
Nadella Building, Progress Close, Leofric Business Park, Coventry, Warwickshire CV3 2TF  
FAX: (44) 0203 233210

\*30-day money-back guarantee.

Shipping charges - UK £4.99. All prices are plus VAT.  
All trademarks are the property of their respective owners.

\*\*With the purchase of Electronics Workbench. Offer valid until October 15, 1994.

CIRCLE NO. 127 ON REPLY CARD

**Just £199\***  
For DOS, Windows or Mac Version.





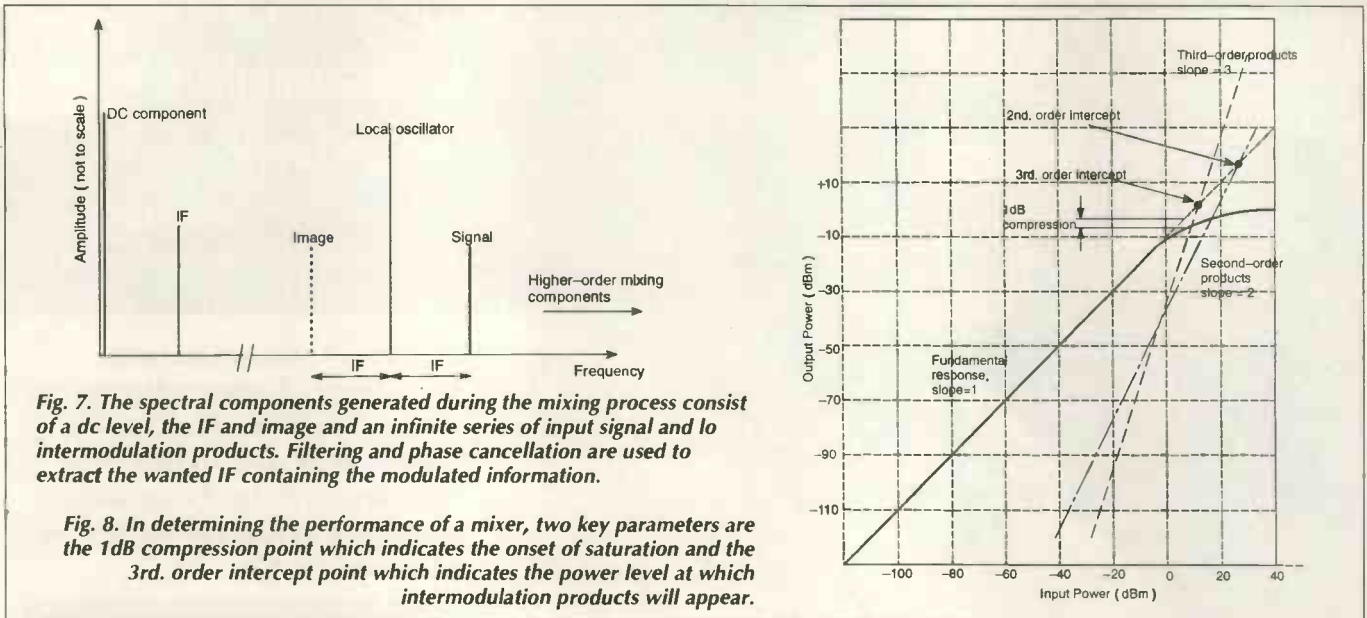


Fig. 7. The spectral components generated during the mixing process consist of a dc level, the IF and image and an infinite series of input signal and lo intermodulation products. Filtering and phase cancellation are used to extract the wanted IF containing the modulated information.

Fig. 8. In determining the performance of a mixer, two key parameters are the 1dB compression point which indicates the onset of saturation and the 3rd. order intercept point which indicates the power level at which intermodulation products will appear.

MHz or less are common in microwave receivers, leading to easier signal processing than would be the case with an input signal at 10's of GHz. Furthermore, all of the information content on the original signal is preserved in the down-conversion process and, knowing the lo frequency, the input carrier frequency can also be deduced.

The switching action overcomes sensitivity problems of the simple detector; The limit for the mixer is set by the efficiency of the conversion process and the thermal noise bandwidth. Other sources of noise, such as lo phase noise, together with the requirement for a finite signal-to-noise ratio, impose further limitations but the overall improvement is, typically, several orders of magnitude over the diode detector.

In very low noise receivers, the lo phase noise is important and so the oscillator can become quite costly. Another point is that whilst the mixer may be broadband in the sense of operating over a wide frequency range, it does not have a wide "instantaneous" bandwidth. This characteristic is fixed by the IF filter response and need only be wide enough to pass the information content of the carrier. Typically, this might be 1-1000MHz and so, if the input frequency is separated from that of the lo by more than this bandwidth, it will not be detected by the mixer. This means that in applications such as surveillance receivers and instrumentation spectrum analyzers, the lo must also be tuneable and often results in a bank of oscillators to cover the full input range. In effect, the mixer receiver sweeps a narrow "window" equal to the noise bandwidth across a much wider RF input band.

**Mixer characteristics**

*Image frequency.* The IF produced by an input signal occurs on both sides of the lo. For example, if the lo was at 30GHz and the required IF was 100MHz, then this could be produced by an input signal at either 29.9GHz

or 31.1GHz. If the wanted signal frequency was, say, at 31.1GHz then the adjacent or interfering signal at 29.9GHz (called the image) would also produce a simultaneous IF, which could be accepted by the receiver and degrade its performance.

*Conversion loss.* Conversion loss of the mixer is a measure of the efficiency of the mixing process and is normally quoted in dB. Conversion loss depends on the quality of the impedance match at the RF and IF ports; loss of input power due to the series resistance,  $R_j$  and capacitance,  $C_j$  of the diode junction. In turn, this loss is also a function of both the lo power level and the ratio of lo frequency to the cut-off frequency of the junction. This cut-off frequency is given by  $1/R_j C_j$ , which should be as high a value as possible.

*Noise figure.* Perhaps the most important mixer parameter and related to the conversion loss, is that of the Noise Figure,  $F$ . This is a measure of the degradation in signal-to-noise ratio caused by the mixer as the signal undergoes the conversion process and becomes the IF. Noise figure can be related to the conversion loss by the inclusion of a noise temperature,  $t_m$ , which takes into account various internal noise mechanisms and the contribution from the IF amplifier,  $F_{IF}$ . So,

$$F = Loss(t_m + F_{IF} - 1)$$

It has become common (though not universal) practice for manufacturers to quote noise figure assuming a nominal 1.5dB for  $F_{IF}$ . Also,  $t_m$  is close to unity for many diodes. Thus, the quoted figure must be adjusted for amplifiers of different noise figures. Like many microwave components, the designer has the choice of buying from a wide range of mixers, already packaged and matched, to a quoted noise figure and, in this case, must be careful as to the exact definition implied. Noise performance is usually measured with a wideband noise source and so injects noise power at both signal and image frequencies.

This results in a 'double sideband' (dsb) noise figure, whereas it is the 'single sideband' (SSB) figure which is needed. As the DSB output will be twice that of the SSB, the noise figure will appear to be 3dB better... check which is the one quoted.

*Dynamic Range and Intermodulation.* Most receivers have to operate over a wide range of signal strengths. The lower limit is determined by the inherent noise level, but it is also useful to define an upper limit. In addition, there is no guarantee that a receiver will have only a single wanted frequency at its input; there is a potential problem of spurious responses. Fig. 8 shows the form of a dynamic range plot for a non-linear device relating the input and output power, in this case for a mixer, but applicable in principle to amplifiers as well.

The difference between the absolute values of the two axes is the conversion loss, shown here for convenience as 10dB. The fundamental response curve is that of the IF and it can be seen that this is a linear relationship up to a certain input power, when the mixer starts to saturate. Eventually, at a particular input power level, a 1dB deviation from linear will occur and this is termed the 1dB compression point of the mixer. Linear dynamic range is then defined from the noise level to this point.

If we have the situation of two closely spaced input signals at frequencies  $f_1$  and  $f_2$  (usually called 'tones' in this context) incident simultaneously at the mixer, then the non-linear device characteristic will result in the generation of harmonics, called intermodulation products. These take the form  $mf_1 \pm nf_2$ , where  $m(\neq -1)$  and  $n(\neq 1)$  are integers. The order of a harmonic is defined as  $m+n$  and the slope of the graph of output power in a particular harmonic against input power is equal to its order. This is shown in Fig. 8 for second and third order intermodulation products, the last of which causes the most concern to mixer users. Its frequency lies close to the wanted IF.

Thus, the better the mixer, the higher the input power level at which this product



becomes significant. Manufacturers quote the point at which the third order curve intersects the fundamental as the 'third-order intercept point'. It is, in fact, the point at which the power in the intermodulation product equals the IF power and defines a spurious-free dynamic range for the mixer.

### Mixer circuits

Considerable variation exists in the choice of diode mixer design, as specialised circuits can be chosen for particular applications. The number of diodes themselves in a particular mixer can vary from one to eight. Good mixer performance also depends on correctly matched lo and output circuitry. Fig. 9a shows a circuit using just one diode, a single-ended mixer. The coupler could be one of the types described earlier in the series, depending on the bandwidth required and the degree of isolation between ports. This last consideration makes wideband operation difficult and there is little scope, other than filtering, to reduce unwanted noise or mixing products. However, the circuit is simple and requires modest local oscillator power, 0dBm or less. A more commonly encountered design is the balanced mixer of Fig. 9b. This circuit was illustrated in microstrip form in Part 3. The coupler can be any of the 90° or 180° hybrid types such as branch line or Lange, depending upon the bandwidth. The two diodes of this configuration are connected in reverse polarity: a complete bipolar IF waveform is obtained by summing the diode outputs. This gives a good impedance match at the input ports, together with improved reduction of spurious mixing products. If a 180° hybrid is used then all even harmonics of one of the inputs (the lo, say) can be suppressed.

Another feature is that any am noise on the lo signal appears in antiphase at the two diode outputs and thus tends to cancel at the IF combiner. Harmonic suppression can be extended further using the double balanced circuit of Fig. 9c to reject all even harmonics of both input signals. Twice the lo power is required, injected via a balun shared with the IF, as there are now four diodes, but the dynamic range is also increased. By extending the basic mixer design still further, it is possible to achieve image rejection without having to attempt what would often be a prohibitively difficult or expensive filtering problem.

Although image and signal inputs produce identical output frequencies, the relative phase of these outputs is different and this can be used as a discriminating factor. Shown in Fig. 9c this type of mixer uses two separate balanced mixers with the signal input routed to each via a 3dB, 90° hybrid coupler; the lo is fed to each at the same phase via a power splitter. A similar, but lower frequency hybrid coupler produces two IF outputs, one of them the upper sideband and the other the lower sideband. It is then only necessary to terminate the output caused by the image.

Such mixers are complex to build over a wide band, but may deliver an image rejection of 20dB or more. However, even if these mix-

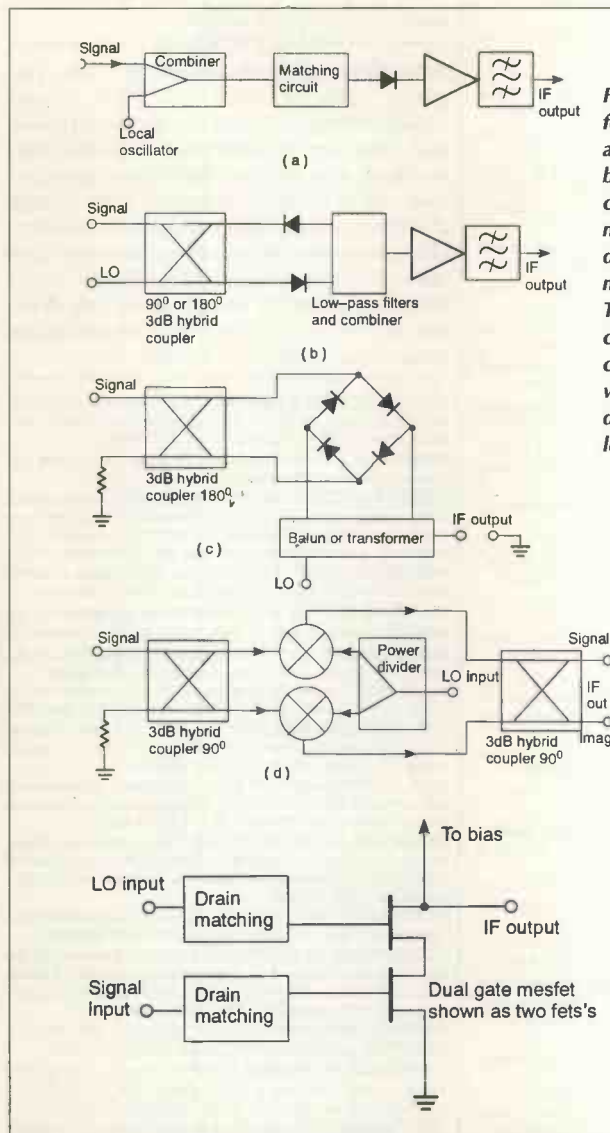


Fig. 9. Schematic circuits for: a) the single-ended mixer; b) the balanced mixer; c) the double balanced mixer; d) the image rejection mixer. The complexity of the circuits varies considerably, together with the number of diodes required and the lo power.

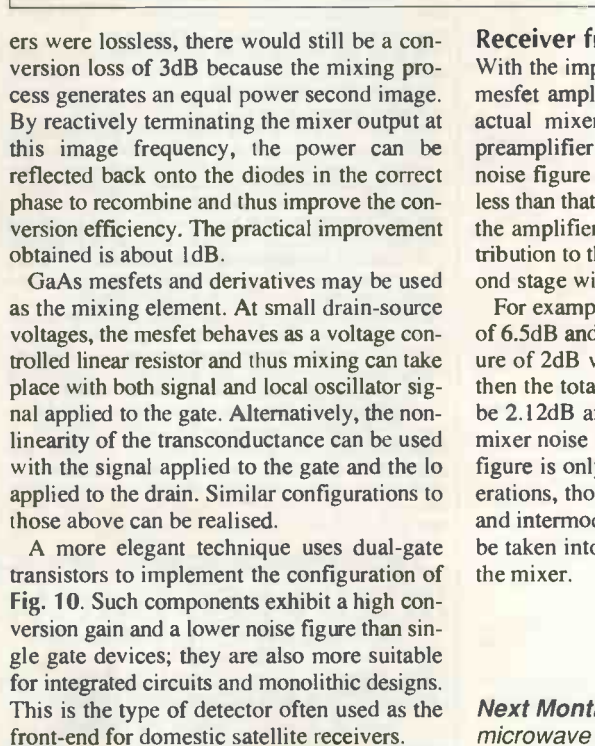


Fig. 10. A dual gate mixer which uses mesfet nonlinearities and features a conversion gain instead of loss. Such devices work into the millimetre wave region.

ers were lossless, there would still be a conversion loss of 3dB because the mixing process generates an equal power second image. By reactively terminating the mixer output at this image frequency, the power can be reflected back onto the diodes in the correct phase to recombine and thus improve the conversion efficiency. The practical improvement obtained is about 1dB.

GaAs mesfets and derivatives may be used as the mixing element. At small drain-source voltages, the mesfet behaves as a voltage controlled linear resistor and thus mixing can take place with both signal and local oscillator signal applied to the gate. Alternatively, the non-linearity of the transconductance can be used with the signal applied to the gate and the lo applied to the drain. Similar configurations to those above can be realised.

A more elegant technique uses dual-gate transistors to implement the configuration of Fig. 10. Such components exhibit a high conversion gain and a lower noise figure than single gate devices; they are also more suitable for integrated circuits and monolithic designs. This is the type of detector often used as the front-end for domestic satellite receivers.

### Receiver front end

With the improvements to the noise figure of mesfet amplifiers, it is usual to precede the actual mixer or detector with a low-noise preamplifier. This is because the achievable noise figure from the amplifier can be much less than that from the mixer; so, provided that the amplifier has a reasonable gain, the contribution to the overall noise of the mixer second stage will be small.

For example, if the mixer has a noise figure of 6.5dB and the preamplifier has a noise figure of 2dB with an associated gain of 11dB, then the total noise figure at the input would be 2.12dB and the contribution of the 6.5dB mixer noise figure to that of the overall noise figure is only 0.12dB. There are still considerations, though, of amplifier dynamic range and intermodulation distortion which have to be taken into account in the same way as for the mixer. ■

*Next Month. Superconductors in microwave circuits.*



**PC PAL VGA TO TV CONVERTER** Converts a colour TV into a basic VGA screen. Complete with built in psu, lead and s/ware. £49.95. Ideal for laptops or a cheap upgrade.

**EMERGENCY LIGHTING UNIT** Complete unit with 2 double bulb floodlights, built in charger and auto switch. Fully cased. 6v 8AH lead acid req'd. (secondhand) £4 ref MAG4P11.

**GUIDED MISSILE WIRE.** 4,200 metre reel of ultra thin 4 core insulated cable, 28lbs breaking strain, less than 1mm thick! Ideal alarms, intercoms, fishing, dolls house's etc. £14.99 ref MAG15P5

**SINCLAIR C6 13" WHEELS** Complete with centre bearing (cyc type), tyre and inner tube. £6 ea ref MAG 6P10. Ideal go kart

**300v PANEL METER 70X60X50MM, A.C.** 90 degree scale. Good quality meter. £5.99 ref MAG 6P14. Ideal for monitoring mains etc.

**ASTEC SWITCHED MODE PSU BM41012** Gives +5 @ 3.75A, +12 @ 1.5A, -12 @ 4A. 230/110, cased, BM41012. £5.99 ref AUG6P3.

**TORRODIAL TX 30-0-30 480VA.** Perfect for Mosfet amplifiers etc. 120mm dia 55mm thick. £18.99 ref APR19.

**AUTO SUNCHARGER** 155x300mm solar panel with diode and 3 metre lead fitted with a cigar plug. 12v 2watt. £9.99 ea ref AUG10P3.

**FLOPPY DISCS DSDD Top quality 5.25" discs.** These have been written to once and are unused. Pack of 20 is £4 ref AUG4P1.

**MOD WIRE** Perfect for repairing PCB's, wire wrap etc. Thin insulated wire on 500m reels. Our price just £9.99 ref APR10P8.

**12v MOVING LIGHT Controller.** Made by Hella, 6 channels rated at 90watts each. Speed control, cased. £34.99 ref APR35.

**ECLATRON FLASH TUBE** As used in police car flashing lights etc, full spec supplied. 60-100 flashes a min. £9.99 ref APR10P5.

**24v AC 96WATT Cased power supply.** New. £13.99 ref APR14.

**MILITARY SPEC GEIGER COUNTERS** Unused and straight from Her Majesty's forces. £50 ref MAG 50P3.

**STETHOSCOPE** Fully functioning stethoscope, ideal for listening to hearts, pipes, motors etc. £6 ref MAR6P6.

**OUTDOOR SOLAR PATH LIGHT** Captures sunlight during the day and automatically switches on a built in lamp at dusk. Complete with sealed lead acid battery etc. £19.99 ref MAR20P1.

**ALARM VERSION** Of above unit comes with built in alarm and pir to deter intruders. Good value at just £24.99 ref MAR25P4.

**CLOCKMAKER KIT** Hours of fun making your own clock, complete instructions and everything you need. £7.99 ref MAR8P2.

**CARETAKER VOLUMETRIC Alarm.** will cover the whole of the ground floor against forced entry. Includes mains power supply and integral battery backup. Powerful internal sounder, will take external bell if req'd. Retail £150+, ours? £49.99 ref MAR50P1.

**TELEPHONE CABLE** White 6 core 100m reel complete with a pack of 100 clips. Ideal 'phone extns etc. £7.99 ref MAR8P3.

**IBM PC CASE AND PSU** Ideal base for building your own PC. Ex equipment but OK. £9.99 each REF: JUN10P2.

**MICRODRIVE STRIPPER** Small cased tape drives ideal for stripping, lots of useful goodies including a smart case, and lots of components. £2 each ref JUN2P3.

**SOLAR POWER LABSPECIAL** You get TWO 6"x6" 6v 130mA solar cells, 4 LEDs, wire, buzzer, switch plus 1 relay or motor. Superb value kit just £5.99 REF: MAG6P8

**SOLID STATE RELAYS** Will switch 25A mains. Input 3.5-26v DC 57x43x21mm with terminal screws £3.99 REF MAG4P10

**300DPI A4 DTP MONITOR** Brand new but shop soiled so hence bargain price! TTL/ECL inputs, 15" landscape, 1200x1664 pixel complete with circuit diag to help you interface with your projects. JUST £14.99. REF JUN15P2.

**MULTICORE CABLE** 300 metre reel of grey 8 core cable ideal for 'phones, intercomms, computers, alarms etc. Comes in special dispensing container to avoid tangles. £15 ref AUG15.

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

**ULTRAMINI BUGC MIC** 6mmx3.5mm made by AKG, 5-12v electret condenser. Cost £12 ea, Our? four for £9.99 REF MAG10P2.

**RGB/CGA/EGA/TTL COLOUR MONITORS** 12" in good condition. Back anodised metal case. £79 each REF JUN79

**GX4000 GAMES MACHINES** returns so ok for spares or repair £9 each (no games). REF MAG9P1

**C64 COMPUTERS** Returns, so ok for spares etc £9 ref MAG9P2

**FUSELAGE LIGHTS** 3 foot by 4" panel 1/8" thick with 3 panels that glow green when a voltage is applied. Good for night lights, front panels, signs, disco etc. 50-100v per strip. £25 ref MAG25P2

**ANSWER PHONES** Returns with 2 faults, we give you the bits for 1 fault, you have to find the other yourself. BT Response 200's £18 ea REF MAG18P1, PSU £5 ref MAG5P12.

**SWITCHED MODE PSU** ex equip, 60w +5v @ 5A, -5v @ 5A, +12v @ 2A, -12v @ 5A 120/220v cased 245x88x55mm IEC input socket £6.99 REF MAG7P1

**PLUG IN PSU 9V 200mA DC** £2.99 each REF MAG3P9

**PLUG IN ACORN PSU** 19v AC 14w , £2.99 REF MAG3P10

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

**ACORN ARCHIMEDES PSU** +5v @ 4.4A on/off sw uncased, selectable mains input, 145x100x45mm £7 REF MAG7P2

**GEIGER COUNTER KIT** Low cost professional twin tube, complete with PCB and components. Now only £19 REF AUG19.

**9v DC POWER SUPPLY** Standard plug in type 150ma 9v DC with lead and DC power plug. price for two is £2.99 ref AUG3P4.

**AA NICAD PACK** encapsulated pack of 8 AA nicad batteries (tagged) ex equip, 55x32x32mm. £3 a pack. REF MAG3P11

**13.8V 1.9A** psu cased with leads. Just £9.99 REF MAG10P3

**360K 6.25** brand new half height floppy drives IBM compatible industry standard. Just £6.99 REF MAG7P3

**PPC MODEM CARDS.** These are high spec plug in cards made for the Amstrad laptop computers. 2400 baud dial up unit complete with leads. Clearance price is £5 REF: MAG5P1

**INFRA RED REMOTE CONTROLLERS** Originally made for hi spec satellite equipment but perfect for all sorts of remote control projects. Our clearance price is just £2 REF: MAG2

**TOWERS INTERNATIONAL TRANSISTOR GUIDE.** A very useful book for finding equivalent transistors, leadouts, specs etc. £20 REF: MAG20P1

**SINCLAIR C6 MOTORS** We have a few left without gearboxes.

## NEW BULL ELECTRICALS STORE IN WOLVERHAMPTON

55A WORCESTER ST TEL 0902 22039

Spec Is12v DC 3,300rpm £25 ref MAG25.

\*\*\*\*\*NEW PRODUCT\*\*\*\*\*

**200 WATT INVERTER** Converts 10-15v DC into either 110v or 240v AC. Fully cased 115x36x156mm, complete with heavy duty power lead, cigar plug, AC outlet socket. Auto overload shutdown, auto short circuit shut down, auto input over voltage shutdown, auto input under voltage shutdown (with audible alarm), auto temp control, unit shuts down if overheated and sounds audible alarm. Fused reversed polarity protected. output frequency within 2%, voltage within 10%. A extremely well built unit at a very advantageous price!!! Price is £64.99 ref AUG65.

**UNIVERSAL SPEED CONTROLLER KIT** Designed by us for the C5 motor but ok for any 12v motor up to 30A. Complete with PCB etc. A heat sink may be required. £17.00 REF: MAG17

**MAINS CABLE** Precut black 2 core 2 metre lengths ideal for repairs, projects etc. 50 metres for £1.99 ref AUG2P7.

**COMPUTER COMMUNICATIONS PACK** Kit contains 100m of 6 core cable, 100 cable clips, 2 line drivers with RS232 interfaces and all connectors etc. Ideal low cost method of communicating between PC's over a long distance. Complete kit £15.99 Ref MAR16P2.

**MINI CYCLOPS PIR** 52x62x40mm runs on PP3 battery complete with shrill sounder. Cheap protection at only £5.99 ref MAR6P4.

**ELECTRIC MOTOR KIT** Comprehensive educational kit includes all you need to build an electric motor. £9.99 ref MAR10P4.

**VIDEO 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 100' range! (tune TV to a spare channel) 12v DC op. Price is £15 REF: MAG15 12v psu is £5 extra REF: MAG5P2

\***FM CORDLESS MICROPHONE** Small hand held unit with a 500' range! 2 transmit power levels. Reqs PP3 9v battery. Tuneable to any FM receiver. Price is £15 REF: MAG15P1

**LOW COST WALKIE TALKIES** Pair of battery operated units with a range of about 200'. Ideal for garden use or as an educational toy. Price is £8 a pair REF: MAG 8P1 2 x PP3 req'd.

\***MINIATURE RADIO TRANSCEIVERS** A pair of walkie talkies with a range of up to 2 kilometres in open country. Units measure 22x52x155mm. Complete with cases and earpieces. 2xPP3 req'd. £30.00 pair REF: MAG30.

**COMPOSITE VIDEO KIT.** Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 REF: MAG8P2.

**LQ3600 PRINTER ASSEMBLIES** Made by Amstrad they are entire mechanical printer assemblies including printhead, stepper motors etc etc In fact everything bar the case and electronics, a good stripper £5 REF: MAG5P3 or 2 for £8 REF: MAG8P3

**SPEAKER WIRE** Brown 2 core 100 foot hank £2 REF: MAG2P1

**LED PACK** of 100 standard red 5m leds £5 REF MAG5P4

**UNIVERSAL PC POWER SUPPLY** complete with flyleads, switch, fan etc. Two types available 150w @ £15 REF: MAG15P2 (23x23x23mm) and 200w @ £20 REF: MAG20P3 (23x23x23mm)

\***FM TRANSMITTER** housed in a standard working 13A adapter! the bug runs directly off the mains so lasts forever! why pay £700? or price is £26 REF: MAG26 Transmits to any FM radio.

\***FM BUG KIT** New design with PCB embedded coil for extra stability. Works to any FM radio. 9v battery req'd. £5 REF: MAG5P5

\***FM BUG BUILT AND TESTED** superior design to kit. Supplied to detective agencies. 9v battery req'd. £14 REF: MAG14

**TALKING COINBOX STRIPPER** originally made to retail at £79 each, these units are designed to convert an ordinary phone into a payphone. The units have the locks missing and sometimes broken hinges. However they can be adapted for their original use or used for something else?? Price is just £3 REF: MAG3P1

**100 WATT MOSFET PAIR** Same spec as 2SK343 and 2SJ413 (8A, 140v, 100w) 1 N channel, 1 P channel, £3 a pair REF: MAG3P2

**TOP QUALITY SPEAKERS** Made for HI FI televisions these are 10 watt 4R Jap made 4" round with large shielded magnets. Good quality. £2 each REF: MAG2P4 or 4 for £6 REF: MAG6P2

**TWEETERS** 2" diameter good quality tweeter 140R (ok with the above speaker) 2 for £2 REF: MAG2P5 or 4 for £3 REF: MAG3P4

**AT KEYBOARDS** Made by Apricot these quality keyboards need just a small mod to run on any AT, they work perfectly but you will have to put up with 1 or 2 foreign keycaps! Price £6 REF: MAG6P3

**PC CASES** Again mixed types so you take a chance next one off the pile £12 REF: MAG12 or two the same for £20 REF: MAG20P4

**HEADPHONES** Ex Virgin Atlantic. 8 pairs for £2 REF: MAG2P8

**PROXIMITY SENSORS** These are small PCB's with what look like a source and sensor LED on one end and lots of components on the rest of the PCB. Complete with fly leads. Pack of 5 £3 REF: MAG: 3P5 or 20 for £8 REF: MAG8P4

\*SOME OF OUR PRODUCTS MAY BE UNLICENSEABLE IN THE UK

**BULL ELECTRICAL**  
250 PORTLAND ROAD HOVE SUSSEX  
BN3 5QT

MAIL ORDER TERMS: CASH PO OR CHEQUE  
WITH ORDER PLUS £3.00 POST PLUS VAT.

PLEASE ALLOW 7-10 DAYS FOR DELIVERY  
TELEPHONE ORDERS WELCOME  
TEL: 0273 203500  
FAX: 0273 323077



**SNOOPERS EAR?** Original made to dip over the earpiece of telephone to amplify the sound-it also works quite well on the cable running along the wall! Price is £5 REF: MAG5P7

**DOS PACKS** MicroSoft version 3.3 or higher complete with all manuals or price just £5 REF: MAG5P8 Worth it just for the very comprehensive manual! 5.25" only.

**DOS PACK** MicroSoft version 5 Original software but no manuals hence only £3 REF: MAG3P8 5.25" only.

**PIR DETECTOR** Made by famous UK alarm manufacturer these are hi spec, long range internal units. 12v operation. Slight marks on case and unboxed (although brand new) £8 REF: MAG8P5

**WINDUP SOLAR POWERED RADIO** AM/FM radio complete with hand charger and solar panel £14 REF: MAG14P1

**MOBILE CARPHONE** £6.99 Well almost complete in carphone excluding the box of electronics normally hidden under seat. Can be made to illuminate with 12v also has built in light sensor so display only illuminates when dark. Totally convincing! REF: MAG6P6

**ALARM BEACONS** Zenon strobe made to mount on an external bell box but could be used for caravans etc. 12v operation. Just connect up and it flashes regularly! £5 REF: MAG5P11

**FIRE ALARM CONTROL PANEL** High quality metal cased alarm panel 350x165x80mm. With key. Comes with electronics but no information. sale price 7.99 REF: MAG8P6

**REMOTE CONTROL PCB** These are receiver boards for garage door opening systems. Another use? £4 ea REF: MAG4P5

**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 MAG5P13 ideal for experimenters! 30m for £12.99 ref MAG13P1

**LOPTX** Line output transformers believed to be for IBM hi res colour monitors but useful for getting high voltages from low ones! £2 each REF: MAG2P12 bumper pack of 10 for £12 REF: MAG12P3.

**HEATSINKS** (finned) TO220, designed to mount vertically on a pcb 50x40x25mm you can have a pack of 4 for £1 ref JUN1P11.

**WATERPROOF JUNCTION BOX** 65mm dia 33mm deep. Four cable entry exit points (adjustable for any size cable) snap fit lid. Ideal for TV, satellite use. £2 ea ref APR2 or 6 for £10 ref APR10P7.

## BOTH SHOPS OPEN 9-5.30 SIX DAYS A WEEK

**INFRARED LASER NIGHT SCOPES**

Second generation image intensifier complete with hand grip attachment with built in adjustable laser lamp for zero light conditions. Supplied with Pentax 42mm camera mount and normal eye piece. 1.6kg, uses 1xPP3, 3xAA's (all supplied) £245+Vat

**NEW HIGH POWER LASERS**

15mW, Helium neon, 3 switchable wave lengths .63um, 1.15um, 3.39um (2 of them are infrared) 500:1 polarizer built in so good for holography. Supplied complete with mains power supply. 790x65mm. Use with EXTREME CAUTION AND UNDER QUALIFIED GUIDANCE. £349+Vat.

\*\*\*\*\*BUY SURPLUS STOCK\*\*\*\*\*  
TURN YOUR SURPLUS STOCK INTO CASH.  
IMMEDIATE SETTLEMENT. WE WILL ALSO QUOTE FOR COMPLETE FACTORY CLEARANCE.

## 1994 CATALOGUE.

MINIMUM GOODS ORDER £50. TRADE ORDERS FROM GOVERNMENT, SCHOOLS, UNIVERSITIES, & LOCAL AUTHORITIES WELCOME. ALL GOODS SUPPLIED SUBJECT TO OUR CONDITIONS OF SALE AND UNLESS OTHERWISE STATED GUARANTEED FOR 30 DAYS. RIGHTS RESERVED TO CHANGE PRICE & SPECIFICATIONS WITHOUT PRIOR NOTICE. ORDERS SUBJECT TO STOCK. QUOTATIONS WILLINGLY GIVEN FOR QUANTITIES HIGHER THAN THOSE STATED.

## 3FT X 1FT 10WATT SOLAR PANELS

14.5v/700mA

£33.95

(PLUS £2.00 SPECIAL PACKAGING CHARGE)

TOP QUALITY AMORPHOUS SILICON CELLS HAVE ALMOST A TIMELESS LIFESPAN WITH AN INFINITE NUMBER OF POSSIBLE APPLICATIONS. SOME OF WHICH MAY BE CAR BATTERY CHARGING, FOR USE ON BOATS OR CARAVANS, OR ANYWHERE A PORTABLE 12V SUPPLY IS REQUIRED. REF: MAG34

## PORTABLE RADIATION DETECTOR

£49.99

A Hand held personal Gamma and X Ray detector. This unit contains two Geiger Tubes, has a 4 digit LCD display with a Piezo speaker, giving an audio visual indication. The unit detects high energy electromagnetic quanta with an energy from 30K eV to over 1.2M eV and a measuring range of 5-9999 UR/h or 10-99990 Nt/h. Supplied complete with handbook. Ref MAG50.



# HIGH voltage versatility

*By producing a new and innovative application for this month's free\* IC, you could become the owner of one of six mos design kits worth up to £750. Full competition details are on p. 840. Since the IC in question is closely related to a 555 timer with integral 600V power mosfet drivers, the opportunities for new ideas are endless.*

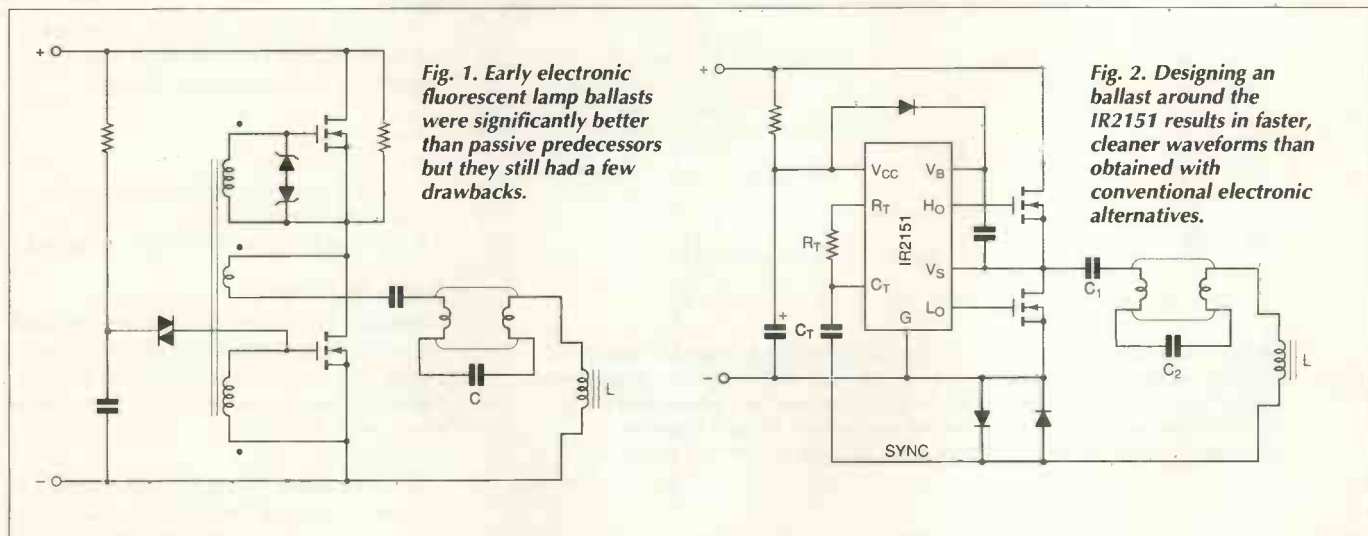
International Rectifier's *IR2151* was developed in response to demand for cheaper and more efficient fluorescent lamp ballasts. Energy bills for lighting represent a significant outgoing for many companies, so the pressure for better and cheaper lamps and drivers is great.

Over the past decade or so, electronic ballasts have been gradually replacing traditional passive circuits. Most electronic designs use two power switches in a half-bridge configuration, also known as a totem-pole. The tube circuits comprise LC resonant circuits with the lamps across one of the reactances, as shown in Fig. 1.

In this circuit the switches are power mosfets driven to conduct alternately by windings on a current transformer. Current in the lamp circuit drives the primary of this transformer, which operates at the resonant frequency of *L* and *C*. Unfortunately, the circuit is not self starting and must be pulsed by the diac con-

## \*Free *IR2151* oscillator and gate drive IC

The first 500 readers completing the coupon between pages 848 and 849 will receive an *IR2151* fluorescent lamp ballast IC completely free of charge. Additional devices can be bought by contacting Ian Spanswick, Polar Electronics, Cherrycourt Way, Leighton Buzzard, Bedfordshire LU7 8YY. Tel. 0525 377093, fax 853070.



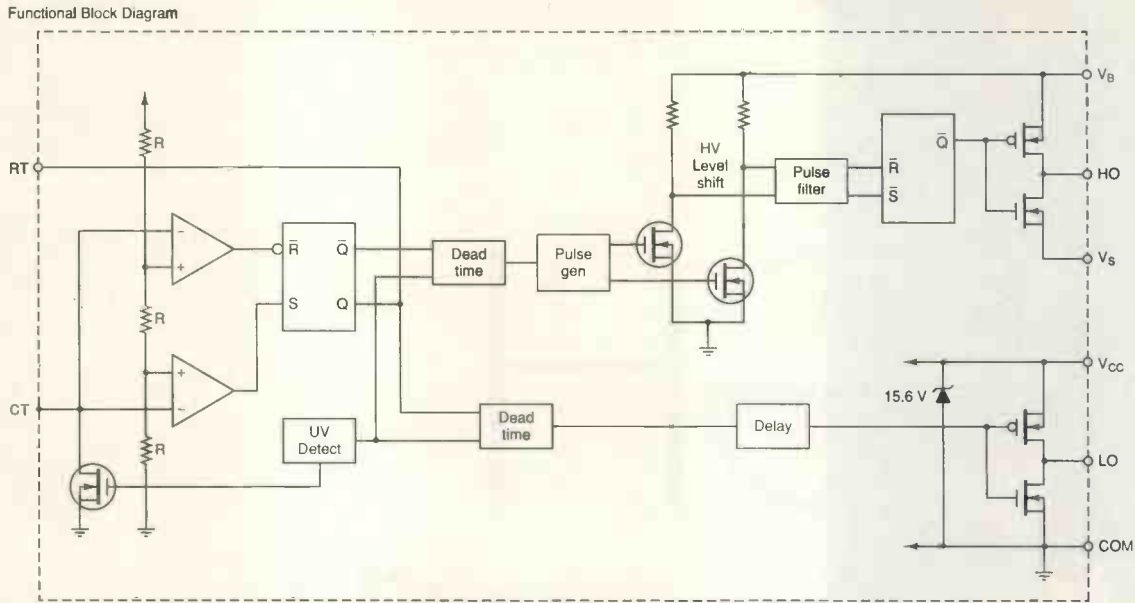


Fig. 3. At the front end of the IR2151 is a timing circuit that is very similar to the 555. Two timing pins are available externally, opening up the possibility for numerous applications other than lamp ballasting.

### Features of the IR2151

- Floating channel bootstrappable
- Operates to 600V dc
- Tolerant to negative transients
- dV/dt immune
- Undervoltage lockout
- Programmable oscillator frequency
- Matched channel propagation delay
- Low side output in phase with RT pin

The IR2151 is a high voltage, high speed, self-oscillating power mosfet and IGBT driver with both high side and low side referenced output channels. Output gate drive is 10 to 15V while rise and fall times are 100 and 50ns respectively.

Proprietary high-voltage IC and

latch-immune cmos technologies make the device rugged. Its front-end features a programmable oscillator similar to the 555 timer.

Incorporated in the output drivers are a high pulse-current buffer stage and an dead time generator designed for minimum driver cross-conduction. Propagation delays for the two channels are matched to simplify use in 50% duty cycle applications.

The floating channel can be used to drive an n-channel power mosfet or igbt in the high side configuration that operates from a high voltage rail from 10 to 600V.

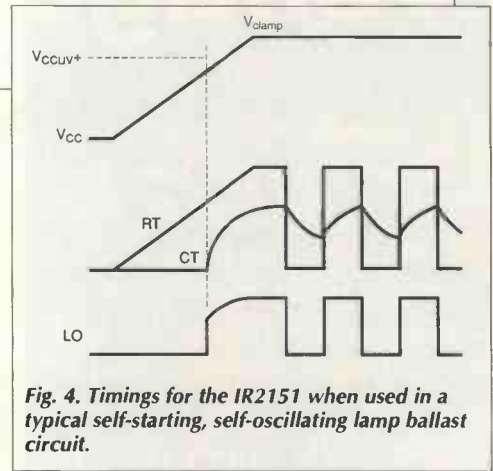


Fig. 4. Timings for the IR2151 when used in a typical self-starting, self-oscillating lamp ballast circuit.

connected to the gate of the lower mosfet.

After initial turn-on of the lower switch, oscillation sustains and a high frequency square wave of between 30 and 80kHz excites the LC resonant circuit. Sinusoidal voltage across C is magnified by the Q at resonance and develops sufficient amplitude to strike the lamp, which then provides flicker-free illumination.

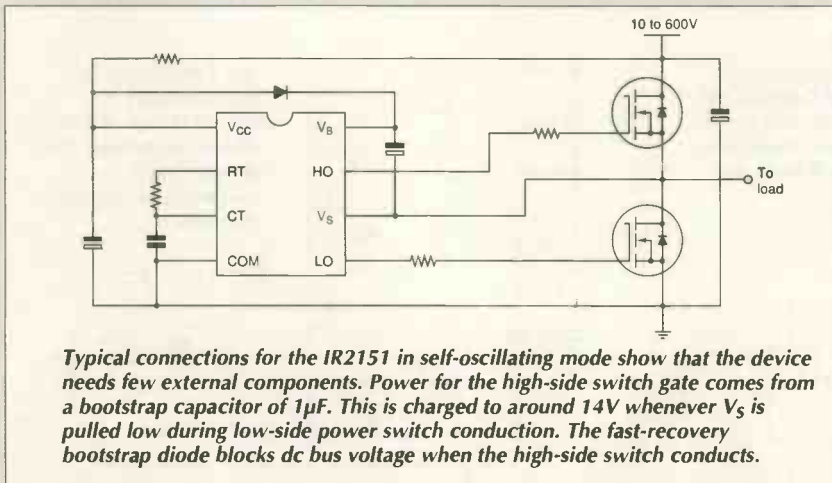
This basic circuit has been the standard for electronic ballasts for years but it suffers from the following inherent shortcomings:

- Not self starting
- Poor switch times
- Labour intensive (toroidal transformer)
- Not amenable to dimming
- Expensive to manufacture in large quantity

### Inside the IR2151

In addition to reducing costs, the International Rectifier IR2151 removes the drawbacks associated with conventional electronic ballasts. Figure 2 illustrates the device in a typical configuration. The mosfets shown could be IRF820 types.

This monolithic power integrated circuit is capable of driving both low and high-side



Typical connections for the IR2151 in self-oscillating mode show that the device needs few external components. Power for the high-side switch gate comes from a bootstrap capacitor of 1µF. This is charged to around 14V whenever Vs is pulled low during low-side power switch conduction. The fast-recovery bootstrap diode blocks dc bus voltage when the high-side switch conducts.



mosfets or igbts from logic level, ground referenced inputs. It provides offset voltage capabilities up to 600V dc, and unlike driver transformers it can provide clean waveforms at any duty cycle between 0 and 99%.

Integrated into the 2151 are timing circuit, level shifting interfaces and high-voltage mosfet drivers, Fig. 3. Operation of the timing circuit is similar to that of a cmos 555. As a result, it is possible to define whether the circuit self oscillates, or is synchronised with an external signal. Simply configure the chip's  $R_T$  and  $C_T$  pins in much the same way as you would those of a conventional 555 timer.

In this type of high-speed mosfet drive circuit, efficiency degrades rapidly if one power mosfet of the pair turns on momentarily before the other turns off. For this reason, the 2151 incorporates a 1µs dead-time generator to help ensure that both power mosfets are never turned on simultaneously. Even when driving power mosfets with 1000pF gate loads, the 2151 is capable of switching on in 100ns and off in 50ns so this safeguard is important.

Propagation delays for the two channels are matched to simplify use in 50% duty cycle applications. When the device is used in self oscillating mode, frequency of oscillation is given by:

$$f = \frac{1}{1.4 \times (RT + 75\Omega) \times CT}$$

Typical timings are shown in Fig. 4.

The IR2155 is intended to be supplied from the rectified ac input voltage and for that reason it was designed for minimum quiescent current. It has a 15V internal shunt regulator so that a single half-watt dropping resistor can be used, assuming 240V ac input. The high voltage rail can be anywhere from 10 to 600V.

Referring again to Fig. 2, note the synchronising capability of the IR2151 driver. The two back-to-back diodes in series with the lamp circuit are effectively a zero crossing detector for the lamp current. Before the tube strikes, the resonant circuit consists of  $L$ ,  $C_1$  and  $C_2$  all in series.

Capacitor  $C_2$  has a lower value than  $C_1$  so it naturally operates at a higher ac voltage than  $C_2$ . It is this voltage which strikes the lamp.

After the lamp strikes,  $C_2$  is effectively shorted by the lamp voltage drop and frequency of the resonant circuit now depends upon  $L$  and  $C_1$ . This causes a shift to a lower resonant frequency during normal operation, again synchronised by sensing the zero crossing of the ac current and using the resultant voltage to control the 2151's oscillator.

In addition to the quiescent current there are two other components of dc supply current that are a function of the application circuit. One is current due to charging input capacitance of the power switches. The other is current due to charging and discharging junction isolation capacitance of the gate driver.

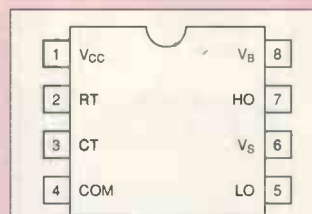
Both components of current are charge related and therefore follow the rule  $Q=CV$ . To charge and discharge the power switch input capacitances, the required charge is a product of the gate drive voltage and the actual input

## IR2151 lead definitions

Pin 2, designated RT, is the oscillator timing resistor input; this resistor normally connects between RT and CT. The signal at this pin is in phase with low-side gate drive output pin LO.

Oscillator timing capacitor input is at pin CT. This capacitor normally connects between CT and the logic and low-side return pin, COM, in order to program the oscillator. Frequency is determined using the equation given in the main article.

High and low-side gate drive outputs are on the HO and LO pins respectively. High-side floating supply feeds via  $V_B$  and is returned via  $V_S$ . Supply voltage for the low side and logic elements feeds in via the  $V_{CC}$  pin. Note that there is an internal zener between this pin and COM so low-impedance supplies above 15V should not be used. Zener voltage is typically 15.6V.



Pin designations for the 8-pin dual-in-line version of the IR2151. The device is also available in small-outline sm packaging.

capacitances and the input power required is directly proportional to the product of charge and frequency and voltage squared:

$$Power = \frac{QV^2}{2} \times f$$

When designing a lamp ballast, follow these pointers. Select the lowest operating frequency consistent with minimising inductor size. Also select the smallest die size for the power switches consistent with low conduction losses. This reduces charge requirements. Usually, dc bus voltage is specified but if there is a choice, use the lowest voltage.

Note that charge is not a function of switching speed. Charge transferred is the same whether the switching speed is 10ns or 10µs.

Because the IR2151 is designed for off-line

supply systems, it contains a zener clamp structure between the chip  $V_{CC}$  and the common pin. This diode has a nominal breakdown voltage of 15.6V. Because of the diode, the IC supply voltage is normally derived by forcing current into the supply lead.

Typically, the current is supplied via a high-value resistor connected to the high-voltage supply and decoupling capacitance is connected between  $V_{CC}$  and the COM pin. In this way, the internal zener clamp determines the nominal supply voltage. For this reason, the circuit should not be driven by a dc, low-impedance power source with a voltage greater than  $V_{CLAMP}$ .

See competition details over page...

## Hints and tips on using the IR2151

- Never forget – the IR2151 is a static-sensitive device and should be handled accordingly.
- Limit current into pin 1 to well within the 25mA absolute maximum. Recommended current supplied to this pin is 5mA.
- Do not try to define the voltage at pin 1. This is set internally by a zener.
- Ensure the diode between  $V_{CC}$  and  $V_B$  has the appropriate reverse recovery capability. Too slow a type and the charge on the bootstrap capacitor could be seriously reduced to the point where efficiency could be affected.
- Remember  $V_{CT+}$  at 800V and  $V_{CT-}$  at 400V determine the 'toggling' of the S-R flip-flop. Defining the 'charge' and 'discharge' currents enable  $t_{ON}$ , and  $t_{OFF}$  to be inequalities – thereby determining the 'duty cycle' of the converter (See Fig. 7 of Application Note AN-995) Note that 'duty cycle' in this instance refers to inequalities in the  $t_{ON}$  of the two channels.
- Observe the waveforms shown in Fig. 4. The apparent 'soft start', determined by the undervoltage detect circuit, might cause problems with transformers because of asymmetry.
- Note that taking  $V_{CC}$  low automatically 'disables' both outputs. This facility allows for protection circuits provided the previous clause is taken into account.
- Observe the  $dV_S/dt$  rating in the data sheet. Exceeding this limit could lead to false triggering of the two outputs.
- A continuation of the previous point is the requirement of ensuring pin 6 never goes more than 25V negative with respect to pin 4. Failure to observe this limit could result in false triggering or to failure of the IC.

# £1800 COMPETITION



## Win one of six design kits

**F**or the six most innovative (and practical) circuits using the IR2151 in any application other than a fluorescent lamp ballast, International Rectifier is giving away a design kit comprising a host of semiconductors complete with storage facilities.

First, second and third best designs will receive prizes valued at £750, £500 and £250 respectively and a further three designs will each receive components and storage facilities to the tune of £100. Components included in the kits have been chosen from across the IR range, which incorporates power mosfets and gate-driver ICs.

Since the IR2151 is essentially a 555

timer with high-voltage output, the scope for imagination is wide. Power conversion and motor control are obvious examples, but the chip need not necessarily be used to drive mosfets or igbts.

This competition is open to all EW+WW readers. Entries must reach EW+WW's editorial offices at Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS before December 1 1994. Please mark your envelope clearly with 'IR design competition'.

The best of the designs will be published in EW+WW. Copyright for all submissions will be assigned to International Rectifier.



## COMPUTER ICs

TMS 9900NL 40 PULLS	£20 ea
8742 1 SHOT	£8 8742 WIPED
TMS320	£5 TMS320 1 SHOT
AM27C020-125L1 SURFACE MOUNT EPROM USED/WIPED	£1.50
MM16450 UART CHIP	£5 ea
P8271 BBC DISC CONTROLLER CHIP EX EQPT	£25
SAA5050 TELETEXT CHIP EX EQPT	£5
28174-20 (2Kx8) EEPROM ex eqpt	£2
D41256C-15 256Kx1 PULLS	9 FOR £5
80C31 MICRO	£2
P8749H MICRO	£5
D8751-8 MICRO	£10
NK48202-20 ZERO POWER RAM EQUIV 6116LP	£4
NEW 4164-15	£1
USED 41256-15	£1
USED 4164-15	60p
BBC VIDEO ULA	£10
8051 MICRO	£1.25
8 x 4164 SIP MODULE NEW	£8
FLOPPY DISC CONTROLLER CHIPS 1771	£16
FLOPPY DISC CONTROLLER CHIPS 1772	£17.50
68000-8 PROCESSOR NEW	£6
HD6384-8	£5
ALL USED EPROMS ERASED AND BLANK CHECKED	
2716-45 USED	£2 100/£1
2732-45 USED	£2 100/£1
2764-30 USED	£2 100/£1.60
27C256-30 USED	£2
27C512 USED	£3.50
1702 EPROM EX EQPT	£5
2114 EX EQPT 50p 4116 EX EQPT	70p
6264-15 BK STATIC RAM	£2
GR281 NON VOLATILE RAM EQUIV 6116	£5
Z80A SIO-O	£1.25
80387-16 CO PROCESSOR (OK WITH 25MHZ 386)	£35
7126 3/2 DIGIT LCD DRIVER CHIP	£2 ea
2816A-30 HOUSE MARKED	£2
USED TMS2532JL	£2.50 2708 USED
TM577C82 USED/WIPED	£5
HM167LP-8	£5p
M27C4001-15	£8
68000-10 PROCESSOR	£6
8255-5	£1
2114 CMOS (RCA 5114)	£1.60

## REGULATORS

LM338K	£6
LM323K 5V 3A PLASTIC	£2
LM323K 5VA METAL	£3
SANKEN STR451 USED IN AMSTRAD MONITORS	£5
78H12ASC 12V 5A	£5
LM317H T05 CAN	£1
LM317T PLASTIC TO220 variable	£1
LM317 METAL	£2.20
7812 METAL 12V 1A	£1
7805/12/15/24	25p
7905/12/15/24	25p
CA3085 T099 variable reg	2/E1
78HGASC+79HGASC REGULATORS	£30 ea
LM123 ST93 5V 3A T03 REGS	£3 ea

## CRYSTAL OSCILLATORS

2M4576 3M6864 5M0 5M76 6M144 7M000 7M3728 8M000	
12M000 14M3181 17M6256 16M257 18M000 20M000 23M587	
24M000 25M175 27M0 27M036 28M322 32M000 35M4816	
40M000 44M4444 44M900 48M000 64M000 1M000 1M8432	
4M000 10M000 16M000 18M432000 19M0500 20M0500	
38M10000 56M6092 76M1 84M0	£1.50 ea

## CRYSTALS

4M0256 10M368 17M6256 18M432 25M000 28M4694 31M4696	
48M000 55M500 111M80 112M80 114M318 114M80 1M0	
1M8432 2M000 2M4576 2M77 3M00 3M2768 3M579545	
3M58564 3M93216 4M000 4M19304 4M433619 4M608 4M9152	
5M000 5M0688 6M0000 6M400 8M000 8M488 9M304 10M240	
10M245 10M7000 11M000 12M000 13M000 13M270 14M000	
14M3818 15M000 16M000 16M5888 17M000 20M000	
21M300 21M855 22M1184 24M000 34M368 36M75625	
36M76875 36M78125 36M79375 36M80625 36M81875	
36M83125 36M84375 38M900 49M504 54M19166 54M7416	
57M75833 60M000 69M545 69M550 6N 26M995 RD27M045	
RD27M095 YW27M145 GN27M195 BL27M245 3M225	£1 ea

## TRANSISTORS

MPSA92	10/£1
N2907A	10/£1
BC477, BC488	10/£1
BC107 BCY70 PREFORMED LEADS	
full spec	£1 £4/100 £30/1000
BC557, BC238C, BC308B	£1/30 £3.50/100
2N3819 FETS short leads	4/£1

## POWER TRANSISTORS

OC29	£1.35 ea
P POWER FET IRF9531 8A 60V	3/£1
N POWER FET IRF531 8A 60V	2/£1
2SC1520 sim BF259	3/£1 100/£22
TIP142 2 1/2 1 ea TIP 112/42B	2/£1
SE3301 100V 10A DARL SIM TIP121	2/£1
PLASTIC 3055 OR 2955 equiv 50p	100/£35
BUZ31 POWER FET TO-220 200V 12.5A	2/£1

## TEXTOL ZIF SOCKETS

28 PIN USED	£3
40 PIN NEW	£10
SINGLE IN LINE 32 WAY CAN BE GANGED FOR USE WITH ANY DUAL IN LINE DEVICES... COUPLING SUPPLIED	2/£1.50

## QUARTZ HALOGEN LAMPS

12V 50watt LAMP TYPE M312	£1 ea
HOLDERS 60p ea	
24V 150 WATTS LAMP TYPE A1/215	£2.50 ea

## MISCELLANEOUS

MINIATURE FERRITE MAGNETS 4x4x3mm	10/£1
ALPS MOTORIZED DUAL 47K LOG pots with spindle, works on 6v-12v	£1.50 ea

TL071 LO NOISE OP AMP	5 for £1
TL081 OP AMP	4 for £1
47000u 25V SPRAGUE 36D	£3.50 (£2)
12 way dil sw	£3 for £1
10NF 63V X7R PHILIPS SURFACE MOUNT 160K available	£30/4000 box
SWITCHED MODE PSU 40 WATT UNCASED QTY AVAILABLE 4-5V 5A, +12V 2A, 12V 500mA FLOATING	£9.95 (£2)
330nF 10% 250V X2 AC RATED PHILIPS	£20/100
220R 2.5W WIREWOUND RESISTOR 60K AVAILABLE	£50/1000
CMOS 555 TIMERS	2/£1
2/3 AA LITHIUM cells as used in compact cameras	2/£1.50
ICM7126CPL CMOS 3 1/2 DIGIT LCD DRIVER CHIP	£2 ea
36 CORE 7/0.2mm OVERALL SCREENED	£50/100m
LITHIUM CELL 1/2 AA SIZE	2 FOR £1
PASSIVE INFRA RED SENSOR CHIP + MIRROR + CIRCUIT	£2 ea
EUROCARD 21-SLOT BACK PLANE 96/96-WAY "PROTONIC 24 VARIBUS" 16.7" x5" FIBREGLASS MULTILAYER PRH PCB	£25 ea
EUROCARD 96-WAY EXTENDER BOARD 290x100mm	£10 ea

*PROTONIC 24" c/w 2 SUPPORT ARMS/EJECTORS	
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/£1
13A MOULDED PLUG+2m lead	£1
MIN. TOGGLE SWITCH 1 POLE c/o PCB type	5/£1
LCD MODULE sim. LM018 but needs 150 to 250V AC for display 40x2 characters 182x35x13mm	£10
TL431 2.5 to 36V TO92 ADJ. SHUNT REG.	2/£1
6-32 UNC 5/16 POZI PAN SCREWS	£1/100
NUTS	£1.25/100
PUSH SWITCH CHANGEOVER	2/£1
RS232 SERIAL CABLE D25 WAY MALE CONNECTORS	£5.90 ea (£1.30)
25 FEET LONG, 15 PINS WIRE BRAID + FOIL SCREENS INMAC LIST PRICE	£30
LCD DISPLAY sim Hitachi LM016L	£5.50
AMERICAN 2/3 PIN CHASSIS SOCKET	2/£1
WIRE ENDED FUSES 0.25A	30/£1
NEW ULTRASONIC TRANSDUCERS 32kHz	£2/pr
Also available 28 slot vari-bus backplane same size + Price	NEW
POWERFUL SMALL CYLINDRICAL MAGNETS	3/£1
BNC 500MHZ SCREENED CHASSIS SOCKET	2/£1
MINI MICROVAVE DIODES AE1 OC1026A	2/£1
D.I.L. SWITCHES 10-WAY 1/8-WAY 80P 4/5/6-WAY	80p
180VOLT 11WATT ZENERS also 12V & 75V	20/£1
MIN GLASS NEONS	10/£1
RELAY 5V 2-pole changeover looks like RS355-741 marked STC 47W8ost	£1 ea
MINIATURE CO-AX FREE PLUG RS 456-071	2/£1
MINIATURE CO-AX PCB SKT RS 456-093	2/£1
PCB WITH 2N2646 UNIJUNCTION WITH 12V 4-POLE RELAY	£1
400 MEGOHM THICK FILM RESISTORS	4/£1
STRAIN GAUGES 40 ohm Foil type polyester backed balcoo grid alloy	£1.50 ea 10+ £1
ELECTRET MICROPHONE INSERT	£0.90
Linear Hall effect IC Micro Switch no 613 S54 sim RS 304-267	£2.50 100+ £1.50
HALL EFFECT IC UGS3040 + magnet	£1
OSCILLOSCOPE PROBE SWITCHED x1 x10	£12
1 pole 12-way rotary switch	4/£1
AUDIO ICS LM380 LM386	£1 ea
555 TIMERS 51 741 OP AMP	6/£1
ZN414 AM RADIO CHIP	80p
COAX PLUG nice ones	4/£1
COAX BACK TO BACK JOINERS	3/£1
4x4 MEMBRANE KEYBOARD	£1.50
INDUCTOR 20uH 1.5A	5/£1
1.25" PANEL FUSEHOLDERS	3/£1
CHROMED STEEL HINGES 14.5x1" OPEN	£1 ea
12V 1.2W small w lamps fit most modern cars	10/£1
STEREO CASSETTE HEAD	£2
MONO CASS. HEAD 1/2 ERASE HEAD	50p
THERMAL CUT OUTS 50 77 85 120°C	£1 ea
THERMAL FUSES 220°C/121°C 240V 15A	5/£1
TRANSISTOR MOUNTING PADS TO TO-18	£3/1000
TO-3 TRANSISTOR COVERS	10/£1
PCB PINS FIT 0.1" VERO	200/£1
TO-220 micas + bushes	10/50p 100/£2
TO-3 micas + bushes	15/£1
Large heat shrink sleeving pack	£2
IEC chassis plug filter 10A	£3
POTS SHORT SPINDLES 2K5 10K 25K 1M 2M5	4/£1
40k U/S TRANSDUCERS EX-EQPT NO DATA	£1/pr
LM335Z 10MV/degree C	£1
LM234Z CONST. CURRENT I.C.	£1
BNC TO 4MM BINDING POST SIM RS 455-361	£1
MIN PCB POWER RELAYS 10.5v COIL 6A CONTACTS 1 p ole c/o	£1
AVEL-LINDBERG MOULDED TRANSFORMER TYPE OB10 15+15V 10VA QTY. AVAILABLE	£2 ea
BANDOLIERY COMPONENTS ASSORTED Rs, Cs, ZENERS	£5/1000

LCD MODULE 16 CHAR. X 1 LINE (SIMILAR TO HITACHI LM10)	£5
KYNAR WIRE WRAP WIRE	£1/REEL
OPT1264A 10W OPTO ISOLATOR	£1.35 ea 100+ £1 ea
"LOVE STORY" CLOCKWORK MUSICAL BOX MECHANISM MADE BY SANKYO	£1 ea
Telephone cable clips with hardened pins	500/£2
10,000uF 16V PCB TYPE 30mm DIAx31mm	2/£1
EC CHASSIS FUSED PLUG B-LEE L2728	3/£1
2A CERAMIC FUSE 1.25" QB	10/£1
40 WAY IDC RIBBON CABLE 100 FOOT REEL	£5+CARR
100mm PCB FUSEHOLDER	5/£1
IEC CHASSIS FUSED PLUG B-LEE L2728	3/£1

## DIODES AND RECTIFIERS

AN15M 3A 600V FAST RECOVERY DIODE	4/£1
1N5407 3A 1000V	8/£1

1N4148	100/£1.50
1N4004 SD4 1A 300V	100/£3
1N5401 3A 100V	10/£1
BA158 1A 400V fast recovery	100/£3
BY127 1200V 1.2A	10/£1
BY254 800V 3A	8/£1
BY255 1300V 3A	6/£1
6A 100V SIMILAR MR751	4/£1
1A 600V BRIDGE RECTIFIER	4/£1
4A 100V BRIDGE	3/£1
6A 100V BRIDGE	2/£1
10A 200V BRIDGE	£1.50
25A 200V BRIDGE £2	10/£1
25A 400V BRIDGE £2.50	10/£22
2KBPO2 IN LINE 2A 200V BRIDGE REC	8/£1

## SCRs

PULSE TRANSFORMERS 1:1+1	£1.25
2P4M EQUIV C106D	3/£1
TICV106D 800mA 400C SCR 3/£1	100/£15
MEU21 PROG. UNIJUNCTION	3/£1

## TRIACS

NEG TRIAC AC08F 8A 600V TO220	£5/2 100/£30
TXAL225 8A 500V 5mA GATE	2/£1 100/£35
BTA 08-400 ISO TAB 400V 5mA GATE	90p
TRAL2230D 30A 400V ISOLATED STUD.	£5 ea
TRIAC 1A 800V TLC381T 16k AVAILABLE	5 FOR £1 £15/100

## CONNECTORS

D25 IDC PLUG OR SOCKET	£1
34-way card edge IDC CONNECTOR (disk drive type)	£1.25
CENTRONICS 36 WAY IDC PLUG	£2.50
CENTRONICS 36 WAY IDC SKT	£4.00
BBC TO CENTRONICS PRINTER LEAD 1.5M	£3
CENTRONICS 36 WAY PLUG SOLDER TYPE	£4
USED CENTRONICS 36W PLUG+SKT	£3
14 WAY IDC BLOCK HEADER SKT	5/£1

## PHOTO DEVICES

HI BRIGHTNESS LED CQX24 RED	5/£1
SLOTTED OPTO-SWITCH OPCOA OPB815	£1.30
2N5777	50p
TL81 PHOTO TRANSISTOR	£1
TL38 INFRA RED LED	5/£1
4N25, OP1252 OPTO ISOLATOR	50p
PHOTO DIODE 50P	6/£2
MEL12 (PHOTO DARLINGTON BASE n/c)	50p
LED's RED 3 or 5mm 12/£1	100/£6
LED's GREEN OR YELLOW 10/£1	100/£6
FLASHING RED OR GREEN LED 5mm 50p	100/£40
HIGH SPEED MEDIUM AREA PHOTODIODE RS651-995	£10 ea

## STC NTC BEAD THERMISTORS

G22 220R, G13 1K, G23 2K, G24 20K, G54 50K, G25 200K	
RES 20°C DIRECTLY HEATED TYPE	£1 ea
FS22BW NTC BEAD INSIDE END OF 1" GLASS PROBE RES	
20°C DIRECT	£1 ea
A13 DIRECTLY HEATED BEAD THERMISTOR 1k res. ideal for audio Wien Bridge Oscillator	£2 ea

## CERMET MULTI TURN PRESETS 3/4"

10R 20R 100R 200R 250R 500R 2K 2K2 2K5 5K 10K 47K 50K 100K 200K 500K 2M	50p ea
---	--------

## IC SOCKETS

14/16/18/20/24/28/40-WAY DIL SKTS	£1 per TUBE
8-WAY DIL SKITS	£2 per TUBE
32-WAY TURNED PIN SKTS. 7k available	3 for £1
SIMM SOCKET FOR 2x30-way SIMMS	£1

## POLYESTER/POLYCARB CAPS

330nF 10% 250V AC X2 RATED PHILIPS TYPE 330	£20/100
100n, 220n 63V 5mm	20/£1 100/£3
1n/3n/5n/6n/2n/10n 1% 63V 10mm	100/£5
10n/15n/22n/33n/47n/66n 10mm rad.	100/£3.50
100n 250V radial 10mm	100/£3
100n 600V Sprague axial 10/£1	100/£6 (£1)
2u2 16u2 rad 22mm, 2u2 100V rad 15mm	100/£10
10n/33n/47n 250V AC x rated 15mm	10/£1
1u 600V MIXED DIELECTRIC	50p ea
1u0 100V rad 15mm, 1u0 22mm rad.	100/£6

## RF BITS

SAW FILTERS SW662/SW661 PLESSEY SIGNAL TECHNOLOGY 379.5 MHZ	£1.50 ea
FX3286 FERRITE RING ID 5mm OD 10mm	10 for £1
ASTEC 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
VIOLET	5-105pF
YELLOW 5-65pF RED 10-110pF GREY	

# Smaller steps to better performance

**M**y DDS signal generator, self-designed, covers about 1Hz-320MHz in approximately 1Hz steps. Output is cw only and an external 0-120dB step attenuator provides 10dB steps.

To add amplitude modulation and fine output adjustment, certain constraints had to be considered. For example, though output from the DDS signal generator was about 0dBm, variation over the full range up to 320MHz was nearly 2dB.

Furthermore, several rf amplifier stages would be needed in the rf path, with each contributing further gain variation. So the whole rf path through the modulator/attenuator was enclosed within a levelling loop. Since the leveller output is maintained constant regardless of input- or load-variations (within reason), the added advantage is that this represents a zero output impedance point. From there, the load can be supplied via a 50Ω resistor, giving an ideal generator output impedance, independent of the actual output impedance of the last rf amplifier in the chain.

the multiplier's ±1V dynamic range. With frequencies up to 320MHz at the multiplier's input, balanced circuitry is not convenient. Fortunately the device's common mode rejection at both X and Y input ports is such that in each case one lead can be grounded and the other driven unbalanced (Fig. 1).

As recommended in the data sheet when using unbalanced inputs, X<sub>1</sub> and Y<sub>2</sub> are grounded, the inputs being applied to pins 1(Y<sub>1</sub>) and 8(X<sub>2</sub>).

Similarly, for convenience, an unbalanced output is taken from W<sub>1</sub>, W<sub>2</sub> being returned to the supply, even though this halves the available pk-pk output current to ±2mA. This alternating current is superimposed on a standing 8.5mA (nominal) dc component and is sunk by an open collector output.

The open collector W outputs must be operated at a voltage slightly above that on pin 6 (V+) – the manufacturer's recommended method is to insert a resistor in series with the supply to pin 6.

The ac component, flowing in 47Ω load resistor R<sub>6</sub> in parallel with the (nominal) 50Ω input impedance of IC<sub>3</sub>, forms the output voltage from the modulator, and is applied to the following amplifier stages.

Note that the 390Ω supply resistor of IC<sub>3</sub> is somewhat lower than the recommended value, so device dissipation will be increased. But this is acceptable for lab use as distinct from a full-temperature-range application.

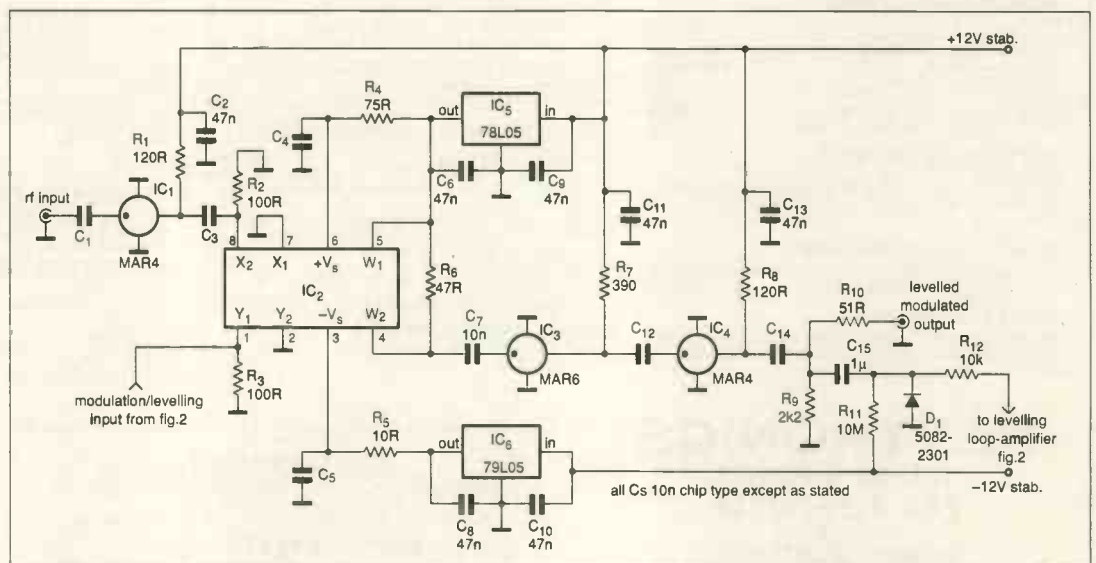
After further amplification, the signal voltage at the output of IC<sub>4</sub> corresponds to +6dBm when the voltage on the Y<sub>1</sub> input of the modulator is rather less than +1V (or -1V). Thus the level delivered to a matched load at the output is just 0dBm. The rf output of IC<sub>4</sub> is dc restored positive-going by D<sub>1</sub>, whose linearity versus signal level is improved somewhat by a hint of

**Active multipliers find many uses in instrumentation. Ian Hickman explores their use in signal generation as variable attenuators and modulators.**

## AD834 characteristics

The AD834 accepts a maximum differential input on both its X and Y balanced inputs of ±1Vpk-pk, producing at its differential W output port a current of ±4mA full scale, according to the relation  $W = XY/1V^2$ . Output from the DDS signal generator was about 0dBm, or only 630mV pk-pk, so some amplification was indicated to take full advantage of

Fig. 1. RF path through the modulator/attenuator/leveller.





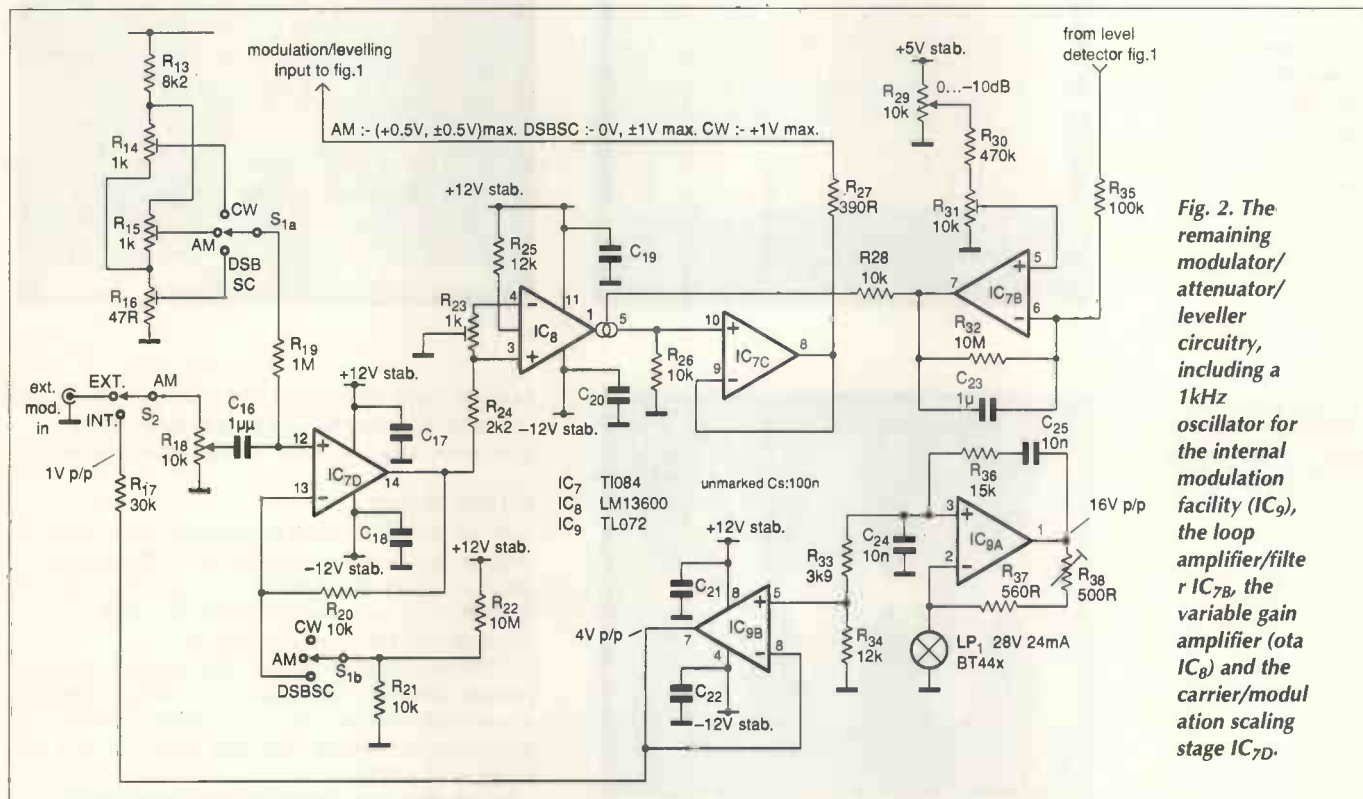


Fig. 2. The remaining modulator/attenuator/leveller circuitry, including a 1kHz oscillator for the internal modulation facility (IC<sub>9</sub>), the loop amplifier/filter IC<sub>7B</sub>, the variable gain amplifier (ota IC<sub>8</sub>) and the carrier/modulation scaling stage IC<sub>7D</sub>.

forward bias via R<sub>11</sub>.

Mean level of the voltage at D<sub>1</sub>'s cathode is (almost) equal to the peak rf voltage, and it is applied via R<sub>12</sub> to the modulator/attenuator/levelling loop (Fig. 2).

### Remaining circuit

The circuitry of Fig. 1 was constructed on a scrap of single sided copper-clad laminate, used as a ground plane. But that of Fig. 2 was built on a piece of 0.1in matrix copper strip board. The level detector output is applied to the loop filter-amplifier, IC<sub>7B</sub> and associated components.

IC<sub>7B</sub> controls the gain of the transconductance amplifier stage IC<sub>8</sub> which receives its input from IC<sub>7D</sub>.

IC<sub>8</sub> is an LM13600, of which one half is unused. (An LM13700 will do too as there is only a minor difference between these two devices. In the LM13600 the emitter current of the input transistor of the Darlington output buffer is controlled pro-rata with the g<sub>m</sub> of the transconductance section, providing improved dynamic range. In the LM13700, it is fixed. Since the output buffer is not used in this application, either device will do.)

R<sub>25</sub> provides the current to operate the LM13600's input linearising diodes.

IC<sub>7D</sub> produces a dc level which determines the carrier at the output, combining it with an ac signal where modulation is required. For maximum cw output, IC<sub>7C</sub> (which buffers the ota's output) applies the required voltage, up to +1V, to the modulator's Y<sub>1</sub> input, via R<sub>27</sub>. This occurs with 0-10dB attenuator control R<sub>29</sub> set to maximum and with R<sub>31</sub> suitably adjusted. R<sub>29</sub> provides an attenuation range of over 10dB, and though its operation is approximately linear rather than logarithmic, it can readily be calibrated with a dB scale. Operation on

am is similar, except that the dc level at the modulator's Y<sub>1</sub> input is halved to allow for up to 100% modulation.

Internal 1kHz modulation oscillator IC<sub>9</sub> is included and the modulation depth can be set by R<sub>18</sub>. R<sub>18</sub> can be calibrated directly in percent amplitude modulation depth, with the level supplied by the internal modulation oscillator making fully-clockwise equal to 100% am. If the internal modulation oscillator is run with a low output swing at IC<sub>9A</sub>, such as 4Vpk-pk, setting up is critical and amplitude control poor, due to inadequate drive to the lamp used to stabilise the loop gain. With the arrangement shown, giving 16Vpk-pk, control is tight with little amplitude bounce at switch-on. A 4Vpk-pk output is picked off by IC<sub>9B</sub>, which is driven from the frequency selective network rather than the output of the maintaining amplifier. IC<sub>9B</sub>'s output has the advantage of the selectivity of the Wien network – though it amounts to 2.5dB at third harmonic relative to the fundamental, every little is worth having.

The measured total harmonic distortion at IC<sub>9B</sub>'s output is 0.01% – almost entirely second harmonic – is presumably due to the IC, as any due to the lamp should be odd order. The result is a little puzzling, as the op-amp spec shows 0.003% thd typical. Nevertheless, the performance is quite creditable for such a cheap, simple circuit.

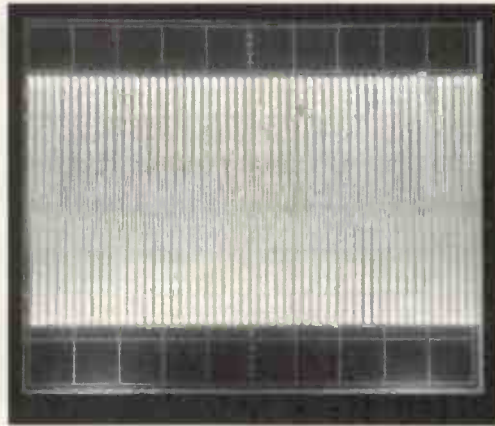
As an alternative, an external modulation source could be connected, which naturally should not exceed 1Vpk-pk, or the modulation index will exceed 100% when R<sub>18</sub> is at maximum.

Since it is easily incorporated and could come in useful, a dsbcs (double side-band suppressed carrier) mode is also included.

Switching S<sub>1</sub> to dsbcs doubles the gain of IC<sub>7D</sub> to give a bipolar drive at the modulator's Y<sub>1</sub> modulation

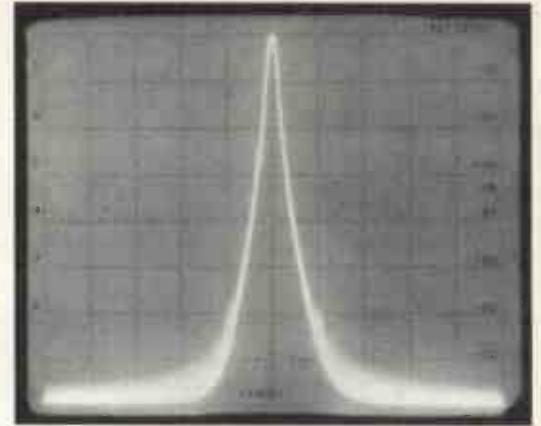
## DESIGN BRIEF

**Fig. 3(a).** CW output at 10MHz into a 50Ω load (viz a spectrum analyser). Scope settings 0.2V/div, 0.5μs/div.



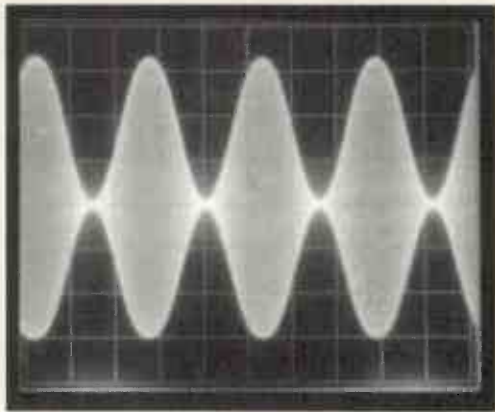
(a)

**3(b).** Spectrum of (a). Centre frequency 10MHz, 20kHz/div, 3kHz if bandwidth, video filter off, 10dB/div, ref level (top of screen) 0dBm.



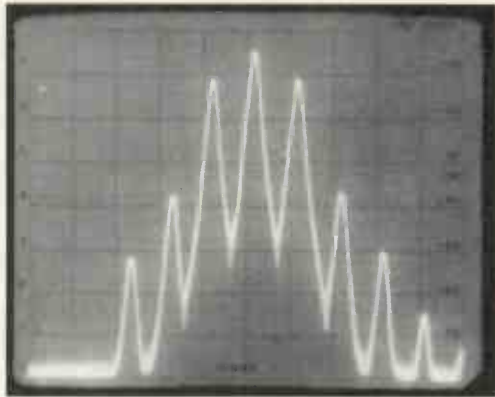
(c)

**Fig. 4(a).** Output at 10MHz with 100% am at 20kHz. Scope settings 0.2V/div, 0.5μs/div.



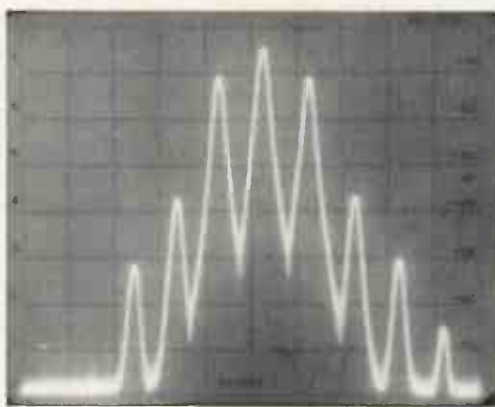
(a)

**4(b).** Spectrum of (a). Centre frequency 10MHz, 20kHz/div, 3kHz if bandwidth, video filter off, 10dB/div, ref level (top of screen) 0dBm.



(b)

**4(c).** As (b) but the input rf level reduced by 6dB. Switching to the 1dB division display indicated that the loop compressed a 6dB reduction in input level to a 0.2dB reduction in output level.



(c)

input.  $R_{16}$  with  $R_{22}$  permits zeroing of any offset at the output of  $IC_{7D}$ , and  $R_{23}$  can then be adjusted for maximum carrier suppression in the dsb-sc output.

### Circuit testing

Tests on the circuit, still in breadboard form, show (Fig. 3a) the maximum cw output at 10MHz, while the same signal displayed on a spectrum analyser (Fig. 3b) indicates a level of 0dBm into 50Ω downstream of the source resistor  $R_{10}$ .

Of the two, I believe the spectrum analyser shows the true picture, the scope indicating about 1.1vpk-pk or over 4dB more than this. But you can't believe a  $X10$  probe, with its 4in earth lead, even at as "low" a frequency as 10MHz.

In fact, the scope trace is included solely for comparison with the am case.

Examining the same 10MHz output, but this time with 100% am and the same scope settings as before, shows that the peak to peak voltage has increased slightly. This is confirmed by the spectrum analyser picture (Fig. 4b).

With 100% modulation, had the peak voltage been the same as before, the carrier component in the scope trace would have been exactly -6dBm, ie 6dB below that in Fig. 3b. The fact that it is barely 5dB down indicates that while the levelling loop tries to control the peak level of the output, it is also partly sensitive to the mean rf level. Shortening the time-constant  $C_{15}(R_9+R_{12}+R_{35})$  compared to the period of the modulation waveform, would result in mean level control and the carrier level would remain unchanged with modulation depth. But this would limit the highest usable modulating frequency to many octaves below the lowest usable radio frequency - at least in am mode. Restriction-free range for both modulation- and carrier-frequency operation is a priority so the present scheme with (near) peak level control has been retained.

### AM and dsb-sc modes

At 100% modulation, the second and third harmonic sidebands are only about 26dB and 40dB down respectively (Fig. 4b) on the wanted fundamental sidebands. The second harmonic modulation is severe enough to be noticeable (Fig. 4a) as a reduction in amplitude of the negative-going peaks of the envelope relative to the positive. As it is the negative peaks which are sensed by the detector circuit, this largely explains the deviation from true peak-level control exhibited by the levelling loop, mentioned above.



## A good circuit simulator can:

- illustrate difficult regimes such as start up and spurious signal injection,
- show up mistakes,
- help with design optimising,
- catalyze new circuit ideas and add to your stock-in-trade solutions,
- save time.

## A good simulator must:

- be friendly.

## SpiceAge is:

- user-friendly — it is intuitive, ergonomic and it conforms to Windows™ standards,
- friendly in operation — the progress of an analysis can be checked in realtime, adjustments made, restarted or aborted. Batch processing (when you get the bad news after a long wait) is not our idea of friendliness,
- supported by friendly engineers — we believe there is no such thing as a silly question. It's your questions that have helped us to produce intuitive interfaces and clear documentation,
- accountant-friendly — the combination of a short learning curve, low first cost and optional modest maintenance makes SpiceAge easy to justify. £868.75 + VAT is the most you can pay for a copy of SpiceAge for Windows,
- constantly being invested in. You have the confidence of buying from a family firm that has specialised in circuit simulation since 1982,
- not just a friendly face — you may have seen the SpiceAge circuit simulator program before but let us bring you up to date with some of its remarkable facilities. *Please contact:*

**Those Engineers Ltd., 31 Birkbeck Road, LONDON NW7 4BP. Tel: 081-906 0155, Fax: 081-906 0969.**



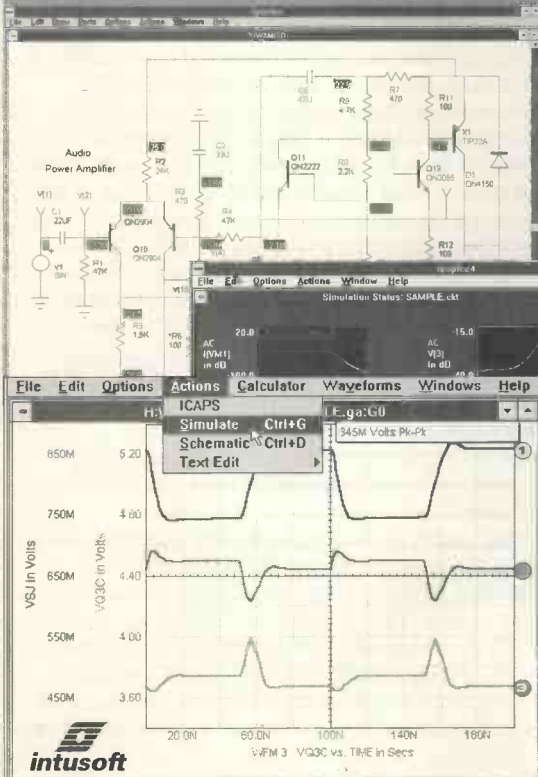
**Those  
Engineers Ltd**



CIRCLE NO. 122 ON REPLY CARD

# Low Cost Analog Simulation

**ICAP/4Lite - Schematic Entry, SPICE and Waveform Display for £400**



ICAP/4Lite, features schematic entry, powerful analog and mixed signal simulation, and extensive device libraries, all integrated in one easy to use environment. With ICAP/4Lite you can simulate all types of designs including Power, ASIC, RF, Mixed Mode, Control Systems, and Mixed Technologies.

**Forget those other low cost and not quite SPICE systems. They cannot compare to ICAP/4Lite...**

- **SPICE 3F based Simulator** - AC, DC, Transient, Temperature, Operating Point
- **UNLIMITED CIRCUIT SIZE**
- **Integrated Schematic Entry**
- **High Performance 32-bit Simulator**
- **Real time waveform display**
- **Over 500 Device Models Included**
- **Inexpensive upgrade path**
- **Windows and Windows NT**
- **Works w/other schematic entry programs**
- **Affordable Prices - £400**

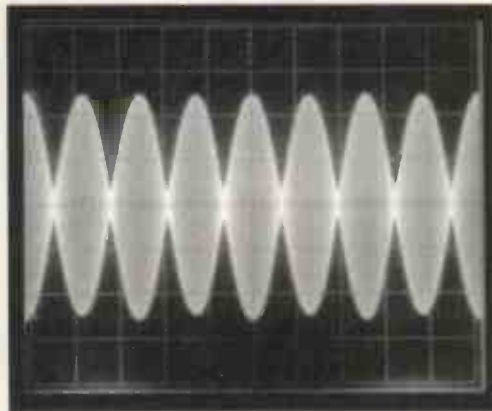
Call or write for free information to:  
Technology Sources Ltd  
Falmouth Avenue  
NEWMARKET, Suffolk CB8 0LZ, UK

Ph: 0638-561460  
Intl +44-638-561460

Fax: 0638-561721  
Intl +44-638-561721

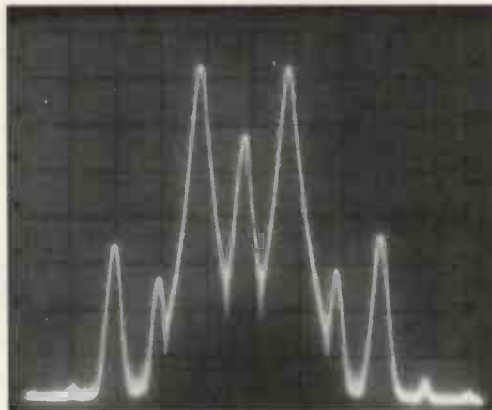
CIRCLE NO. 123 ON REPLY CARD

Fig. 5(a). Output at 200MHz in dsb mode with 20kHz modulation. 0.2V/div vertical (but effectively uncalibrated at this frequency, on account of the probe earth lead inductance), 20µs/div horizontal.



(a)

5(b). Spectrum of (a). Spectrum analyser settings as Figure 3(b) except centre frequency is 200MHz.



(b)

The levelling loop is really quite effective (Fig. 4c), compressing a 6dB reduction in input level to a 0.2dB reduction at the output. Similarity of Figs. 4b and c shows that the second and third order distortion sidebands arise not in  $IC_1$ , nor (according to its spec sheet) in  $IC_2$ , but in ICs 3 and 4, both of which are running just a few dBs below their 1dB compression point. An improvement would be to modify the detector circuit to sense the positive peak, or better still use a peak-to-peak detector.

In all modes – cw, am and dsb –  $R_{29}$  provides the function of a 0-10dB output attenuator, though, for the reasons indicated, with am the modulation should be adjusted for the desired depth before the output level is set.

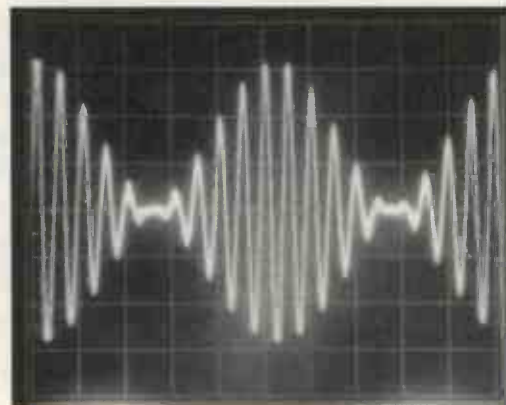


Fig. 6. 10MHz output with 100% amplitude modulation at 1MHz, measured upstream of the 51Ω output resistor  $R_{10}$ . 0.2V/div. vertical, 0.2µs/div horizontal.

At 200MHz in the dsb mode, the  $Y_1$  input of the modulator is taken both positive and negative, on alternate half cycles of the 20kHz modulating frequency (Fig. 5a) So phase of the rf reverses twice per cycle of the modulation. The corresponding spectrum (Fig. 5b) shows that the carrier is only 15dB down on the 199.980MHz and 200.020MHz sidebands – despite adjustment of  $R_{23}$  for maximum carrier suppression.

The residual carrier is a component in quadrature with that controlled by  $R_{23}$  and is not affected by the nulling procedure. It is presumably due to capacitive feedthrough in, or around,  $IC_2$ . As expected in this mode, second order distortion sidebands are way down, much lower than third order.

In dsb mode, output level is set solely by  $R_{29}$  – the “output attenuator”. Any external modulation input should be set to 1Vpk-pk and modulation depth control  $R_{18}$  to maximum. In this mode, “modulation depth” is meaningless. Whatever the modulation input level, the loop will always try to set the peak output level to that demanded by  $R_{29}$ .

### Surprising operating frequency

The circuit will operate with input carrier frequencies down to about 1MHz. For lower frequencies, all the capacitors in the rf path, such as  $C_1$  and  $C_3$  etc, should be increased in value. Similarly, the external modulation facilities, while not dc coupled, should work down to a few Hz.

Highest usable modulation frequency is set by the frequency responses of  $IC_{7C}$  and  $IC_{7D}$ , and  $IC_8$ . Response of the modulator’s  $Y$  input (like its  $X$  input) extends up to 500MHz.

An unexpected result was produced by a 10MHz carrier 100% amplitude modulated at 1MHz, monitored at the junction of  $C_{15}$  and  $R_{10}$ . The modulation envelope seems a very respectable sine wave (Fig. 6).

Finding that the  $LM13600$  worked quite happily at this frequency was no surprise, its typical 3dB bandwidth is 2MHz. But the  $TL084$  will typically swing only  $\pm 2.5V$  into  $2k\Omega$  at 1MHz, even on  $\pm 15V$  rails. So how was  $IC_{7C}$  coping on  $\pm 12V$ , with a load of around  $500\Omega$ ? A quick check with a scope at  $IC_7$  pin eight showed that its output – a sine wave swinging entirely positive from 0V upwards – was distinctly poor. The positive peak was nicely rounded but the negative peak at 0V was distinctly pointed, though this does not show up very well in the scope trace.

You can’t get a quart out of a pint pot after all!

### Extending the range

For my requirements, the design is adequate and only remains to be recast in a tidier form than the present breadboard.

But clearly the usable modulating frequency range could be greatly extended by substituting more modern, faster, op-amps in place of  $IC_{7C}$  and  $IC_{7D}$ , and using a faster variable gain amplifier.

To go with current feedback op-amps, the ultimate choice for the variable gain amplifier is obviously yet another  $AD834$ . AM or dsb could then be produced with modulating frequencies up to hundreds of MHz. ■



# M & B RADIO (LEEDS)

THE NORTH'S LEADING USED TEST/EQUIPMENT DEALER

## SIGNAL GENERATORS

MARCONI 2018 80KHZ TO 520MHZ SYNTHESIZED	£750
MARCONI 2008 10KHZ TO 520MHZ INC RF PROBE KIT	£300
MARCONI 2015/2171 SYNCHRONIZER 10MHZ TO 520MHZ	£325
MARCONI 2016 10KHZ TO 120MHZ AM/FM	£200
MARCONI 2015 10MHZ TO 520MHZ AM/FM	£195
HP8683D 2.3GHZ TO 13GHZ OPT001/003 SOLID STATE GENERATOR	£4750
HP3336A SYNTHESIZER/LEVEL GENERATOR	£650
HP8440A 500KHZ TO 512MHZ OPT001	£550
HP8620C SWEEPER MAINFRAMES (AS NEW)	£300
HP8630C/86290B RF PLUG-IN 2GHZ TO 18.6GHZ	£2750
HP4206A 10KHZ TO 1MHZ OSCILLATOR	£750
FARNELL S5G520 10MHZ TO 520KHZ SYNTHESIZED	£400
POLRAD 1106ET 1.8GHZ TO 4.6GHZ WITH MODULATOR	£400
GIGA GRI101A 1GHZ TO 10GHZ PULSE GENERATOR (AS NEW)	£750
SAYROSA MA30 FREQUENCY OSCILLATOR 10HZ TO 0KHZ	£200
RHODE & SCHWARZ SMC1 4.8GHZ TO 12.6GHZ	£450
ADRET 20230A 1MHz SYNTHESIZED SOURCE	£195
HP8672A SYNTHESIZED SIGNAL GENERATOR 2GHZ TO 18GHZ	£6200
HP3586A SELECTIVE LEVEL METER 50HZ TO 32.5MHZ	£1850

## SPECTRUM ANALYSERS

HP8903A 20HZ TO 100KHZ AUDIO ANALYSER	£3000
HP8565A 10MHZ TO 22GHZ SPECTRUM ANALYSER	£4250
B&K 2033 1HZ TO 20KHZ AUDIO ANALYSER	£2750
HP3581A WAVE ANALYSER 15HZ TO 50KHZ (AS NEW)	£850
HP3582A 0.02HZ TO 25.5KHZ DUAL CHANNEL AUDIO ANALYSER	£3000
HP8558B 10MHZ TO 1500MHZ WITH 180T MAINFRAME	£2800
HP1417 8552A/8554B 100KHZ TO 1250MHZ + 8553B 110MHZ UNIT	£1000
UNIT	£1700
HP1827/8557A 10KHZ TO 350MHZ	£950
HP1827/8558B 100KHZ TO 1500MHZ	£1600
HP1417 8553B/8553B 110MHZ WITH 8443A TRACKING GENERATOR	£2000
HP8553B 1HZ TO 110MHZ LATE MODEL ANALYSER PLUG-INS	£200
HP3580A 5KHZ TO 50KHZ AUDIO ANALYSER	£1500
HP3581C SELECTIVE VOLTMETER 15HZ TO 50KHZ	£750
TEXSCAN ALS1 4MHZ TO 1000MHZ ANALYSER	£750
EATON 2075B NOISE GAIN ANALYSER 10MHZ TO 2GHZ	£2000
TEKTRONIX TL13 1KHZ TO 1800KHZ (supplied with scope mainframe)	£2500

## OSCILLOSCOPES

TEKTRONIX 2445A 150MHZ 4 CHANNEL	£1550
TEKTRONIX 2445 150MHZ 4 CHANNEL	£1100
TEKTRONIX 2215 60MHZ 2 CHANNEL	£325
TEKTRONIX 2215 60MHZ 2 CHANNEL	£400
PHILIPS 3305 35MHZ DIGITAL STORAGE	£550
PHILIPS PM3217 50MHZ 2 CHANNEL	£300
PHILIPS PM3244 50MHZ 2 CHANNEL	£450
PHILIPS PM3055 50MHZ 2 CHANNEL	£350
GOULD 5110 100MHZ INTELLIGENT OSCILLOSCOPE	£750
GOULD OS3000 20MHZ 2 CHANNEL SWEEP	£175
LEADER LB034L 40MHZ DELAYED SWEEP	£325
TEKTRONIX SC504/TM503/DMS01 PORTABLE 80MHZ SCOPE/DVM	£600
TEKTRONIX 475 80MHZ	£400
TEKTRONIX 465 100MHZ DUAL TRACE	£345
TEKTRONIX 465B 100MHZ OSCILLOSCOPE	£400
TEKTRONIX 466 100MHZ STORAGE	£395

## HP1722B 275MHZ MICROPROCESSOR CAL MEASUREMENTS

(AS NEW)	£700
HP180 50MHZ 2 CHANNEL (with manual/2 50mhz probes)	£150
TEKTRONIX 7633/7A26/7A13/7B53 200MHZ 4 CHANNEL STORAGE	£600
TEKTRONIX 7603/7A26/7A29/7B53A 1GHZ OSCILLOSCOPE	£750
IWATSUI 556122 100MHZ 4 CHANNEL CURSOR READOUT	£290
KIKUKU C06100 100MHZ 5 CHANNEL	£500
NICOLET 4094A DIGITAL OSCILLOSCOPE (TO CLEAR)	£950
GOULD OS400 100MHZ DIGITAL STORAGE	£195
GOULD OS2508 15MHZ 2 CHANNEL	£95
TEKTRONIX 7704/7A13/7A26/7B15/7B53AN 4 CHANNEL	£500
TEKTRONIX 5103N/510M/5A20M/5A20N OSCILLOSCOPE	£250

## TEST EQUIPMENT

TEKTRONIX 521A PAL VECTOR SCOPE	£750
TEKTRONIX 1411 PAL GENERATOR SCA11/75G11	£1750
SYSTEMS VIDEO 2360 COMPONENT VIDEO GENERATOR	£1500
PHILIPS PM5567 PAL VECTOR SCOPE	£750
HP5005A SIGNATURE MULTIMETER	£495
BRUEL & KJAER 2511 VIBRATION METER	£750
BRUEL & KJAER 2203 PRECISION SOUND LEVEL METER/V80812 FILTER	£450
BRUEL & KJAER 1022 BEAT FREQUENCY OSCILLATOR	£400
BRUEL & KJAER 4709 FREQUENCY RESPONSE ANALYSER	£250
BRUEL & KJAER 2305 LEVEL RECORDER	£235
HP3779A PRIMA MULTIMETER ANALYSER	£600
HP3780A PATTERN GENERATOR/DIGITAL	£350
HP3762A DATA GENERATOR	£350
HP3468D DIGITAL MULTIMETER LCD	£400
HP3466A DIGITAL MULTIMETER LED	£350
HP8750A STORAGE NORMALISER	£395
HP8405A VECTOR VOLTMETER & ACCESSORIES 1000MHZ	£650
HP3400A TRUE RMS VOLTMETER ANALOGUE	£145
HP3403C TRUE RMS VOLTMETER	£150
HP3406A BROADBAND SAMPLING VOLTMETER	£225
HP11683A RANGE CALIBRATOR	£300
HP11667A POWER SPLITTER 18GHZ (NEW)	£500
HP10529A LOGIC COMPARTOR	£85
HP394A VARIABLE ATTENUATOR 1GHZ TO 2GHZ	£85
HP334A DISTORTION METER OPT H15	£250
HP5182A 258MHZ FREQUENCY COUNTER	£125
HP5142A MICROWAVE FREQUENCY COUNTER (OPT 001/003)	£1750
HP8444A TRACKING GENERATOR	£1000
MARCONI 2300B MODULATION METER 120MHZ	£300
MARCONI 2331A DISTORTION FACTOR METER	£200
MARCONI 2432 560MHZ FREQUENCY COUNTER	£150
MARCONI 2432A 560MHZ FREQUENCY COUNTER	£200
MARCONI 2404 ELECTRONIC VOLTMETER 1500MHZ	£65
MARCONI 2403 RF MILLIVOLTMETER 1500MHZ	£95
MARCONI 2910/4 TV LINEAR DISTORTION ANALYSER	£600
MARCONI 2913 TEST LINE GENERATOR + INSERTOR	£600
MARCONI 2914A INSERTION SIGNAL GENERATOR	£600
MARCONI 2306 PROGRAMMABLE INTERFACE UNIT	£450
MARCONI 2700 LCR BRIDGE BATTERY	prices from £495
FARNELL RB103035 ELECTRIC LOAD	£225
FARNELL TOPS 3D TRIPLE OUTPUT DIGITAL PSU	£65
FARNELL B3075 POWER SUPPLY 0-30 VOLT 5 AMP	£190
FARNELL B3070 POWER SUPPLY 0-30 VOLT 20 AMP	£190
FARNELL LAS20 RF AMPLIFIER 1.5MHZ TO 520MHZ	£155
FARNELL TM8 TRUE RMS SAMPLING RF METER (AS NEW) 1 GHZ	£350
FLUKE 3330B PROG CONSTANT CURRENT VOLTAGE CALIBRATOR	£750
FLUKE 103A FREQUENCY COMPARATOR	£295
EXACT 334 PRECISION CURRENT CALIBRATOR	£195

BALLANTINE 6125C PROG TIME/AMPLITUDE TEST SET	£500
HALCYON 500B/521A UNIVERSAL TEST SYSTEM	£500
AVO RM215 L/2 AC/DC BREAKDOWN/IONISATION TESTER	£300
AILTECH 533X-11 CALIBRATOR 1 HP355C/HP355D ATTENUATORS	£400
BIRD TENULINE 8343 100W 6DB ATTENUATORS (NEW)	£100
BIRD TERMALINE 818 90W COAXIAL RESISTOR	£85
BIRD 8329 COAXIAL ATTENUATOR 30db 2000watt cont.	£500
NARDA 7676/150W 6DB ATTENUATORS	£65
NARDA 3001-30 DIRECTIONAL COUPLER 460MHZ TO 950MHZ	£100
NARDA 3022 BI-DIRECTIONAL COUPLER 1GHZ TO 4GHZ	£250
KEFO DP1 PHASE METER 1HZ TO 100KHZ (NEW)	£325
IWATSUI SC7104 10HZ TO 1000MHZ FREQUENCY COUNTER	£275
RACAL 9009 MODULATION METER 30MHZ TO 1500MHZ	£275
RACAL 9903 50MHZ TIMER COUNTER	£95
RACAL 9904M 50MHZ TIMER COUNTER	£145
RACAL 9915 10HZ TO 520MHZ FREQUENCY COUNTER	£150
RACAL 9919 10HZ TO 1100MHZ FREQUENCY COUNTER	£300
RACAL DANA 1999 10HZ TO 1300MHZ FREQ/TIMER COUNTER	£500
RACAL DANA 9000 520MHZ MICROPROCESSING TIMER COUNTER	£250
RACAL DANA 9303 TRUE RMS RF LEVEL METER	£700
RACAL DANA 488 IEEE-STD BUS ANALYSER	£200
RACAL DANA 9302 RF MILLIVOLTMETER 10KHZ TO 1500MHZ	£400
RACAL DANA 1902 THERMAL PRINTER	£150
RACAL 964 TWO TONE GENERATOR SYNTHESIZED	£250
WAYNE KERR CT496 LCR BRIDGE BATTERY PORTABLE	£495
PHILIPS PH8152 DUAL PEN RECORDER	£295
DYMAR 2085 AF POWER METER	£200
TEKTRONIX 528A VIDEO WAVEFORM MONITOR	£300
TEKTRONIX 338 LOGIC ANALYSER 32 CHANNEL 20MHZ	£400
TEKTRONIX 318 LOGIC ANALYSER 16 CHANNEL 50MHZ	£450
SIEMENS U2323 PSOPHOMETER (NEW)	£500
SIEMENS D2108 LEVEL METER 200HZ TO 30MHZ	£650
SIEMENS W2108 LEVEL OSCILLATOR 30MHZ	£650
WANDEL & GOLTERMAN PSS19 LEVEL GENERATOR 25MHZ	£650
SAYROSA AMM AUTOMATIC MODULATION METER 2GHZ	£200
BRUEL & KJAER 2425 ELECTRONIC VOLTMETER 0.5HZ TO 500KHZ	£195
DRANETZ 626A MAINS DISTURBANCE ANALYSER FITTED WITH 6036 interface/6002A dc monitor/6001 line analyzer/6006 ac monitor/6020 by board/ rf monitor	£1250
SCHLUMBERGER 7702 DIGITAL TRANSMISSION ANALYSER	£1250
MARCONI 6950/6910 POWER METER 10MHZ TO 20GHZ	£850
MARCONI 6573A VSWR INDICATOR	£495
HP431A/478A RF POWER METER 10MHZ TO 10GHZ	£600
HP435A/8482H RF POWER METER TO KHZ TO 4.2GHZ	£650
HP435B/8482H RF POWER METER 100KHZ TO 4.2GHZ	£850
HP435B/8481A RF POWER METER 10MHZ TO 10GHZ	£1000
HP436A DIGITAL POWER METER	£650
HP8447D AMPLIFIER 0.1MHZ TO 1300MHZ	£500
HP432A CRYSTAL DETECTOR	£4150
SCD RF AMPLIFIER 10MHZ TO 1000MHZ 10 WATT 40dB	£1000
BIRD COAXIAL ATTENUATOR 500W 30dB	£200

## BULK PURCHASE SPECIALS

BECKMAN DM110 DIGITAL MULTIMETERS WITH CASE/PROBES	£50
SOLARTON 5000 HIGH SPECIFICITY BENCH DVM	£40
AVO 8 MKV MULTIMETERS	£60
BIRD 43 THRU LINE WATTMETERS	£75
SIEMENS PDMS2 PORTABLE LCD RADIATION METER (NEW)	£45
EX GERMAN ARMY PORTABLE RADIATION METERS	£35
FARNELL LFM2 AUDIO OSCILLATORS SINESQUARE	£50
HP431C RF POWER METERS TO 12GHZ HP ATTENUATOR	£50

ALL PRICES PLUS VAT AND CARRIAGE · ALL EQUIPMENT SUPPLIED WITH 30 DAYS WARRANTY

**86 Bishopgate Street, Leeds LS1 4BB**  
**Tel: (0532) 435649 Fax: (0532) 426881**

CIRCLE NO. 132 ON REPLY CARD

# SECOND USER TEST EQUIPMENT & COMPUTERS

- ▶ Broad Product Range?
- ▶ DC to Light?
- ▶ BS5750 Registered?
- ▶ Onsite NAMAS Lab?
- ▶ Sale Or Return?
- ▶ Full Warranty?
- ▶ Part Of Livingston Hire?
- ▶ Outstanding Service?

*No Problem*  
*No Problem*  
*No Problem*  
*No Problem*  
*No Problem*  
*No Problem*  
*No Problem*  
*No Problem*

- ◆ Analytical & Environmental
- ◆ Calibrators
- ◆ Communications Test
- ◆ Component Analysers
- ◆ Computers & Peripherals
- ◆ Digital Design & Test
- ◆ Electrical & Power
- ◆ EMC Test
- ◆ Frequency Counters
- ◆ Noise Source / Measure
- ◆ Oscilloscopes
- ◆ Power Meters
- ◆ Power Supplies
- ◆ Radio Comms
- ◆ Recorders & Data Acquisition
- ◆ Signal Analysers
- ◆ Signal Sources
- ◆ Voltmeters & Multimeters

Call now or check the card for your monthly copy of Carston Direct - Europe's most comprehensive guide to second user Test Equipment and Computers

**081-943 4477** 

2-6 Queens Road, Teddington, TW11 0LR *The Intelligent Alternative to New*

CIRCLE NO. 133 ON REPLY CARD

*What's the Problem?*



Call or write for  
our free catalog!

**Danbar Sales Company**  
14455 N. 79th St. # C, Scottsdale, AZ 85260 USA  
Phone (602) 483-6202 Fax (602) 483-6403

Wanted: Test Equipment  
Immediate cash paid

<p><b>Wandel &amp; Goltermann TSA-1</b> Transmission System Analyzer, 100 Hz to 180 MHz, spectrum analysis, selective level, demodulation, &amp; phase jitter.</p> <p><b>\$ 2250.00</b></p> <p>Same as above but includes network analyzer. <b>\$ 2750.00</b></p>	<p><b>Racal-Dana 1996 Universal Counter</b> DC to 1.3 GHz, 1 nS single shot time interval resolution, 9-digit resolution in 1 second, full GPIB programmability, phase, slew, and duty cycle measurement.</p> <p><b>Special \$ 950.00</b></p>	<p><b>Anritsu MS 420B</b> Network/ Spectrum Analyzer, 10 Hz to 30 MHz, 100 dB dynamic range, built in synthesizer. Measures frequency spectrum, magnitude, phase and delay, 10 Hz to 30 kHz resolution BW, lin/log sweep, sweep markers, CRT readout, IEEE-488 interface, 75 Ohm.</p> <p><b>\$ 2750.00</b></p>
<p><b>Wandel &amp; Goltermann PS 19</b> Level Generator, 80 Hz to 25 MHz, 0.1 Hz resolution, level displayed in dB/dBo or in dBm/dBmO.</p> <p><b>\$ 2850.00</b></p>	<p><b>Racal-Dana 9300</b> True RMS Voltmeter, analog, ac voltmeter, 5 Hz to 60 MHz and a dynamic range of 10 uV to 316 v.</p> <p><b>\$ 350.00</b></p>	<p><b>Tektronix 492 Spectrum Analyzer</b> 50 kHz to 21 GHz, 80 dB dynamic range, has option 02, digital storage. Please call for complete specs.</p> <p><b>\$ 7750.00</b></p>
<p><b>Wandel &amp; Goltermann SPM-19</b> Selective Level Meter, 50 Hz to 25 MHz, high frequency accuracy; maximum resolution 0.1 Hz, absolute or relative level measurements.</p> <p><b>\$ 3850.00</b></p>	<p><b>Racal-Dana 9302</b> True RMS Millivoltmeter, 10 kHz to 1.5 GHz, amplitude range 1 mV to 3 V full scale, LCD readout.</p> <p><b>\$ 650.00</b></p>	<p><b>Hewlett-Packard 6227B</b> 0 to 25 V, 0 to 2 A. Contains two identical, independently adjustable power supplies. A front panel switch selects either independent or tracking operation. New boxed.</p> <p><b>\$ 900.00</b></p>
<p><b>Wandel &amp; Goltermann SG-4</b> Storage Display Unit provides digital image storage for use with the SPM-16 &amp; the SPM-19. Stationary, flickerfree image.</p> <p><b>\$ 1500.00</b></p>	<p><b>Racal-Dana 9303</b> True RMS RF Level Meter, frequency range 10 kHz to 2 GHz, level range of 30 uV to 3V. Basic accuracy of 1%.</p> <p><b>Special \$ 950.00</b></p>	<p>Danbar Sales Company is pleased to offer you quality used test equipment at affordable prices. All equipment is guaranteed for 90 days. All prices listed are in US dollars. We accept Visa and Mastercard. Please call or write for our catalog.</p>
	<p><b>Racal-Dana 9919 UHF Frequency Counter</b> 8 digit, 2 input channels; input (A) 80 MHz to 1 GHz, (B) 10 Hz to 100 MHz.</p> <p><b>\$ 550.00</b></p>	

CIRCLE NO. 134 ON REPLY CARD



**HATELY ANTENNA TECHNOLOGY** GM3HAT

**CROSSED FIELD ANTENNA**

**ELECTRO-MAGNETIC DELAY-LINE RADIATOR**

100 Watt EMDR I £189

The newest and most popular design of Crossed Field Antenna is the Electro-Magnetic Delay-Line Radiator in which three wires constitute a double circuit, in which half the power is phase advanced to initiate a MAGNETIC field, and half the power is delayed to induce an ELECTRIC field. The two fields being therefore adjusted to be in synchronism all along the cable through every RF cycle, create an electro-magnetic RADIO WAVE EMISSION which moves away to space at the velocity of light. A process we have called POYNTING VECTOR SYNTHESIS; Refs. EW+WW March 1989, and December 1990, authors F. M. Kabbary and M. C. Hately and B. G. Stewart.

The EMDR antenna is non-resonant but radiates energy all along its length. The voltages and currents are low in value and safe, so that an amateur, or commercial station, with a restricted site may have it placed anywhere, e.g. inside a loft space, lying on the tiles over a roof, or taped to the outside of a balcony or walkway of a block of flats. At the input to the PHASING UNIT, the system presents a pure resistance of 50 ohms to the source at any of the NINE HF BANDS available to holders of the Class A licence; i.e. 1.8 MHz through to 29.7 MHz. The EMDR receives also.

The EMDR I is 8.5 metres long (28ft) and is useful for stations on upper floors. For use from ground floor to taller buildings there is also a longer version the EMDR 2 being 15.5 metres long (52ft) priced £199 inclusive of VAT and postage.

**LEAFLET or VIDEO DOCUMENTARY £5 Deposit**

In order to explain the THEORY and OPERATION of the Crossed Field Antennas, a leaflet is available on application (telephone 0224 316004 any day 08.30 to 21.30) free of charge. Alternatively a full length video documentary will be lent for a returnable deposit of £5. This contains practical demonstrations and recordings of two-way contacts. Send a cheque or Postal Order to:-

**HATELY ANTENNA TECHNOLOGY** GM3HAT  
1 Kenfield Place, ABERDEEN, ABI 7UW, Scotland, G.B.

CIRCLE NO. 135 ON REPLY CARD

**The MICRO MODULE**  
**A NEW LOW COST controller**  
**that gives you customisation**  
**for as little as £95 one off**

**and that's just the half of it!..**

For users of  
PCs, 8051 &  
68000

**FEATURES**

- 16/32 bit 68307 CPU for fast operation
- Up to 1 Mbyte of EPROM space onboard
- Up to 512Kbyte SRAM space onboard
- 32 Kbyte SRAM fitted as standard
- RS232 serial with RS485 option
- MODBUS & other protocols supported
- Up to 22 digital I/O channels
- 2 timer/counter/match registers
- I<sup>2</sup>C port or Mbus & Watch dog facilities
- Large Proto-typing area for user circuits
- Up to 5 chip selects available
- Program in C, C++, Modula-2 & Assembler
- Real Time multitasking Operating System
- OS9 or MINOS with free run time license option
- Manufacturing available even in low volumes
- A full range of other Controllers available

CIRCLE NO. 136 ON REPLY CARD

**P.C. 'C' STARTER PACK AT ONLY £295**

The Micro Module will reduce development time for quick turnaround products/projects and with the P.C. 'C' Starter pack allow you to start coding your application immediately, all drivers and libraries are supplied as standard along with MINOS the real time operating system all ready to run from power on. The 'C' Starter pack includes: A Micro Module with 128 Kbyte SRAM, PSU, Cables, Manuals, C compiler, Debug monitor ROM, Terminal program, Downloader, a single copy of MINOS, Extensive example software, and free unlimited technical support all for £295.

**BMS**

Cambridge Microprocessor  
Systems Limited

Unit 17-18 Zone 'D', Chelmsford Rd. Ind. Est.,  
Great Dunmow, Essex. U.K. CM6 1XG  
Phone 0371 875644 Fax 0371 876077



# SEETRAX CAE - RANGER - PCB DESIGN

## Ranger1 £100

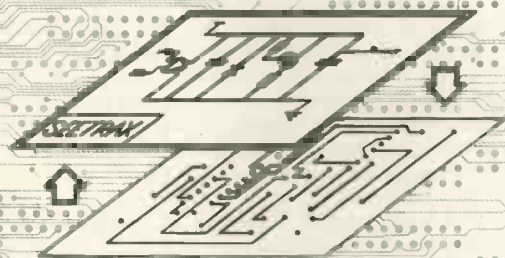
- \* Schematic capture linked to PCB
- \* Parts and wiring list entry
- \* Outline (footprint) library editor
- \* Manual board layout
- \* Full design rule checker
- \* Back annotation (linked to schematic)
- \* Power, memory and signal autorouter - £50

## Ranger2 £595

- All the features of Ranger1 plus
- \* Gate & pin-swapping (linked to schematic)
- \* Pick & highlight
- \* Auto track necking
- \* Copper flood fill
- \* Power planes (heat-relief & anti-pads)
- \* Top-up & retry autorouter

## Ranger3 £3500

- All the features of Ranger2 plus
- \* UNIX or DOS versions
- \* 1 Micron resolution and angles to 1/10th degree
- \* Hierarchical or flat schematic
- \* Unlimited design size
- \* Any-shaped pad
- \* Split power planes
- \* Optional on-line DRC
- \* 100% rip-up & retry, push & shove autorouter



All systems upward compatible. Trade-in deals available.

Call **Seetrax CAE** for further information/demo packs  
Tel 0705 591037 Fax 0705 599036

Seetrax CAE, Union Dairy House, Broadway Lane,  
Lovedean, Hampshire, PO8 0SG

All trademarks acknowledged

### Outputs to:

- \* 9 and 24 pin dot-matrix printers
- \* HP Desk/Laser Jet, Canon BJet, Postscript (R3 only)
- \* HP-GL, Houston Instruments plotters
- \* Gerber photoplotters
- \* NC Drill Excellon, Sieb & Meyer
- \* DXF

CIRCLE NO. 137 ON REPLY CARD

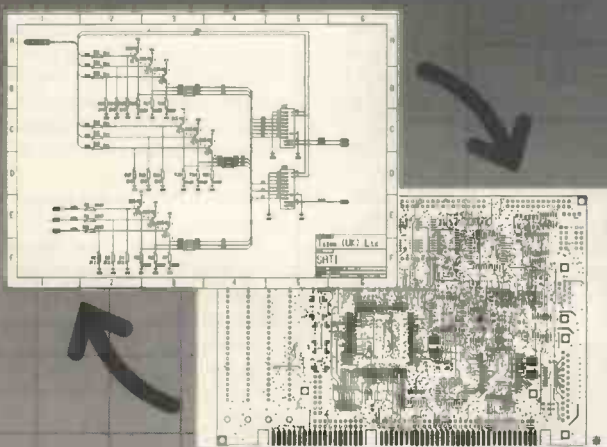
Finally an upgradeable PCB CAD system to suit any budget ...

## Board Capture

### BoardCapture - Schematic Capture

- \* Direct route link to BoardMaker2
- \* Partials & revision with part history
- \* Full embedded wiring and connections
- \* Single-sheet multi-page and hierarchical design
- \* Shaded routing
- \* Unlimited wire, pad, and connection
- \* Dynamic connectivity simulation
- \* Automatic on-line annotation
- \* Integrated on-line fly library editor
- \* Context sensitive editing
- \* Extensive component-based power control
- \* Back annotation from BoardMaker2

£395



## Board Maker

- BoardMaker1 - Entry level
- \* Full set of standard tools
- \* 9 and 24 pin dot matrix
- \* Layer markers support
- \* 24 pin dot matrix drill output
- \* Gerber files
- \* Layer markers and assembly drawing

£95

### BoardMaker2 - Advanced level

- \* Full set of BoardMaker1 plus
- \* Full netlist support - Orcad, Simulink, Tspice, Cadstar
- \* Full Design Rule Checking - mechanical & electrical
- \* No board modification with the software
- \* Component libraries with test simulation
- \* Report generator - Customer ABC, BOM
- \* Thermal power plane support with full DRC

£295

NEW

## Board Router

### BoardRouter - Gridless autorouter

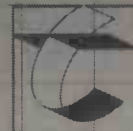
- \* Simultaneous multi-layer routing
- \* SMD and analogic support
- \* Full interrupt, resume, pan and zoom while routing

£200

### Output drivers - Included as standard

- \* Printers - 9 & 24 pin Dot matrix, HPLaserjet and PostScript
- \* Penplotters - HP, Graphic, Roland & Houston
- \* Photoplotters - All Gerber 3X00 and 4X00
- \* Excellon NC Drill 9 Annotated drill drawings (BM2)

Call for info or full  
evaluation kit  
Tsien (UK) Limited  
Tel (0354) 695959  
Fax (0354) 695957



tsien

Tsien (UK) Ltd, Aylooby House, Wenny Road, Chatterel, Cambridge PE16 8UT

CIRCLE NO. 138 ON REPLY CARD

# LETTERS

Letters to "Electronics World + Wireless World" Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

## Split decision

I think there is scope for confusion in Norm Dye and Helge Granberg's article concerning hybrids (Using RF Transistors: Combined efforts bring power pay-offs, August, 1994). In particular, the rat-race and Wilkinson hybrids are classed as 90°, or quadratic couplers (p. 696).

I thought that a quadratic coupler or hybrid was one which split a single input into two outputs differing in phase (from each other) by 90°; or combined two inputs, differing in phase by 90°, into a single output.

The line coupler and branch line coupler come into this category, but the rat-race and Wilkinson do not. It would have been helpful if Figs. 4, 5 and 6 could have been labelled to show the relative phases of inputs which enable the hybrids to operate with the particular input and output ports. This would have indicated the differences clearly.

In the two diagrams of the hybrid shown in Fig 3, the phase of the output on the right hand side should be -90° not 90°, and in the description of the operation of the rat-race, I think it helps to substitute "combiner" with "splitter" at one point, but I still remain slightly confused.

If any reader wants to know the

theoretical bandwidths and other characteristics of these and other hybrids when splitting or combining, I would recommend they refer to 'Hybrid networks and their uses in rf circuits' (*The Radio and Electronic Engineer*, Vol 54, No 11/12. pp.473-489, Nov/Dec 1984).

**Dick Manton**  
Surrey

## Listening post

Contrary to Jerry Mead's view (*Letters*, Nov 93) an open mind is not "the most valuable tool in any scientific research project". Of greater importance are a critical mind, lots of hard work and a thorough knowledge of the technology of the relevant fields – usually called "theory" but mostly based on fact.

An open mind is important for researchers to realise that their endeavours may be misdirected, but I feel sure Jerry would not suggest we need to keep an open mind on the phlogiston theory or the concept of a flat earth.

Jerry says he ranks "developmental listening" (whatever that is, he does not say) "as being as valid in the design of an amplifier as the quest for product safety, long term reliability, applications suitability and an acceptable cost of

production". But while safety, reliability, suitability and cost are important engineering constraints in the design of audio amplifiers, they are secondary to output power, sensitivity, frequency response and distortion – all of which are vital to audible performance.

Back in January 1978, in *Wireless World*, Peter Baxandall claimed to have designed an amplifier that "was not listened to at all, but subsequently came top in an independent subjective assessment of many competitive designs from various countries"; and that "Quad... adopt the attitude that if you understand what you are doing thoroughly enough, there is no need for listening tests during the design and development of amplifiers".

Jerry may argue that this is ancient history but in the intervening years I have heard no plausible reason why this should not still be true.

Like Doug Self (*Letters*, January, 1994), I have little confidence in Jerry Mead's experimental procedure which shows scant regard for established testing methods. He would do well to take up some of the recommendations given in Lipshitz and Vandekooy's excellent paper ('The great debate: subjective evaluation', *J Audio Eng Soc*, Vol 29, No 7/8, July/August, 1981).

It is too easy to trick, even experienced, listeners into believing that they hear non-existent artefacts during audio testing. Late last year I took part in a listening test to determine the audible effects of different audio cables. The test was inconclusive, and though no-one demonstrated any real consistency in identifying the correct cable the best results were from one subject who readily admitted he was guessing.

For the test proper we listened to some modern music with which I was unfamiliar. It was spectrally fairly simple in that it had little dynamic nature and few transients, but it sounded sweet enough.

After the test I asked if I could play a CD of my own. The more transient nature of the piece clearly showed that the sound was distorted and was very unpleasant – those who owned the gear probably thought so too, judging by their reaction.

The equipment was based around an ME pre-amp and power amp,

designed, I am told, to exhibit fairly high levels of distortion (a few percent). With classical music, it was quite obvious and there was no doubt that a \$100 personal cassette player could easily deliver superior performance.

My point is that the perceived performance of any audio equipment depends strongly on the music played. It also shows the futility of increasing the distortion levels in audio equipment to suit the personal tastes of a few, since this can only be done at the cost of reducing the suitability of that equipment for general use.

I have been following the debate over the subjectivists' claims for many years. Perhaps the most annoying aspect is how often they claim to have discovered new 'sonic' artefacts – usually due to poor experimental method – with new theories sought to explain those artefacts while ignoring perfectly valid theories which are already tried and tested.

Such ignorance will continue to attract scorn and their claims are likely to be dismissed with 'facility and derision' for some years to come.

**Phil Dennis**  
University of Sydney  
Australia

## Crossover critic

In discussions about the merits of precious-metal loudspeaker cables, I cannot recall anyone raising the issue of crossover networks.

The path between amplifier and listener contains an easily measured performance limiter – the impedance of the crossover network – rising to several ohms. It is likely to exceed the cable loop impedance at only a few hundred hertz either side of the crossover point and the result is frequency-dependent drive-unit damping which significantly affects transient response.

Based on this I have a number of questions:

Why is the 'golden ear' brigade (who appear to detect small changes in cable impedance) not clamouring for systems having the minimum of impedance between amplifier and drive unit?;

why are cable manufacturers not insisting on the removal of filters

## Radar replication

George Pickworth's account of the coherer is an outstanding example of the way that technical history is enhanced by modelling ancient hardware. I should like to suggest an expansion of his work.

It seems generally accepted that the first working radar was made by Christian Hulsmeyer in 1904. His patent describes a spark transmitter and a conventional coherer mounted one above the other – the decoherer was coupled to an alarm bell which rang when a signal was received. A description of the apparatus appeared in *Wireless World* under the title 'The Telemobilscope'.

There seems little doubt that the device would not work if installed on board ship if for no other reason than that the coherer would almost certainly be reset by vibration (it is interesting to note that the large induction coil was mounted in gimbals to keep the whole assembly vertical; Hulsmeyer's is certainly the first radar to use a stabilised antenna).

A demonstration given in Rotterdam in 1904 seems to have persuaded members of a maritime convention that the Telemobilscope worked and had a range of around 3km, yet examination of the patent specifications casts considerable doubt on Hulsmeyer's claims.

Replication is the only way to establish if Hulsmeyer deserves his place in the first chapter of so many books published since WWII.

**Harold W Shipton**  
St Louis  
USA



## £1 BARGAIN PACKS

In fact...cheaper than £1 because if you buy 10 you can choose one other and receive it free!

- 1 x 12v Stepper Motor. 7.5 degree. Order Ref: 910.
- 1 x 10 pack Screwdrivers. Order Ref: 909.
- 2 x 5 amp Pull Cord Ceiling Switches. Brown. Order Ref: 921.
- 5 x reels Insulation Tape. Order Ref: 911.
- 4 x 14mm Ball-races. Order Ref: 912.
- 2 x Cord Grip Switch lamp Holders. Order Ref: 913.
- 1 x DC Voltage Reducer. 12v-6v. Order Ref: 916.
- 1 x 10 amp 40v Bridge Rectifier. Order Ref: 889.
- Lightweight Stereo Headphones. Moving coil so superior sound. Order Ref: 896.
- 2 x 25W Crossovers. For 4ohm loudspeakers. Order Ref: 22.
- 2 x Nicad Constant Current Chargers. Easily adaptable to charge almost any nicad battery. Order Ref: 30.
- 18v-0-18v 10va Mains Transformer. Order Ref: 813.
- 2 x White Plastic Boxes. With lids, approx. 3" cube. Lid has square hole through the centre so these are ideal for light operated switch. Order Ref: 132.
- 2 x Reed Relay Kits. You get 8 reed switches and 2 coil sets. Order Ref: 148.
- 12v-0-12v 6va Mains Transformer. PCB mounting. Order Ref: 938.
- 1 x Big Pull Solenoid. Mains operated. Has 1/2" pull. Order Ref: 871.
- 1 x Big Push Solenoid. Mains operated. Has 1/2" push. Order Ref: 872.
- 1 x Mini Mono Amp. 3W into 4 ohm speaker or 1W into 8 ohm. Order Ref: 495.
- 1 x Mini Stereo 1W Amp. Order Ref: 870.
- 15V DC 150ma PSU. Nicely cased. Order Ref: 942.
- 1 x In-Flight Stereo Unit is a stereo amp. Has two most useful mini moving coil speakers. Made for BOAC passengers. Order Ref: 29.
- 1 x 0-1mA Panel Meter. Full vision fact 70mm square. Scaled 0-100. Order Ref: 756.
- 2 x Lithium Batteries. 2.5V penlight size. Order Ref: 874.
- 2 x 3m Telephone Leads. With BT flat plug. Ideal for phone extensions, fax, etc. Order Ref: 552.
- 1 x 12V Solenoid. Has good 1/2" pull or could push if modified. Order Ref: 232.
- 4 x In-Flex Switches. With neon on/off lights, saves leaving things switched on. Order Ref: 7.
- 2 x 6V 1A Mains Transformers. Upright mounting with fixing clamps. Order Ref: 9.
- 2 x Humidity Switches. As the air becomes damper, the membrane stretches and operates a micro switch. Order Ref: 32.
- 5 x 13A Rocker Switch. Three tags so on/off, or changeover with centre off. Order Ref: 42.
- Mini Cassette Motor. 9v. Order Ref: 944.
- 1 x Suck or Blow-Operated Pressure Switch. Or it can be operated by any low pressure variation such as water level in tanks. Order Ref: 67.
- 1 x 6V 750mA Power Supply. Nicely cased with mains input and 6V output lead. Order Ref: 103A.
- 2 x Stripper Boards. Each contains a 400V 2A bridge rectifier and 14 other diodes and rectifiers as well as dozens of condensers, etc. Order Ref: 120.
- 12 Very Fine Drills. For PCB boards etc. Normal cost about 80p each. Order Ref: 128.
- 5 x Motors for Model Aeroplanes. Spin to start so needs no switch. Order Ref: 134.
- 6 x Microphone Inserts. Magnetic 400 ohm, also act as speakers. Order Ref: 139.
- 6 x Neon Indicators. In panel mounting holders with lens. Order Ref: 180.
- 1 x In-Flex Solderstat. Keeps your soldering iron etc always at the ready. Order Ref: 196.
- 1 x Mains Solenoid. Very powerful as 1/2" pull, or could push if modified. Order Ref: 199.
- 1 x Electric Clock. Mains operated. Put this in a box and you need never be late. Order Ref: 211.
- 4 x 12V Alarms. Makes a noise about as loud as a car horn. All brand new. Order Ref: 221.
- 2 x (6"x4") Speakers. 16 ohm 5 watts, so can be joined in parallel to make a high wattage column. Order Ref: 243.
- 1 x Panostat. Controls output of boiling ring from simmer up to boil. Order Ref: 252.
- 2 x Oblong Push Switches. For bell or chimes, these can switch mains up to 5A so could be foot switch if fitted in pattress. Order Ref: 263.
- 50 x Mixed Silicon Diodes. Order Ref: 293.
- 1 x 6 Digit Mains Operated Counter. Standard size but counts in even numbers. Order Ref: 28.
- 2 x 6V Operated Reed Relays. One normally on, other normally closed. Order Ref: 48.
- 1 x Cabinet Lock. With two keys. Order Ref: 55.
- 6 1/2" 8 ohm 5 watt Speaker. Order Ref: 824.
- 1 x Shaded Pole Mains Motor. 3/4" stack, so quite powerful. Order Ref: 85.
- 2 x 5 Aluminium Fan Blades. Could be fitted to the above motor. Order Ref: 86.
- 1 x Case. 3 1/2x2 1/4x1 1/4 with 13A socket pins. Order Ref: 845.
- 2 x Cases. 2 1/2x2 1/4x1 1/4 with 13A pins. Order Ref: 565.
- 4 x Luminous Rocker Switches. 10A mains. Order Ref: 793.
- 4 x Different Standard V3 Micro Switches. Order Ref: 340.
- 4 x Different Sub Min Micro Switches. Order Ref: 313.

## BARGAINS GALORE

**Infra Red Controller.** Made from Thorn TV sets but suitable for other control purposes. Fully built and ready to operate, real bargain, £2. Order Ref: 2P304.

**Half Effect.** Give positive or negative pulses when magnet passes over. Mounted on small PCB, 2 for £1. Order Ref: 1032.

**Digital Multi Tester.** 30 range, model no 3800, normal price £40, our price £25. Order Ref: 25P14. Brand new and guaranteed.

**Water Pump** with spindle for operation by portable drill, £5. Order Ref: 5P240.

**Three More Transformers.** Order Ref: 4P81 is a 12V-0-12V 40W, clamp mounted, price £4 each less 10% for 10 or more. Order Ref: 5P236 is a 43V at 2.4A, frame mounted, heavy construction, will withstand considerable overloads, price £5. Order Ref: 3P181 is a 12V 3A frame mounting type but without the frames, price £3. We have tested this and find it quite suitable for 50W lamps.

**Multi Voltage Auto-Transformer.** Could be used to give 350W at 115V for operating regular 115V equipment or it could give this same current at 85V, 120V or 130V. Another use for it is to boost the output from a long line. Could give a 30V or 50V boost up to 300W. Probably has many other uses for its outputs are 85V, 115V, 120V, 130V, 200V, 220V and 240V. A big transformer, price £4. Order Ref: 4P79.

**If You Use An Inverter** to operate radios or TV and similar frequency controlled equipment, then it is advisable to know the frequency of the inverter, otherwise this and/or the equipment it operates can be damaged. We have 100mm square faced panel meters which electronically display the frequency of the supply, providing it is between 45 and 55Hz. Really top class instrument, price £15. Order Ref: 15P19.

**Mains Klaxon Type Alarm.** Very loud output but adjustable. Completely encased, shelf or wall mounting, £5. Order Ref: 5P226.

**12V 10A Switch Mode Power Supply** for only £9.50 and a little bit of work because you have to convert our 135W PSU. Modifications are relatively simple - we supply instructions. Simply order PSU Ref: 9.5P2 and request modification details, price still £9.50.

**Speed Controller for 12v DC Motors.** Suitable for motors with horse powers up to one third and drawing currents up to 30A. Gives very good control and speed. Uses mosfets and is based on a well tried circuit which appeared in the *Model Engineer* some time ago. The complete kit with case and on/off switch is available, price £18. Order Ref: 18P8.

**Fig 8 Flex.** Fig 8 flat white pvc, flexible with 4 sq. mm cores. Ideal for speaker extensions and bell circuits. Also adequately insulated for mains lighting. 50m coil £2. Order Ref: 2P345. 12m coil £1. Order Ref: 1014.

**Friedland Underdome Bell.** Their Ref: 792. A loud ringer but very neat, 3" diameter, complete with wall fixing screws, £5. Order Ref: 5P232.

**12v 10amp Switch Mode Power Supply.** For only £9.50 and a little bit of work because you have to convert our 135W PSU. Modifications are relatively simple - we supply instructions. Simply order PSU Ref: 9.5P2 and request modification details. Price still £9.50.

**Medicine Cupboard Alarm.** Or it could be used to warn when any cupboard door is opened. The light shining on the unit makes the bell ring. Completely built and neatly cased, requires only a battery. £3. Order Ref: 3P155.

**Don't Let It Overflow!** Be it bath, sink, cellar, sump or any other thing that could flood. This device will tell you when the water has risen to the pre-set level. Adjustable over quite a useful range. Neatly cased for wall mounting, ready to work when battery fitted. £3. Order Ref: 3P156.

**Very Powerful Mains Motor.** With extra long (2 1/2") shafts extending out each side. Makes it ideal for a reversing arrangement for, as you know, shaded pole motors are not reversible. £3. Order Ref: 3P157.

**Solar Panel Bargain.** Gives 3v at 200mA. Order Ref: 2P324.

### £1 Super Bargain

12V axial fan for only £1, ideal for equipment cooling, brand new, made by West German company. Brushless so virtually everlasting. Needs simple transistor drive circuit, we include diagram. Only £1. Order Ref: 919. When we supply this we will include a list of approximately 800 of our other £1 bargains.

**40W-250W Light Dimmers** On standard plate to put directly in place of flush switch. Available in colours, green, red, blue and yellow. £2.50. Order Ref: 2.5P9. Or on standard 3x3 cream metal switch plate, £3. Order Ref: 3P174.

**45A Double Pole Mains Switch.** Mounted on a 6x3 1/2 aluminium plate, beautifully finished in gold, with pilot light. Top quality, made by MEM. £2. Order Ref: 2P316.

**Touch Dimmers 40W-250W,** no knob to turn, just finger on front plate, will give more, or less light, or off. Silver plate on white background, right size to replace normal switch £5. Order Ref: 5P230.

### Motorise that Trolley!

You could with Sinclair C5 1/3rd hp 12v battery motor  
Still available, price £21. Order Ref: 21P1

**12/24 DC Solenoid.** The construction of this is such that it will push or pull. With 24V this is terrifically powerful but is still quite good at 12V. £1. Order Ref: 877.

**Don't Stand Out In The Cold** Our 12m telephone extension lead has a flat BT socket one end and flat BT plug other end, £2. Order Ref: 2P338.

**20W 5" 4 Ohm Speaker** mounted on baffle with front grille, £3. Order Ref: 3P145. Matching 4 ohm 20W tweeter on separate baffle, £1.50. Order Ref: 1.5P9.

### LCD 3 1/2 Digit Panel Meter

This is a multi range voltmeter/ammeter using the A-D converter chip 7106 to provide 5 ranges each of volts and amps. Supplied with full data sheet. Special snip price of £12. Order Ref: 12P19.

**Telephone Extension Wire** 4 core correctly colour coded, intended for permanent extensions, 25m coil, £2. Order Ref: 2P339.

**High Power Switch Mode PSU.** Normal mains input, 3 outputs: +12V at 4A, +5V at 16A and -12V at 1/2A. Completely enclosed in plated steel case. Brand new. Our special offer price of £9.50. Order Ref: 9.5P1.

**Phillips 9" High Resolution Monitor.** Black and white in metal frame for easy mounting. Brand new, still in maker's packing, offered at less than price of tube alone, only £15. Order Ref: 15P1.

**High Current AC Mains Relay** This has a 230v coil and changeover switch rated at 15A with PCB mounting with clear plastic cover. £1. Order Ref: 965.

## BARGAINS GALORE

**Ultra Thin Drills,** actually 0.3mm. To buy these regular costs a fortune. However, these are packed in half dozens and the price to you is £1 per pack, Order Ref: 797B.

**You Can Stand On It!** Made to house GPO telephone equipment, this box is extremely tough and would be ideal for keeping your small tools in, internal size approx. 10 1/2"x4 1/2"x6" high. Complete with carrying strap, price £2. Order Ref: 2P283B.

**Ultra Sonic Transducers.** Two metal cased units, one transmits, one receives. Built to operate around 40kHz. Price £1.50 the pair, Order Ref: 1.5P/4.

**Power Supply with Extras.** Mains input is fused and filtered and the 12V DC output is voltage regulated. Intended for high class equipment, this is mounted on a PCB and, also mounted on the board but easily removed, are two 12V relays and Piezo sounder, £3. Order Ref: 3P80B.

**Insulation Tester with Multimeter.** Internally generates voltages which enable you to read insulation directly in megohms. The multimeter has four ranges, AC/DC volts; 3 ranges DC milliamperes, 3 ranges resistance and 5 amp range. These instruments are ex-British Telecom but in very good condition, tested and guaranteed OK, probably cost at least £50, yours for only £7.50 with leads, carrying case £2 extra. Order Ref: 7.5P/4.

**This instrument** slightly faulty but movement and casing guaranteed okay. Supplied complete with circuit diagram, £3. Order Ref: 3P176.

**Mains Isolation Transformer.** Stops you getting "to earth" shocks. 230V in and 230V out. 150 watt, £7.50. Order Ref: 7.5P/5 and a 250W version is £10. Order Ref: 10P97.

**Mains 230V Fan.** Best make "PAPST", 4 1/2" square, metal blades, £8. Order Ref: 8P8.

**2MW Laser.** Helium neon by Philips, full spec. £30. Order Ref: 30P1. Power supply for this in kit form with case is £15. Order Ref: 15P16, or in larger case to house tube as well £18. Order Ref: 18P2. The larger unit, made up, tested and ready to use, complete with laser tube £69. Order Ref: 69P1.

**12v 8ohm speaker,** only £1.50 and waterproof.

**Solar Charger.** Holds 4AA nicads and recharges these in 8 hours, in very neat plastic case £6. Order Ref: 6P3.

**Ferrite Aerial Rod.** 8" long x 3/8" diameter, made by Mullard. Complete with two coils, 2 for £1. Order Ref: 832P.

**Air Spaced Trimmer Caps.** 2-20pf. ideal for precision tuning UHF circuits, 4 for £1. Order Ref: 818B.

**Modem Amstrad FM240** As new condition but customer return, so you may need to fault find, £6. Order Ref: 6P34.

**Amstrad Power Unit.** 13.5V at 1.9A or 12V at 2A encased and with leads and output plug, normal mains input £6. Order Ref: 6P23.

**80W Mains Transformer.** Two available, good quality, both with normal primaries and upright mounting, one is 20V 4A, Order Ref: 3P106 and the other 40V 2A, Order Ref: 3P107, only £3 each.

**Project Box.** Size approx. 8"x4"x1 1/2" metal, sprayed grey, loured ends for ventilation otherwise undrilled. Made for GPO so best quality, only £3 each, Order Ref: 3P74.

**Sentinel Component Board** Amongst hundred of other parts, this has 15 ICs, all plug in so do not need soldering. Cost well over £100, yours for £4. Order Ref: 4P67.

**Sinclair 9V 2.1A Power Supply** Made to operate the 138K Spectrum Plus 2, cased with input and output leads. Originally listed at around £15, are brand new, our price is only £3. Order Ref: 3P151.

**Experimenting with Valves.** Don't spend a fortune on a mains transformer, we can supply one with standard mains input and secs. of 250-0-250V at 75mA and 6.3V at 3A, £5. Order Ref: 5P167.

**15W 8 Ohm 8" Speaker & 3" Tweeter.** Made for a discontinued high quality music centre, gives real hi-fi and only £4 per pair, Order Ref: 4P57.

**Water Pump.** Very powerful, mains operated, £10. Order Ref: 10P74.

**0-1mA Full Vision Panel Meter.** 2 3/4" square, scaled 0-100 but scale easily removed for re-writing, £1 each, Order Ref: 756.

**VU Meter.** Illuminate this from behind becomes on/off indicator as well, 1 1/2" square, 75 each, Order Ref: 366.

**Amstrad Keyboard Model KB5** This is a most comprehensive keyboard, having over 100 keys including, of course, full numerical and qwerty. Brand new, still in maker's packing, £5. Order Ref: 5P202.

**1 RPM Motor.** This is only 2W so will not cost much to run. Speed is ideal for revolving mirrors or lights. £2. Order Ref: 2P328.

**Unusual Solenoid.** Solenoids normally have to be energised to pull in and hold the core, this is a disadvantage where the appliance is left on for most of the time. We now have magnetic solenoids which hold the core until a voltage is applied to release it. £2. Order Ref: 2P327.

**Mains Filter.** Resin impregnated, nicely cased, pcb mounting. Order Ref: 2P315.

**200VA Mains Transformer.** Secondary voltages 8v-0-8v. So you could have 16v at 12A or 8v at 25A. Could be ideal for car starter charger, soil heating, spot welding, carbon rod welding or driving high powered amplifiers etc. £15. Order Ref: 15P51.

**Prices include VAT.** Send cheque/postal order or ring and quote credit card number. Add £3 post and packing. Orders over £25 post free.

## M&B ELECTRICAL SUPPLIES LTD

Pilgrim Works (Dept. WW),  
Stairbridge Lane, Bolney,  
Sussex RH17 5PA

Telephone (0444) 881965 -  
phone for Fax  
Callers to 12 Boundary Road,  
Hove, Sussex



which severely limit any improvement their superbly-constructed products may give?; why are amplifier designers, offering 'damping factors' of thousands measured at the output terminals, not concerned that you are lucky to get a damping factor of five measured at the drive unit?, and why do loudspeaker manufacturers care so little about the transient response of their products that they sacrifice damping for the sake of convention in the placement of filters?

Current technology allows systems to be constructed with one power amplifier for each driver, tailored to the needs of bass, middle, treble units. All crossover networks can be organised at the amplifier inputs, with each drive unit connected direct to an amplifier output. Such systems achieve maximum frequency-

## Busman's I<sup>2</sup>C kits

Following publication of 'Busman's guide to I<sup>2</sup>C' (*EW+WW*, June, pp.479-485), we are offering *EW+WW* readers the *Cameo* development board at the reduced cost of £99 plus vat and delivery (total cash-with-order price including £5 delivery and £18.20 vat is £122.20). The board normally costs £187.41 (inc vat). An information pack giving full details of the board's functions can also be obtained by sending a C4 sae with a £0.57 stamp.

As readers will appreciate, the *Cameo* board allows design and development of 8051 programs, and contains the powerful Philips 80C552 plus monitor prom and up to 32K of user ram. Our offer, which lasts until the end of December, includes a user manual, circuit diagram, and disc with *Cameo WorkBench* comms and example programs. Now for the mistakes. Readers should also note that:

Page 481, Fig. 1, the test for the last data byte sets SDA high for both true and false. There should be an ACK for every byte except the last data byte (Set SDA low ACK if yes).

Page 482, for communications with the *Cameo* board, the comms program need not be *procomm*, any *RS232* comms package will do.

Page 482, the internal registers on frequency synthesiser *TSA6057* are shown in hex, but the base 16 figures after each data byte should be in subscript to avoid confusion: eg 40<sub>16</sub> instead of 4016.

**M B Button**  
Technical Director TDR Ltd  
29 The Dawneys  
Crudwell, Malmesbury  
Wiltshire SN16 9HE  
Tel 0666-577464

independent damping, and incidentally allow complete overload protection for the drivers. So if you really can tell the difference between bell-wire and gold-plated super conductors, then the improvement with this arrangement will be absolutely dazzling.

**Wal Hensby**  
Essex

## Historical insight

RL Tuft's reference to speakers driven by moving-iron and balanced-armature (iron) movements (*Letters*) made me wonder if he also remembers the inductor-dynamic-movements, two-iron armatures, producing somewhat better low-frequency response than the other two types.

Back in the late 1920s and early thirties, many of us used to make our own cones, or other diaphragms with suitable frames or mountings for the speaker assembly. We described our interest as high quality sound reproduction, as we did when we progressed to moving coil drives, initially with dc-energised magnets, often at 6V from accumulators or from dc mains supply at 200-230V.

We aspired to owning a PG Voight MC speaker unit - energised in those days by dc - though a very fine example with a permanent magnet came from Ferranti, the Ferranti *M1*. It received a good review in *Wireless World* at that time, with pretty even response up to at least 2000cps.

Ex BBC engineer PR Turner, with a Mr Hartley, produced an interesting unit, a permanent magnet with plastic, brown Bakelite sheet, hand-made into a cone. This worked well, with good low frequency output, in a suitable enclosure, and plenty of hf.

The Hartley Turner MC improved units allowed quite high quality sound to be reproduced from the main medium-wave BBC transmitters. Unfortunately, after dark, a filter was needed to reduce the effect of the accompanying 10kHz whistle caused by the carrier beating with an adjacent transmitter - unless located fairly close to the desired transmitter.

From late 1937 a somewhat better source became available, sound from Alexander Palace and its television signals. The result was good and I must thank the 'magic' of Alan Blumlein at EMI labs, Hayes, for that pleasure.

I am still an enthusiast for high-quality sound reproduction and my custom-made speakers, making changes from time to time. I keep a pair of Peter Walkes *ELS63s* just for reference.

Finally, I must mention my interest in Douglas Self's work. I often wonder what is his opinion of the Quad 405-2 circuitry. I have

## Discrete behaviour

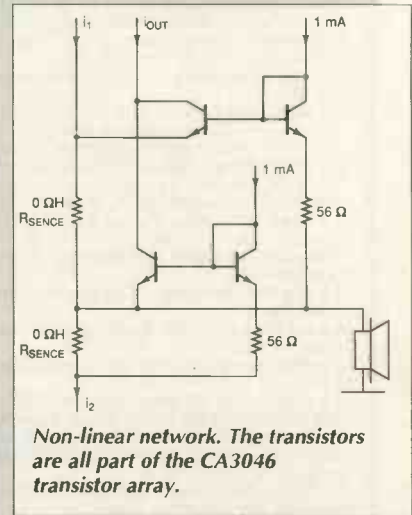
Douglas Self is correct (*Letters*, August 1994). The circuits described in the references of my previous letter (June) are unsuitable for a discrete amplifier. But I would like to point out that in my original letter I described an output stage of an amplifier which consisted of discrete components and a CA3046 transistor array. This output stage uses the non-linear common-mode loop technique.

Unfortunately, my letter was too long and this part was not published.

As an alternative, instead of the harmonic mean I have used a different non-linear function which gives similar results but is easier to implement. In the non-linear network (see figure) the output current is approximately proportional to  $\exp(-c.i_1) + \exp(-c.i_2)$ , where  $c = qR_{\text{sense}}/kT$  and  $i_1$  and  $i_2$  are the currents through the output transistors. The common-mode loop forces the output current of the network to remain constant.

I would be happy to send Douglas Self the complete amplifier schematic and a short description.

**Marcel van de Gevel**  
Haarlem  
The Netherlands



modified slightly so that I have and, frankly, find these amplifiers difficult to fault. Again I have another high grade mosfet unit as a comparative assessment.

I moved to Scarborough in 1989 from the south but have not yet encountered anyone who appears to be a contemporary of mine. I look forward to making more contacts.  
**Harry Dix**  
Scarborough

## Big science squashes little projects

I agree with R Burfoot (*Letters*, July) that during the past few years, the electronics industry has declined. But it would be grossly unfair to blame the Ministry of Defence. If it had not been for government contracts, inertial navigation, radar and many other major developments might not have taken place.

The tax-payer's money was spent wisely and the national investment has already been returned a thousand-fold.

So what can we do now to halt the decline in electronics?

One answer might be for Government to award contracts for small-but-promising civil projects - studies in robotics, laser technology, artificial intelligence, navigation etc.

But are today's government research funds being wisely spent? The UK, like the USA, has embarked on prestigious but costly research programmes in big science.

As a consequence, small industries have been starved of funds.

To take an example from the US, where the government spent \$2-billion on an 86km tunnel for the super-conducting super collider only to have the project eventually cancelled by Congress. Surely, there are better ways of spending taxpayers money than seeking a Grand Unified theory or looking for new particles, gravity waves, black holes and dark matter.

The hard fact is that in the short term, big science projects - worthy as they are - are most unlikely to create work or generate wealth. While we wait, our industry is dying.

**John Ferguson**  
Camberley

## Fourier dice

Of course R H Pearson (*Letters*, August) is quite right - formally, but in my letter (June) 'Fourier's theory' was loosely used as a collective noun for the many design theories - with and without computer aid - that revolve around simple harmonic vibrations and circular functions.

Although mathematically versatile, these concepts fail to do full justice to the wealth of nuances shaping the signals produced by everyday reality, sound and vision alike.

Hence most reproduction standards/looks a pronounced artificiality.

**H G Groenevelt**  
Rotterdam  
Netherlands



**Tektronix Das 9100** Logic analysers. Complete - £700.  
**Nicolet 800A** Logic Analysers - 48 Ch-16 Bit - £450.  
**HP7580B-7585B** Drafting Plotter - £1,000.  
**Bradley 127** DC Voltage Calibrator - £250.  
**Bradley 125B** AC Calibrator + Ratio Transformer 1255 + PI 1254B 50 C/s 60-400-1KC/s - £250.  
**Marconi 6460/1** Power Meters + Heads RF various - £250 ea.  
**Marconi 6460** Power Meters + Heads RF various - £150 ea.  
**Marconi CT499 MKII** RF Watt Meter Absorption 1-3-10-30-100W - 50ohm+70ohm Converter Adaptor - £350. Includes RF Adaptors Low Loss.  
**HP59500A** Multiprogrammer Interface.  
**HP6940B** Multiprogrammer or HP6941B - £100-£200.  
**Datalab DL1200** Waveform Recorder - £300.  
**Solatron 1170** FX Response ANZ-Led - £300.  
**HP59401A** Bus System ANZ.  
**STC Optical Fibre** Reflectometer OFR6 - £300.  
**HP3497A** Data Acquisition Control Unit - £300.  
**Redifon Synthesized Receiver R1001-CW-AM-USB-LSB-PIC-STORE**-Led Readout - 15KC/s-30MC/s - £600.  
**Racal LA1117** Piccolo Modem - £150.  
**Redifon RFS11** Pre-Selector - Post Selector - 1MC/s-32MC/s - £200.  
**Sayrosa 3-39MC/s** Programmable Freq Syn-Type 607+607B - £200-£300.  
**Racal TA1816** 1Kw Solid State Transmitter - MA1034+3 Pare Amps - £1,000.  
**H.C.D. Research Ltd** Precision Oscillator 1519 5000/1000KHz - £250.  
**Nimbus 400Hz** Converter Mains - 240AC-50OC/s Input-Output 115V-400Hz - 500VA Programmable 0-125V. G500 FPL - £300. G200R as above - 200V/A - £200.  
**Hedinalr + Montford** Environmental Ovens etc. Big+Small - £200-£1,000.  
**ICL Clean Linez** Unit - £300.  
**HP6943A** Multiprogrammer extenders - £300.  
**HP6525A** DC P.U.O.-4000V-50MA - £350.  
**Polaroid+CR-9** Cameras for Oscilloscopes - £100.  
**HP3710A** IF-BB Transmitter, HP3702B IF/BB Receiver + 3705A Phase Detector - £250.  
**Moor & Reed Frequency Converter** 400C/s 3 Phase Type SFC 6K/3AXR - Solid State - 20Amps/Mains 240V AC-50C/s Input - £600.  
**HP7586B** Plotter Large Quantity Accessories Pens etc - HP-IB-RS2320 - £1,000.  
**Benson 16 BZ80** Asynchronous Interface + Accessories & Pens etc - £600.  
**Imtec 6000** Microfilm Reader & Printer, A4-A2 sizes - Plain Paper - Various Lenses - £750.  
**Fluke Y5020** Current Shunt - £150.  
**B&K 2107** FX Analyser - £250.  
**B&K BFO 1022** - £200.  
**Tektronix Spectrum ANZ-1L5-50HZ - 1MC/s - £150 - 1L20-10MC/s-4200MC/s - £250.**  
**FARNELL P.U.** AP60-50-60V-50Amps - £1,000.  
**Tracor 527E** Frequency Difference Meter - £350.  
**HP8900B** Peak Power Calibrator - £250.  
**B&K 2425** Electronic Voltmeter - £200.  
**HP4437A** 600 ohms Attenuator - £150.  
**HP6177C** DC Current Source - £250.  
**B&K Two Channel Level Recorder** - £400.  
**Tektronix 2213** 60MC/s Oscilloscope - £300 - 2213A - £350.  
**Tektronix 2215** 60MC/s Oscilloscope - £350.  
**Tektronix 2445** 150MC/s Oscilloscope - £1,200.  
**Tektronix 2246** 100MC/s Oscilloscope - £1,000.  
**Tektronix 2225** 150MC/s Oscilloscope - £800.  
**Tektronix 2245** 100MC/s Oscilloscope - £700.  
**Tektronix 491** Spectrum ANZ 10ML/s-40GHC - £1,000.  
**Farnell P.U.** H30/100 - £500.  
**Schlumberger S1 4922** Radio Code ANZ - £400.  
**Aerial Array** on metal plate 9"x9" containing 4 aerials plus Narda detector. 100-11GHZ using N type and SMA Plugs & Sockets - ex equip - £100.  
**Marconi TF2175** Power Amplifier - 1.5MC/s-520MC/s + Book - £100.  
**Schlumberger 2741** Programmable Microwave Counter - 10HZ-7.1GHZ - £750.  
**Schlumberger 2720** Programmable Universal Counter - 0-1250MC/s - £600.  
**Tektronix 576** Calibration Fixture - 067-0597-99 - £250.  
**Texscan Rotary Attenuators** BNC/SMA - 0-10-60-100DBS - £50-£150.  
**HP809C** Slotted Line Carriage - Various frequencies to 18GHZ - £100-£300.  
**HP532-536-537** Frequency Meters Various Frequencies - £150-£250.  
**S.E. Lab SM215** MkII Transfer Standard Voltmeter - 1000 Volts.  
**Alltech Stoddart P7** Programmer - £200.  
**HP6181** DC current source - £150.  
**HP59501A** HP-IB Isolated D/A Power supply programmer.  
**HP3438A** Digital Multimeter - £150.  
**HP6177c** DC Current Source - £150.  
**HP6207B** DC Power Supply - £100.  
**HP741B** AC/DC differential voltmeter standard (old colour) - £100.  
**HP6209B** DC Power Unit - £100.  
**Fluke 431C** High voltage DC supply.  
**Tektronix M2** Gated Delay Calibration fixture - 067-0712-00.  
**Tektronix Precision DC Divider** Calibration fixture - 067-0503-00.  
**Tektronix Overdrive Recovery** Calibration fixture - 067-0608-00.  
**HP5011T** Logoc Trouble Shooting Kit - £150.  
**PPM 8000** Programmable Scanner.  
**Fluke 730A** DC Transfer Standard.  
**B&K 4815** Calibrator Head - £150.  
**B&K 4812** Calibrator Head - £150.  
**HP FX Doubler** 938A or 940A - £300.  
**HP461A** Amplifier 1KC-150MC/s - Old Colour - £100.  
**Alltech Precision** Automatic noise figure indicator type 75 - £250.  
**Adret FX Synthesizer** 2230A - 1MC/s - £250.  
**Marconi TF2512** RF Power Meter - 10 or 30 Watts - 50 ohms - £80.  
**Marconi 2830** Multiplex Tester.  
**Marconi 2828A** Digital Simulator.  
**Marconi 2831** Channel Access Switch.  
**Marconi TF2337A** Automatic Distortion Meter - £150.  
**HP489A** Micro-Wave Amp-1-2GHZ - £500.  
**Fluke 893A** Differential Meters - £100 ea.  
**EG&G Parc Model 4001** Indicator 4203 Signal Averager PI.

**Tecktronix Plug-In AM503-PG501-PG508-PS503A-PG502.**  
**Cole Power Line** Monitor T1085 - £250.  
**Claude Lyons LCM1P** Line Condition Monitor - £250.  
**Bell & Howell TMA3000** Tape Motion Analyser - £250.  
**HP5345A** Automatic Frequency Converter - .015-4GHZ - £350.  
**HP3200B** VHF Oscillator - 10-500MC/s - £200.  
**Sencore SC61** Waveform ANZ-Microprocessor 60-100MC/s - £350.  
**Schlumberger 3531D** Date Acquisition System - £300.  
**Marconi 6700A** Sweep Oscillator with 1-2GHZ PI 6730A - £400.  
**B&K 2218** Sound Level Meter - £600.  
**EIP 331** 18GHZ Counter-Microwave - Led - £700.  
**EIP 351D** 18GHZ Counter-Microwave - Led - £800.  
**EIP 451** 18GHZ Counter-Microwave - Led - £900.  
**EIP 545** 18GHZ Counter-Microwave - Led - £1,200.  
**Systron Donner 6054D** 18GHZ Counter - Led - £800.  
**Systron Donner 6057** 18GHZ Counter - Microwave - Nixey - £600.  
**HP5340A** 18GHZ Counter Microwave - Led - £1,200.  
**HP5340A** 18GHZ Counter Microwave - Nixey - £800.  
**Systron Donner 6061** 18GHZ Counter Microwave - Nixey - £500.  
**Austron 6014** FX Multiplier - £250.  
**Austron 2004** Receiver Loran - £250.  
**Austron 1201A** Linear Phase Recorder - £250.  
**Austron 2010A** Disciplined FX Standard - £250.  
**Microtel MSR-903** Microwave Receiver -.03-18GHZ - AM-FM - £2,000.  
**Microtel MSR-903** Microwave Receiver -.1-18GHZ - AM-FM - £2,000.  
**Microtel MSR-903A** 18GHZ FX Counter for Above - £1,000.  
**Alltech NM17/27** EMI/Field Intensity Meter -.01-32MC/s - £1,000.  
**Alltech NM37/57** EMI/Field Intensity Meter - 30-1000MC/s - £1,000.  
**Alltech NM65T** EMI/Field Intensity Meter - 1-10GHZ - £1,000.  
**Fluke 5205A** Power Amp - £1,200.  
**B&K 1623** Tracking Filter.  
**B&K 2607** Measuring Amp.  
**B&K 2134** Sound Intensity Analyser  
**B&K 280** Microphone Power Supply.  
**B&K 4408** Two Channel Microphone Selector.  
**B&K 4910** Stroboscope.  
**B&K 1606** Pre-Amp Vibration.  
**B&K 4420** Distribution Analyser.  
**B&K 1014** B.F.O. Oscillator.  
**B&K J2707** Power Amplifier.  
**B&K 2305** Level Recorders.  
**B&K 2307** Level Recorders.  
**B&K 7003** Tape Recorders.  
**B&K 2615** Charge Amplifier.  
**Fluke 9010A** Micro-systems trouble shooter & many Pods - £350 + Pods or Probe.  
**Racal/Dana 5002** Wide Band Level Meter.  
**Racal/Dana 5006** Digital Multimeter.  
**Racal/Dana 5005-S-4622** Digital Multimeter.  
**AVO RM215 - L/2** AC/DC Breakdown Leakage & Ionisation Tester - £400-£450.  
**Fluke 80K - 40** High Voltage Probes - New in Case - £100.  
**Watkins Johnson 340A-4** RX LF-1-800KC/s AM-FM-CW - Led Readout - £750.  
**Watkins Johnson DMS - 105A** Demodulator-AM-FM-SSB - Led Readout - £600.  
**Watkins Johnson RS-111-1B-40** VHF Receiver - 30MC/s-1000MC/s - AM-FM-CW - Pan Display - £700.  
**Watkins Johnson 373A-2** HF Receiver - 0.5-30MC/s - AM-FM-CW - £400-£500.  
**Watkins Johnson** Receivers from 1KC/s to 10,000MC/s also Tuning Heads - Amps-Counter Readouts - Signal Displays - Distribution Amps - HF Multicouplers - IF Demodulators - Signal Monitors etc.  
**Racal MA1720** TX Drive Units 1-30MC/s - £500-£750.  
**Racal MA1723** TX Drive Units 1-30MC/s - £1,000-£1,500.  
**Racal MA1724** TX Drive Units 1.6-25MC/s - £500.  
**Racal RA1792** HF RX-100KC/s-30MC/s - £1,000 Back Lighting.  
**Racal RA1772** HF RX-15KC/s-30MC/s - £600.  
**Racal RA171L** HF RX. 5MC/s-30MC/s - £100-£250.  
**Plessey PR2250G & H-HF** RX LF to 30 MC/s-Memory-Led Readout - £650-£1,000.  
**B&K 2609** Measuring Amp - £250.  
**B&K 1613** Filter - £100.  
**B&K 4215** Artificial Mouth - £250.  
**B&K 4219** Artificial Voice - £250.  
**B&K 4220** Piston Phone - £120.  
**Dynamic Sciences R-1250** Tempet Receiver - 100HZ-1000MC/s - AM-FM - £2,000  
**HP3406A** Sampling Voltmeter (Broadband) - New Colour - £200.  
**HP7404A** Oscilloscope Recorder - 4 Track - £350.  
**HP9872B** Plotter - 4 pen - £300.  
**HP11710B** .01-11MC/s - Down Converter for 8640B - £350.  
**HP11720A** Pulse Modulator - 2-18GHZ - £1,000.  
**HP8403A** Modulator - 0.4-12.4GHZ (8731-8735B) Modulators - £100-£250.  
**HP Pin Modulators** for above - Various frequencies - 0.4-12.4GHZ - £150.  
**HP8699B** Sweep Plug-in - 0.1-4GHZ - Using Yigs-Solid State - £300.  
**HP8690B** Mainframe - £250. All PI available -.1-40GHZ Sweep.  
**Racal-SG Brown** Comprehensive Headset Tester (with artificial head) Z1A200/1 - £350.  
**Marconi 893B** AF Power Meter - £200.  
**Microwave Systems MOS/3600** Microwave Frequency Stabilizer - 1GHZ-40GHZ - £1,000.  
**ACL SR-209-6** Field Intensity Meter Receiver - PI's - 5MC/s-4GHZ - P.O.R.  
**Alltech 136** Precision Test RX + 13505 Head - 2-4GHZ - £350.  
**SE Lab Eight Four** FM 4 Channel Recorder - £200.  
**Datron 1065** Auto Cal Digital Multimeter & Instruction Manual - £400.  
**Datron 1061** Auto Cal Digital Multimeter & Instruction Manual - £400.  
**Racal MA259** FX Standard - Output 100 KC/s - 1-5MC/s Internal Nicad Battery - £150.  
**Edwards E2M8** Rotary Vacuum Pumps - Brand New & Boxed - £500 ea.  
**Fluke 9100A** Troubleshooter & Pods - New Boxed - £750-£1,000.  
**HP1140 & 1743** Oscilloscopes 100MC/s - £300-£450.  
**Tektronix PI 7A19-7A29-3A-4-6-7m11-**  
**Tektronix 7000 Series Oscilloscopes** We can supply all variations of Main Frames and Plug-ins for this range from stock up to 1GHZ - £300-£3,000.

All items in this advert are in stock at time of printing, most items are held in quantity at both our warehouses which is probably the largest stock of electronic surplus in the UK. Bulk and trade buyers from UK and abroad are welcome by appointment to bring own transport for quick purchasing and loading of listed and non-listed items.

Johns Radio, Whitehall Works, 84 Whitehall Road East, Birkenshaw, Bradford BD11 2ER. Tel. No. (0274) 684007. Fax (0274) 651160.

CIRCLE NO. 140 ON REPLY CARD



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 - ALL EXPANDABLE - ALL PC COMPATIBLE

## THE OFFER OF 1994!



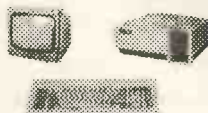
### SPECIAL BUY AT 286 40Mb HD + 3Mb Ram

LIMITED QUANTITY only of these 12MHz HI GRADE 286 systems Made in the USA to an industrial specification, the system was designed for 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 £149.00 (E)**

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3 1/2" floppy disk drive (instead of 1.2 Mb)	£32.95
NE2000 Ethernet (thick, thin or twisted) network card	£49.00

### PC SCOOP COMPLETE COLOUR SYSTEM ONLY £99.00



A massive bulk purchase enables us to bring you a COMPLETE ready to run colour PC system at an unheard of price! The Display Electronics PC99 system comprises of fully compatible and expandable XT PC with 256k of RAM, 5 1/4" 360k floppy disk drive, 12" CGA colour monitor, standard 84 key keyboard, MS DOS and all connecting cables - just plug in and go!! Ideal students, schools or anybody wishing to learn the world of PC's on an ultra low budget. Don't miss this opportunity. Fully guaranteed for 90 Days.

Order as PC99COL **£99.00 (E)**

Optional Fitted extras: 640k RAM	£29.00
2nd floppy drive, specify 5 1/4" 360k or 3 1/2" 720k	£29.95

Above prices for PC99 offer ONLY.



### Computer Controlled Laser Video Disk Player

One of the most amazing surplus deals that we ever been able to offer you! The Philips VP410 LaserVision player, in as new condition, unit features full computer control, Plays standard 12" LaserVision disks with startling visual and audio quality in two channel stereo or mono. When controlled by a computer, it may also be used as a versatile high quality storage / retrieval medium. It will play back either LaserVision CAV (active play) or CLV (Long Play) discs (which covers most types of commercially available video discs). Some of the many features of this incredible machine are:

- RS-232 INTERFACE
- RGB/COMPOSITE VIDEO OUTPUT
- BNC+SCART INTERFACE
- PAL/RGB DECODER
- IR+WIRED REMOTE CONTROL
- FAST RANDOM ACCESS

**SPECIAL PURCHASE Only £399.00 (F)**

### BBC Model B APM Board

WIN £100 CASH!

£100 CASH FOR THE MOST NOVEL DEMONSTRABLE APPLICATION

BBC Model B type computer on a board. A major purchase allows us to offer you the PROFESSIONAL version of the BBC computer at a parts only price. Used as a front end graphics system on large networked systems the architecture of the BBC board has so many similarities to the regular BBC model B that we are sure that with a bit of experimentation and ingenuity many useful applications will be found for this board!! It is supplied complete with a connector panel which brings all the I/O's to 'D' and BNC type connectors - all you have to do is provide +5 and +12 V DC. The APM consists of a single PCB with most major IC's socketed. The IC's are too numerous to list but include a 6502 / 6512 CPU, RAM and an SAA5050 teletext chip. Three 27128 EPROMS contain the custom operating system on which we have no data. On application of DC power the system boots and provides diagnostic information to the video output. On board DIP switches and jumpers select the ECNET address and enable the four extra EPROM sockets for user software. Appx. dims: main board 13" x 10". I/O board 14" x 3". Supplied tested with circuit diagram, data and competition entry form.

Only £29.95  
2 for £53 (B)

### 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, full height lockable half louvered back door and 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 bays.

Overall dimensions are: 77-1/2" H x 32-1/2" D x 22" W. Order as:

- Rack 1 Complete with removable side panels. **£295.00 (G)**
- Rack 2 Rack, Less side panels **£175.00 (G)**

Over 1000 racks in all sizes from stock!  
Call with your requirements.

### LOW COST RAM UPGRADES

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 disk supplied. In good used condition fully tested and guaranteed.

Windows compatible. Order as: ABOVE CARD **£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 **£32.95 (A1)**
- 512k **£38.95 (A1)**
- 1 MEG x 9 SIMM 9 chip 120ns only **£29.95 (A1)**

### No Break Uninterruptible PSU's

Brand new and boxed 230 volts 1 KVA uninterruptible power supply from system from Densel. Model MUD 1085-AHBH. Complete with sealed lead acid batteries in matching case. Approx time from interrupt is 15 minutes. Complete with full manual.

Order as: MUD 1 **£575.00 (G)**

EMERSON ACCUCARD UPS, brand new 8 Bit half length PC compatible card for all IBM XT/AT compatibles. Card provides DC power to all internal system components in the event of power supply failure. The Accusaver software provided uses only 6k of base RAM and automatically copies all system, expanded and video memory to the hard disk in the event of loss of power. When power is returned the machine is returned to the exact status when the power failed! The unit features full self diagnostics on boot and is supplied with full fitting instructions and manual. Normal price £189.00

Only £99.00 (B) or 2 for £195 (C)

### FLOPPY DISK DRIVES 3.5"- 8"

5.25" from £22.95 - 3.5" from £24.95

Massive purchases of standard 5.25" and 3.5" 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 3.5" supported on your PC).

3.5" Panasonic JU363/4 720K or equivalent	£24.95 (B)
3.5" Mitsubishi MF355C-L. 1.4 Meg. Laptops only *	£36.95 (B)
3.5" Mitsubishi MF355C-D. 1.4 Meg. Non laptop	£29.95 (B)
5.25" Teac FD-55GFR 1.2 Meg	£29.95 (B)
5.25" BRAND NEW Mitsubishi MF501B 360K	£22.95 (B)

\* Data cable included in price.

Shugart 800/801 8" SS refurbished & tested	£195.00 (E)
Shugart 851 8" double sided refurbished & tested	£250.00 (E)
Mitsubishi M2894-63 8" sided switchable NEW	£250.00 (E)
Mitsubishi M2896-63-02U 8" DS slimline NEW	£285.00 (E)

Dual 8" drives with 2 mbyte capacity housed in a smart case with built in power supply. Ideal as exterior drives! **£498.00 (F)**

### HARD DISK DRIVES

End of line purchase scoop! Brand new NEC D2246 8" 85 Mbyte of hard disk storage! Full Industry standard SMD Interface. Ultra hi speed data transfer and access time, replaces Fujitsu equivalent model. complete with manual. Only **£299.00 (E)**

3.5" FUJII FK-309-26 20mb MFM I/F RFE	£59.95 (C)
3.5" CONNER CP3024 20 mb IDE I/F (or equiv.) RFE	£69.95 (C)
3.5" CONNER CP3044 40mb IDE I/F (or equiv.) RFE	£99.00 (C)
3.5" RODIME R03057S 45mb SCSI I/F (Mag. & Acorn)	£99.00 (C)
5.25" MINISCRIBE 3425 20mb MFM I/F (or equiv.) RFE	£49.95 (C)
5.25" SEAGATE ST-238R 30 mb RLL I/F Refurb	£69.95 (C)
5.25" CDC 94205-51 40mb HH MFM I/F RFE tested	£89.95 (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!

The TELEBOX consists of an attractive fully cased mains powered unit, containing all electronics ready to plug into a host of video monitors made by manufacturers such as MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD and many more. 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. 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	£32.95
TELEBOX STL as ST but with integral speaker	£36.50
TELEBOX MB Multiband VHF-UHF-Cable-Hyperband tuner	£69.95

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

### FANS & BLOWERS

MITSUBUSHI MMF-D6D12DL 60 x 25 mm 12v DC	£4.95 10 / £42
MITSUBUSHI MMF-09B12DH 92 x 25 mm 12v DC	£5.95 10 / £53
PANCAKE 12-3.5 92 x 18 mm 12v DC	£7.95 10 / £69
EX-EQUIP 120 x 38mm AC fans - tested specify 110 or 240 v	£6.95
EX-EQUIP 80 x 38mm AC fans - tested specify 110 or 240 v	£5.95
VERO rack mount 1U x 19" fan tray specify 110 or 240v	£45.95
IMHOFF 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

### IC's TRANSISTORS DIODES

OBSOLETE - SHORT SUPPLY - BULK

5,000,000 items EX STOCK

For MAJOR SAVINGS - SAE or CALL FOR LATEST LIST

Issue 12 of Display News now available - send large SAE - PACKED with bargains!



LONDON SHOP  
Open Mon-Sat 9:00-5:30  
215 Whitehorse Lane  
South Norwood  
LONDON SE25

DISTEL © The Original  
FREE On line Database  
Info on 1000's of items  
V21, V22, V22 BIS  
081 679 1888

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

ALL ENQUIRIES  
081 679 4414  
FAX 081 679 1927

All prices for UK Mainland. UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona Fide account orders accepted from Government, Schools, Universities and Local Authorities - minimum account order £50. Carriage charges (A)=£3, (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 £33. 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 1994. E & O.E.

CIRCLE NO. 141 ON REPLY CARD



# NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information

## ACTIVE

### Asics

**0.6µm PLDs.** Altera's new *FLEX 8000A* family of programmable logic devices is a redesign of the earlier *Flex 8000* family, in a new 0.6µm triple-layer metal cmos sram process. There are seven family members, from 2500 to 16000 usable gates, all of them drop-in compatible with the earlier types. Performance improvement over the 8000 family is 75%, from 43MHz to 70MHz. Altera UK Ltd. Tel., 0628 488811; fax, 0628 890078.

### A-to-D and D-to-A converters

**500k sample/s a-to-d.** Sampling at 500k samples per second and using only 75mW from a single 5V supply, Linear's *LTC1278* 12-bit analogue-to-digital converter offers a sinad ratio of 70dB and thd of 74dB at the Nyquist frequency. Integral and differential non-linearity errors are  $\pm 1$ lsb, there are no missing codes over the whole temperature range and drift is 45ppm/ $^{\circ}$ C. With  $\pm 5$ V supplies, the device provides  $\pm 2.5$ V output. A 5mW

40Msample/s A-to-D. Harris claims the first 10-bit, 40Msample/s analogue-to-digital converter with a simple and reliable pipeline architecture. The *HS702* uses the company's HBC-10 BiCMOS process to overcome the power v. accuracy compromises of cmos and bipolar solutions and exceeds the performance of any previous device while using about 0.5W less power than its bipolar competitor. The device operates from one 5V supply and offers a maximum integral non-linearity error of 2LSB, with a differential error of 1LSB, digitising a 10MHz 2.5Vpk-pk differential or single-ended input to 10-bit linearity at a minimum 53dB s:n ratio (51dB sinad at 10MHz). An evaluation kit, the *HS702-EV*, includes clock driver circuitry, a reference voltage generator and a choice of input drive circuitry, together with demo board, sample, data sheet and user's guide. Harris Semiconductor UK. Tel., 0276 686886; fax, 0276 682323.

shutdown feature is included, with rapid wake-up. Linear Technology (UK) Ltd. Tel., 0276 677676; fax, 0276 64851.

### Low-power a-to-d converters.

Harris's 5V *HS1810* 12-bit sampling a-to-d converter has a 10µs conversion time, sampling at 100,000 samples per second. Analogue input bandwidth is 1MHz and integral linearity is 2lsb over the industrial temperature range. Parallel data outputs are of the three-state bus driver type and there is a selectable choice of resolution. The *HS1813* is a 3-6V type with a track/hold amplifier, 25µs conversion time and 40,000 samples/s. Thame Components Ltd. tel., 0844 261188; fax, 0844 261681.

### Discrete active devices

**Power transistors.** Motorola's *MJ3281A* and *MJ1302A* are PowerBase complementary silicon power transistors for audio, disk head positioning and other high-power linear uses. They are rated at 200V/15A/250W and their  $f_T$  is typically 30MHz. Motorola Inc. Tel., 0908 614614; fax, 0908 618650.

**SM IGBT/Hexfred package.** *SMD-CoPacks*, introduced by IR, combine an insulated-gate bipolar transistor and a *Hexfred* fast-recovery epitaxial diode in one surface-mounting package, thereby saving about 40% of the cost of separate devices and up to 70% of the size. First available are *IRGBC20KD2-S/MD2-S*, rated at 10A and 13A respectively. International Rectifier. Tel., 0883 713215; fax, 0883 714234.

**Diode arrays.** *Rohm* surface-mounted diode arrays contain up to four devices in one package, the range including common-cathode, common-anode and isolated devices. Diode types offered are 0.1-4A Schottky barrier devices, small-signal Schottky types with 0.37V forward drops, 4ns switching arrays and band switching arrays with 1.2pF capacitance at 1MHz and resistance of 0.9Ω at 100MHz. Pin diodes are available in packs of two devices. Flint Distribution. Tel., 0530 510333; fax, 0530 510275.

### Linear integrated circuits

**Digitally controlled pot.** The Xicor *E<sup>2</sup>POT X9314*, in an 8-pin dip, is a digitally controlled potentiometer with a logarithmic taper to replace the mechanical type in audio circuitry. 'Wiper' position is controlled by asserting chip select, choosing



direction and pulsing the device until the position is reached at one of 32 steps per pulse. Position is then stored in internal memory. Resistance of the *X9314* is 10kΩ. Micro Call Ltd. Tel., 0844 261939; fax, 0844 261678.

### 20MHz function generator.

Producing accurate, high-frequency sinusoidal, square, triangular and pulse waveforms with few external components and in response to a 2-digit code, the Maxim's *MAX038* also produces a sync. output. Frequency is controlled by a 2-700µA current and an external capacitor. An external modulating voltage provides pwm or sawtooth waveforms. Maxim Integrated Products UK Ltd. Tel., 0734 845255; fax, 0734 843863.

### Jfet op-amp for capacitive loads.

Linear Technology says its *LT1457* is the first jfet-input op-amp to be optimised for driving large capacitive loads, the dual *C-Load* device being able to handle at least 10nF loads without oscillation. Input offset is 450µV in a plastic dil and 1200µV in SO-8, drifting at 4µV/ $^{\circ}$ C; input bias current is 50pA; voltage noise 13nV/ $\sqrt{\text{Hz}}$ ; and slew rate 4V/µs. Linear Technology (UK) Ltd. Tel., 0276 677676; fax, 0276 64851.

**900MHz mixer/exciter.** Designed as a linear up-converter for American and Japanese digital cellular radio, Motorola's *MRFIC2101* 900MHz transmit mixer and exciter is suitable for analogue cellular and other 900MHz systems such as GSM and ISM. There is a double-balanced mixer and a local-oscillator buffer to

**Laser diodes.** Two laser diodes from MPS have power stabilisation, slow start and a heat sink. *CJ51F* (1mW) and *CJ52G* (5mW) continuous diodes are complete with optics and electronics, but are only 22mm long and 12mm in diameter. Power supply needed is 3V. MPS Electronics. Tel., 0702 554171; fax, 0702 553935.

reduce LO power and eliminate the need for an external LO balun. The device has a fast power-down control. Motorola Inc. Tel., 0908 614614; fax, 0908 618650.

### Logic building blocks

**Low-voltage logic.** Designed expressly for relatively low-performance applications such as palm-tops and point-of-sale equipment, two families of 3.3V low-voltage cmos by TI, *LV-HCMOS* and *LVC*, are said to be equivalent to the 74F series in 5V ttl. The 0.8µm *LVC* family consists of gates and MSI and 8-bit Widebus devices with a standby consumption of 20µA and 7ns propagation delay. Texas Instruments. Tel., 0234 270111; fax, 0234 223459.

### Memory chips

**Configurable flash memory.** AMD's *Am29F400* 4Mbit 5V-only flash memory is user-configurable in 512 by 8 or 256 by 16 form. Eleven sectors of unequal size can be erased



## NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information



RF and microwave VCOs. *Vari-L*'s range of voltage-controlled oscillators are meant for use in battery-powered equipment, accepting supplies of 3V, 5V, 12V or 15V. Frequencies covered are 25-50MHz to 3-4.8GHz, phase noise varying between 82dBc/Hz to 118dBc/Hz. Packaging includes surface-mount, flatpack, SMA and TO-8. Acal Electronics Ltd. Tel., 0344 727272; fax, 0344 424262.

individually, in multiples or all together. Boot sectors at top or bottom of the address map cope with different microprocessors, the devices having T or B as a suffix. Selected sectors can be protected and embedded algorithms detect and correct erase errors. Advanced Micro Devices (UK) Ltd. Tel., 0483 740440; fax, 0483 756196.

**16Mbit dram.** Toshiba has a 50ns, 16Mbit dram in a 300mil SOJ package. The *TCS5116400BSJ-50* is based on a 0.5µm process and features hyper-page mode operation. Toshiba Electronics (UK) Ltd. Tel., 0276 694600; fax, 0276 691583.

**1Mbit srams.** One megabit srams by IBM in the *IBM 04XXX* family operate at up to 167MHz in second-level cache applications supporting high-performance microprocessors, with a pipeline access of 4ns or flowthrough of 8ns. Versions with burst mode are available for use with *PowerPC* and

Pentium processors. The srams are in 64Kword by 18bit or 32Kword by 36bit form and features include single-clock read/write, self-timed write and low-voltage tti i/o interfaces. Blue Micro Electronics. Tel., 0604 603310; fax, 0604 603320.

**16Mb, 500Mbyte/s drams.** NEC's 16Mb and 18Mb *Rambus* dynamic random access memories offer a 2ns access time and a peak data transfer rate of 500Mbyte/s. The *µPD488130* and *µPD488170* 16Mb and 18Mb capacity Rdrams incorporate a Rambus Interface communicating over a byte-wide channel, called the Rambus Channel, to give a transfer rate of one byte in 2ns. If four such channels are used in a system, bandwidth is 2Gbyte/s. Each Rdram has two independent sense amplifier caches to increase data transfer to the arrays and reduce latency. Packaging is a 32-pin vertical SM type. NEC Electronics (UK) Ltd. Tel., 0908 691133; fax, 0908 670290.

### Microprocessors and controllers

**8-bit risc microcontroller.** With 2048 12-bit words of one-time programmable program memory, 73 8-bit bytes of static ram for data and up to 2:1 code compaction referred to non-risc types, Microchip's *PIC16C58A* runs at 20MHz with a 200ns instruction execution time and is claimed to be the fastest available in its class. On-chip peripherals include an 8-bit clock/counter with a programmable prescaler, start-up timer, watchdog timer with *RC* oscillator and 12 i/o lines. Arizona Microchip Technology Ltd. Tel., 0628 850303; fax, 0628 850178.

**Fast 8051 controller.** While drop-in compatible with the 8051, Dallas's *DS87C520* runs over eight times as fast. It also has 16Kbyte of eeprom and 1.2Kbyte of sram. The 8051 core has been redesigned to use only four clocks per cycle instead of twelve, running at 33MHz to give a peak execution cycle of over 8Mips, no change in software or development tools being needed. Power management allows the user to reduce power by 80% by slowing the clock. Dallas Semiconductor Corporation. Tel., 021 782 2959; fax, 021 782 2156.

**Low-voltage, 4-bit controller.** The *µPD753108* microcontroller, an addition to NEC's 1.8-6V 4-bit range, is provided with a 24 by 4 bit lcd driver. All *75XL* devices have an instruction cycle time of 0.95µs at 1.8V and 0.67µs at 6V, although NEC point out that, since the instruction set is more powerful than that of the earlier *75X* series, fewer instructions are needed for the same tasks. NEC Electronics (UK) Ltd. Tel., 0908 691133; fax, 0908 670290.

**8-bit cmos microcontroller.** Zilog's *Z86C04* cmos device is one of the Z8 microcontroller family, with 1Kbyte of rom and 124byte of general-purpose

ram and packaged in either an 18-pin dip or 18-pin SOIC. Temperature range is -40°C to 105°C. Power consumption is 50mW and the unit is provided with brown-out protection, fast instruction points of 1.25µs, and stop and halt modes. Fourteen i/o lines are at cmos levels, eleven of them being digital, Schmitt-triggered inputs. Clock speed is 8MHz. Gothic Crellon Ltd. Tel., 0734 788878; fax, 0734 776095.

**150MHz processor.** As well as reducing the prices of its 100MHz and 133MHz *Orion R4600* processors, IDT has released the 150MHz version, which is claimed to outperform the Pentium at the price of a 486DX. The device has the *Flexbus*, which is a software initialisation mechanism allowing bus interface frequency to be tailored to suit system requirements. Five-volt version are now available, with 3.3V models arriving later in the year. Integrated Device Technology. Tel., 0372 363734; fax, 0372 378851.

### Mixed-signal lcs

**Engine-knock detection.** Harris's *HIP9010* is a mixed-signal device known as an engine knock signal processor, to be used in knock detection subsystems in vehicle ignition control systems. It amplifies and filters the output of a piezoelectric transducer during a short interval about top-dead-centre, so that the signal can be separated from engine noise. Analogue gain and filter characteristics are changed digitally by the system microcontroller to accommodate varying engine conditions. Harris Semiconductor UK. Tel., 0276 686886; fax, 0276 682323.

### Optical devices

**Minature camera.** Henderson has announced a new range of pcb mounting cameras of both the pinhole type and those using the range of interchangeable lenses from 3.6mm to 16mm. Camera units are on a single board measuring 42mm square and are sensitive down to 0.5lux. A range of housings is available, and a remote 12V supply that feeds the unit through a multicore cable. Henderson Security Electronics Ltd. Tel., 9684 274874; fax, 0684 294845.

**Laser sensor.** A laser photoelectric sensor from Keyence, the *LZ-155* series produces a spot 0.05mm in diameter with a positioning accuracy of 0.005mm horizontally. Detection distance is up to 60mm, at which distance the spot is visible even on a black surface. The device is intended for positioning and counting very small objects, for which a multi-turn potentiometer adjusts sensitivity. Keyence UK Ltd. Tel., 0908 696900; fax, 0908 696777.

### Oscillators

**Custom crystal oscillators.** ACT announces a facility for manufacture of temperature-compensated crystal oscillators with many choices of

operating temperature and stability within the limits of -40°C to 85°C and ±5% to ±0.5%. There are six package styles, including hermetically sealed metal. Lead times are down to 20 days. Advanced Crystal Technology. Tel., 0635 528520; fax, 0635 528443.

### Power semiconductors

**Lamp driver.** Microlinear's *ML4874* drives small cold-cathode fluorescent tubes used as backlighting for liquid-crystal displays. The device drives the tubes differentially, taking less power than is the case with single-ended drives and expending less power on stray capacitance in the lcd housing. Efficiency is 95%, obtained by the use of a resonant threshold detection arrangement. Ambar Components Ltd. Tel., 0844 261144; fax, 0844 261789.

**TSSOP power mosfets.** The new *Litefoot* power mosfets from Siliconix come in n-channel and p-channel form and are small enough to fit on any standard PCMCIA card, being only half the size of others on the market. Power dissipation is 1.5W with no heat sink besides the PCB and breakdown lies between 12V and 30V. On resistance for a single p-channel device is 75mΩ and that for a single n-channel type 50mΩ. Single, dual and complementary devices are available. Siliconix/Termic Marketing. Tel., 0344 485757; fax, 0344 427371.

## PASSIVE

### Passive components

**High power factor capacitors.** *Type 6124* and *Type 7124* from Tecate are metallised polyester and metallised polypropylene capacitors intended for use in equipment such as lighting, snubbers and small motors where power factor correction is needed. Standard tolerances are ±5%, ±10% and -5 +100%, dissipation factor being 1% maximum. Both types have an optional thermal cut-off and a bleeder resistor to discharge the capacitor to lower than 50V in a minute. Voltage ratings are 160-250V ac in values of 1-3µF (6124) and 160-500V/1-25µF (7124). Tecate Industries Inc. Tel., 0101 619 448-4811; fax, 0101 619 448-0912.

**Transient suppressors.** Semtech has transient voltage suppressors in the *SL series* which exhibit only 5pF capacitance. They are designed for use on data lines and handle 300W peak pulse power with a response time of 1ps. Reverse standoff voltages are 5V, 12V, 15V and 24V, breakdown 6-26.7V and maximum clamping voltage at 1A, 9.8-43V. Semtech Ltd. Tel., 0592 773520; fax, 0592 774781.

**Tantalum capacitors.** Components in AVX's *TAZ* range of high-reliability tantalum capacitors intended for use in medical implantable devices are now reduced in size. The capacitors



are qualified to Weibull C failure rates and are available with low leakage current and nine configurations of termination and finishes. AVX Ltd. Tel., 0252 336868; fax, 0252 346643.

**Trimmer capacitors.** For those applications not involving high rf power, Jackson's C824 series of air-spaced trimmers use a low-loss composition front panel and aluminium rotors and stators. Maximum capacitances are 10pF to 100pF and minimum for all types is 5pF, with a linear capacitance/angle relation. Working voltage is 350V. Jackson Brothers Ltd. Tel., 081-681 2754; fax, 081-681 3728.

**Dielectric filter.** AVX announces the PDFC series of dielectric filters meant for use in telecomms, particularly in the DECT sector. Frequency range is 1.8-2GHz, insertion loss 3dB and, for compatibility with the newest equipment, size is 6.5 by 5.5 by 3mm. Filters to provide lower insertion loss and improved stop-band attenuation are available to order. AVX Ltd. Tel., 0252 336868; fax, 0252 346643.

### Connectors and cabling

**Protected jack connectors.** Murata announces a series of modular jack connectors with built-in varistors for surge and noise suppression in ISDN terminal equipment. Built-in inductors ensure noise reduction over a wide frequency range. They are rated at 50V dc at 200mA, have a typical impedance of 600Ω at 100MHz, a varistor voltage of 250V between line and earth and a -25°C to 60°C operating range. Murata Electronics (UK) Ltd. Tel., 0252 811666; fax, 0252 811777.

### Displays

**DVM module.** DMS-40LCD by Datel is a series of 4.5-digit LCD meters contained in plastic dips measuring 0.9in by 2.1in by 0.43in, with 0.4in characters. The devices have dual inputs to allow signal input of  $\pm 200\text{mV}/\pm 2\text{V}$ ,  $\pm 2\text{V}/\pm 20\text{V}$  or  $\pm 20\text{V}/\pm 200\text{V}$ . Power needed is one

### TV test patterns

Contained in a hand-held case, the OZAN television test pattern generator is powered by a 9V battery, although a mains unit is supplied for continuous bench use. It is connected to the rf and line sockets of television receivers and video recorders. Four PAL test patterns – colour bars to the BBC 95% or EBU 100% luminance, grey scale with eight 14.3% steps, cross hatch and red purity – and a 1kHz audio tone are generated, the RF video and audio coming from a 75Ω coaxial socket on channel 36 with audio set to the 6MHz sub-carrier (5.5MHz for other standards). Two 75Ω phono sockets provide composite video at 74Ω and the audio line out at 1kΩ.



**Colour lcd.** Sharp's LQ6RA54 is a 5.5in thin-film transistor lcd module in which the pixels are arranged in a stripe rather than in the delta formation of RGB elements, easing the problems of writing graphical information. A black mask reduces internally reflected light by over 80% over previous types and surface reflections are avoided by means of a polariser. Vertical viewing angle is switchable to either above or below the display centre line. Hero Electronics Ltd. Tel., 0525 4055015; fax, 0525 402383.

5V line at 2.5mA or 9V at 1.5mA. Backlighting is available. Datel (UK) Ltd. Tel., 0256 880444; fax, 0256 880706.

**Bargraph DMM.** Lascar has a large-digit bargraph multimeter that is provided with a 3.5-digit display visible from 10m, even in low light, by virtue of its led backlighting. Connection of the DMM 977 to the display is by IDC connector. Lascar Electronics Ltd. Tel., 0794 884567; fax, 0794 884616.

### Filters

**Two-port saw resonators.** Saw resonators in RF Monolithics's RP and RS series, which have nominal phase angles of 180° and 0° respectively, now exhibit a frequency tolerance of  $\pm 75\text{kHz}$ . Five of the devices are available for low-power UHF transmitters in applications including the DTI MPT1340 at 418MHz and the pan-European ETS-300-220 at 433.92MHz. Insertion losses are typically 5.7dB and 6.3dB at the two frequencies. Quantelec Ltd. Tel., 0993 776488; fax, 0993 705415.

### Instrumentation

**EMC probe.** An active near-field probe by Seaward locates the source of radiated emissions, completing the company's emc test package to the requirements of the EC Directive on Electromagnetic Compatibility. The probe will localise emissions from pcb-mounted components, cables and case apertures and joints in the frequency range 1MHz-1GHz. Although the probe was designed for use with Seaward's spectrum

analyser, it is now suitable for most analysers with minor mods. Seaward Electronic Ltd. Tel., 091-586 3511; fax, 091-586 0227.

**Simm tester.** ITM has introduced the TA1011 Test Head for the Excel 1000 bench-top production memory tester from TMI Inc., which carries out 100% testing of virtually all memory modules, including 30-pin and 72-pin simms with page-mode up to 40 bits wide and organised in configurations from 64K by 9 to 16M by 9; it also handles 2K and 4K refresh-type drams. The system is controlled by a PC AT and a bus interface for the PC is supplied. Instrumentation Test & Measurement Ltd. Tel., 0202 872771; fax, 0202 871052.

### Microwave

**Sweepers/synthesisers.** Giga-Tronics offers the GT 9000 microwave synthesiser and the GT 9000S synthesised microwave sweeper. They are improved versions of earlier instruments, offering a 2-20GHz range. Phase noise of the 9000S at 2GHz is  $-95\text{dBc}/\text{Hz}$  at 10kHz offset. Output power +13dBm from 10MHz to 20GHz and harmonics at 6dBm are less than  $-65\text{dBc}$ . Pulse mod. is standard and AM, FM and scan mod. are options. The 9000S is the same, but with analogue and digital frequency and power sweeping. Sematron UK Ltd. Tel., 0734 819970; fax, 0734 819786.

### 100MHz logic analyser.

The TA320S self-contained logic analyser by TTI has 32 channels and a 100MHz acquisition rate. Display is by supertwist lcd capable of

### Eight-channel dso

Two instruments in the Yokogawa DL5100 series of digital storage oscilloscopes, DL5180 and DL5140 offer 1Gsample/s sampling and 500MHz bandwidth on all channels, with a 4Kword/channel memory and 8-bit resolution. The display is a 640 by 480 dot colour tft lcd, an interesting feature being the colour accumulation, in which pixels vary their colour according to the number of times they are written. A history memory acquires and reads out up to 120 sets of waveform data and either measured or saved to disk in the internal 3.5in drive. All 120 scans can be viewed simultaneously. The instruments incorporate an Intel i960 32-bit risc processor for automatic measurements and computation, up to 19 standard parameters being measured automatically. Martron Instruments Ltd. Tel., 0494 459200; fax, 0494 535002.





## NEW PRODUCTS CLASSIFIED

Please quote "Electronics World + Wireless World" when seeking further information

displaying high-res. graphics or 40-column text and control and data entry is by a combination of soft keys and an alphanumeric keypad. There is also an RS-232 interface to transfer data to and from a computer. The instrument has thirty-two data channels at up to 25MHz and eight at 100MHz for asynchronous working. Events down to 5ns in length can be captured. Optional disassembler pods, each with its own internal software, support a range of popular microprocessors. State and timing displays are selectable and data can be grouped under user-defined names. Search-and-compare facilities are provided, as is non-volatile storage of acquisitions and set-ups. Thurlby Thandar Instruments Ltd. Tel., 0480 412451; fax, 0480 450409.

**RF counter.** *HP53181A* by H-P is one of the company's lower-cost instruments for frequency measurement to 225MHz or up to 3GHz with optional second channels. Period measurement is performed quickly and there is a limit-testing feature with an analogue display mode for pass/fail testing. An HP-IB port provides SCPI(1) compatible programming and an RS-232 talk-only interface gives printer control or data transfer to a computer at more than 200 formatted measurements per second. Hewlett-Packard Ltd. Tel., 0344 362277; fax, 0344 362269.

**1GHz spectrum analysers.** Two spectrum analysers by Promax, the *AE-366* and *AE-566*, cover the 1-1000MHz frequency range (1750MHz with an optional converter) and cost £2094 and £2800 respectively, the 566 having its own tracking generator and a normalising function to reduce errors caused by connections. Display dynamic range is 70dB and measuring range 15-130dBµV, the display being log. or linear in the vertical direction. Best resolution bandwidth is selected automatically. Alban Electronics Ltd. Tel., 0727 832266; fax, 0727 810546.

**ELF field meter.** Over 5-200Hz, Holaday's hand-held *HI-3627* three-axis magnetic field meter measures 0.2mG to 20G, which makes it very suitable for power frequency field measurement. Outputs from three orthogonal sensing coils combine vectorially, the result being indicated by an analogue meter which has a recorder output. Batteries are rechargeable. Holaday Industries. Tel., 0628 478155; fax, 0628 476871.

## Literature

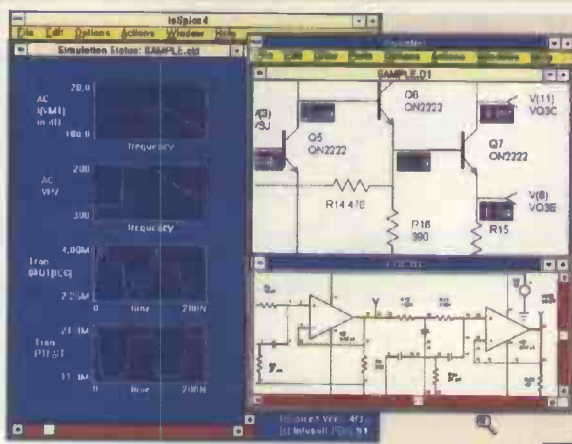
**RF/wireless communication.** Anglia's *RF/Wireless Communication Components Designer's Data Book* is now available, covering a large range of components. At the end of the book, three articles describe the use of ICs for digital links, attenuator and amplifier ICs for digital systems and Ina/mixer ICs. Anglia Microwaves Ltd. Tel., 0277 630000; fax, 0277 631111.

**PC instrumentation.** Intelligent Instrumentation, a Burr-Brown company, has published the 7th edition of *Handbook of Personal Computer Instrumentation*. Topics

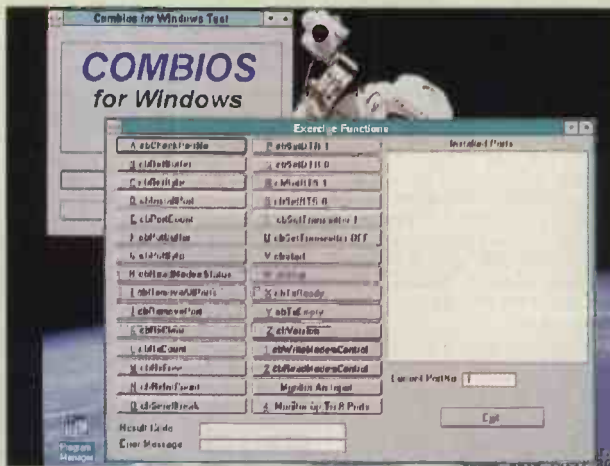
covered include signal conditioning, wiring, shielding and data acquisition, together with notes on techniques and applications. The range of II's hardware and software is described. The handbook is free to 'qualified individuals'. Intelligent Instrumentation. Tel., 0923 896989; fax 0923 896671.

**Visual C for embedded processors.** Since Intel has abandoned embedded C compilers and assemblers, Hitex

has produced a guide to the use of the Microsoft C8 Compiler and Visual Workbench for use with embedded processors. It shows how to integrate emulator debuggers into the Workbench to allow rapid swapping between editing and debugging, in addition to many programming tricks needed to address peripherals such as real-time clocks. *Embedding Microsoft C* is available free. Hitex (UK) Ltd. Tel., 0203 692066; fax, 0203 692131.



**Low-cost Spice.** *ICAP/4Lite* by Intusoft is a low-cost analogue and mixed-signal circuit simulator, based on the company's professional version of Spice. Instead of providing all the traditional Spice facilities and limiting the size of circuit – a common method of producing a cheaper version – Intusoft has allowed unlimited circuit size and reduced the available facilities. The software performs analyses of frequency response, DC conditions, transients and temperature. It also has a schematic entry program to produce a complete Spice netlist, both compatible with the Intusoft professional version. Spice simulation is based on the 32-bit IsSpice4, which gives a real-time waveform display with interactive component changes, printed or displayed inside IsSpice4 or in a reduced version of IntuScope, a graphical analysis program. The ICAP/4Lite package includes schematic entry, IsSpice4 simulator and IntuScope, with a library of over 500 parts. Technology Sources Ltd. Tel., 0638 561460; fax, 0638 561721.



**COMBIOS for Windows.** *COMBIOS for Windows* provides all the functions found in COMBIOS for DOS, allowing users to develop applications to implement driver buffered serial comms on up to 64 ports. Features include serial ports at any i/o address, all input channels buffered up to 40Kbyte/port, the provision of standard baud rates and data formats and a GUI. It supports any serial RS 232 comms port using the 8250 or 16450 uart and any RS 422/485 port that will enable the transmitter using the uart out 1 line. The facility is independent of language and is not TSR. Impicon Liveline Ltd. Tel., 0800 525 335 (free); fax, 0273 570215.

**Strain-gauge selector.** In 52 pages, the *HBM* catalogue provides comprehensive data on a range of strain gauges and advice on their use in stress analysis and in various types of transducer. Components and materials for use with the gauges are described in an accessories section. HBM United Kingdom Ltd. Tel., 081-420 7170; fax, 081-420 7336.

## Power supplies

**Switching controller.** The *MAX1771* step-up switching controller from Maxim provides 90% efficiency over a 30mA-2A load, by virtue of its current-limited, pulse-frequency-modulated control, which also takes only 100µA current from the supply. Switching frequency is 300kHz and an n-channel mosfet switch takes loads up to 24W. From inputs of 2-16.5V, output is preset to 12V, adjustable by two resistors. Maxim Integrated Products UK Ltd. Tel., 0734 845255; fax, 0734 843863.

**PSU approval.** Gardner's *LCS40* switched-mode power supply has been awarded the Industry Approvals EN 60950, UL 1950 and CSA 22.2. It is the first in a new family meant for the medium-volume European market, providing any (reasonable) combination of inputs and outputs at a fair cost. Inputs are 85-265V ac and 120-370V dc and operating frequency is 47-440Hz. Gardner's Ltd. Tel., 0202 482284; fax, 0202 470805.

**Triple psu.** The *Calex Model 3.15.1000* low-noise linear power supply provides ±15V at 100mA to drive amplifier and data conversion circuits and 5V at 1A for logic. Output noise is typically 2mV rms and there is overvoltage and short-circuit protection. Input-to-output isolation is 1500V rms. The supply is for mounting on a pcb, measuring 3.5 by 2.5 by 1.5in. Calex Electronics Ltd. Tel., 0525 373178; fax, 0525 851319.

**Dc-to-dc converters.** New low-profile versions of the *Cosel Z* series of converters, the *ZU* series are available from XP in 15W and 25W form, total package height being 8.5mm. In common with the standard Z units, the ZU models have input ranges of 9-18V, 18-36V and 37-72V, 500V input-to-output isolation and short-circuit protection, but also have output trim and remote on/off. Stabilisation is 0.1% typical, regulation 1% max. for single output types and noise and ripple 40mV typical. XP plc. Tel., 0734 845515; fax, 0734 843423.

**Mobile AC.** When plugged into the cigarette lighter socket of, for example, a car, Powerline's *PAC1400* provides up to 140W of continuous ac power or up to 200W for about five minutes; 400W start-up surge can be given for 100ms. This output is sufficient to power a laptop computer or to recharge power packs. The car battery is fully protected. Powerline Electronics Ltd. Tel., 0734 868567; fax, 0734 755172.

**Transient protection.** A wide range of *Claude Soule* modules to protect power circuits and data lines against



transients is now available from Europa. They are DIN rail-mounted, leaded or boxed and protect against rfi, voltage surges or both. Three series, 8748, 8777 and 8776 protect peripherals such as strain gauges in industrial equipment, coaxial video lines and antenna feeders respectively. Europa Components & Equipment plc. Tel., 081-953 2379; fax, 081-207 6646.

**Bendy battery.** Ultralife's new U3VF-X primary lithium cell is pliable, under 1mm thick and available in virtually any shape. Five versions cover the 70mAh-2500mAh range, weight being 1g-67g. After 10 years, 80% of capacity remains. The cells are suitable for building-in or as stand-alone units when encased in a plastic jacket or hard case. Suvincon Ltd., 021 643 6888; fax, 021 643 2011.

**Radio communications products**

**Antenna switching relays.** Among their other functions, Teledyne's TO-5 and Centigrad relays are suitable for switching between built-in cellular telephone antennas and car antennas. Teledyne claims its TO-5 device to be the smallest and most reliable sealed relay available. The Centigrad type is an industrial subminiature, hermetically sealed armature relay. Teledyne Electronic Technologies. Tel., 081-571 9596; fax, 081-571 9637.

**RF power amplifiers.** Models 604L and 607L from ENI cover the frequency range 500kHz-1GHz and 800kHz-1GHz, with linear outputs of 4W and 7W and gains of 40dB and 43dB respectively. They can cope with any load vswr, from open-circuit to short-circuit, without damage. Holaday Industries. Tel., 0628 478155; fax, 0628 476871.

**Coaxial switch.** The Toesel Model TS 360-00 is a fail-safe spdt coaxial switch consuming 220mA at 28V. It is a break-before-make type and has position-indicator contacts rated at 60V/350mA maximum, 4V/10mA minimum. Higher power is optional; a special dielectric material allows the switch to handle 1kW at 1GHz, against 200W at 1GHz for the standard type. Switching time is 100ms and life is about a million operations. Anglia Microwaves Ltd. Tel., 0277 630000; fax, 0277 631111.

**Transducers and sensors**

**Hostile-media pressure transducer.** For use in wet and corrosive media, the Sensit p-192 pressure transducer offers pressure ranges of 1-40 bar gauge reference at a sensitivity of 4mV/bar at full pressure and a maximum of ±1% of full-range error from all causes. Offset voltage is 1mV. Kynmore Engineering Co. Ltd. Tel., 071 405 6060; fax, 071 405 2040.

**Angular measurement.** The Cline Labs Angular Measurement System is a battery-powered standalone system needing no external power or extra electronics. It consists of a gravity-referenced clinometer, digital readout and a cable to connect the two. Angular range is ±60° or ±19.9° to a resolution of 0.1° or 0.01° with linearity varying between ±0.1°, 1% of angle and monotonicity, depending on the range of angles being measured. Frequency response is 0.5Hz. Kynmore Engineering Co. Ltd. Tel., 071 405 6060; fax, 071 405 2040.

**COMPUTER**

**Computer peripherals**

**Magneto-optical storage.** With a 1.3Gbyte capacity and average seek time of under 40ms, Sony's RMO-S570 magneto-optical drive is meant for digital photography and other data-intensive application. Recording density is not constant over the whole disk, but increases on the outer tracks, the increases occurring in zones; inside each zone the density is constant. Maximum data transfer rate is 2Mbyte/s and a 1Mbyte buffer memory improves performance by reducing mechanical movement. Sony Computer Peripherals & Components. Tel., 0932 816000; fax, 0932 817001. **PCMCIA mass storage.** Solid-State

**File Cards** by IBM form an effective alternative to hard disks in portable computers. They are in PCMCIA Type 1 and Type 2 form, both with a PCMCIA-ATA interface. 3.3mm thick types have capacities of 3Mb, 5Mb, 10Mb and 20Mb, while the 5mm thick Type 2 has either 30Mb or 40Mb. The cards use a single 5V supply at less power than disks and are not, of course, subject to the relatively long access time of disks. An integral controller and dram buffers eliminate the need for flash memory blocks to be erased before new data can be stored. Blue Micro Electronics. Tel., 0604 603310; fax, 0604 603320.

**Software**

**Data acquisition for Windows.** Version 4.1 of The Windmill data acquisition software suite for Windows now supports Network DDE in Windows for Workgroups, allowing other Windows applications on other workstations to use data collected by Windmill. Windmill charting and logging modules are now controllable by other applications supporting DDE, for example by Visual Basic programs. Data acquisition from plug-in cards, bench-top units or other sources is at the rate of 50/s down to 1/hour. Windmill Software Ltd. Tel., 061 833 2782; fax, 061 833 219



8 CAVANS WAY,  
BINLEY INDUSTRIAL ESTATE,  
COVENTRY CV3 2SF  
Tel: 0203 650702  
Fax: 0203 650773  
Mobile: 0860 400683

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

**OSCILLOSCOPES**

Gould OS4000, OS4200, OS4020, OS245	from £125
Gould OS3000 - 40MHz, dual ch.	£250
Nicolet 4035 - 20MHz digital storage	£600
Gould 4050 - 35MHz digital storage	£750
Gould 5110 - 100MHz intelligent oscilloscope	£950
Hewlett Packard 1707A, 1707B - 75MHz dual ch.	from £275
Hewlett Packard 1740A, 1741A, 1744A, 100MHz dual ch.	from £350
Hewlett Packard 182C - 100MHz 4 ch.	£350
Hewlett Packard 54201A - 300MHz digitizing	£2550
Hitech V-422 - 40MHz dual ch.	£300
Nicolet 3081 - Low freq D.S.O.	£1100
Nicolet 4094 - 4 channel low frequency D.S.O.	£500
Tektronix 468 - 100MHz D.S.O.	£800
Tektronix 2213 - 60MHz dual ch.	£425
Tektronix 2215 - 60MHz dual ch.	£450
Tektronix 2235 - 100MHz dual ch. (portable)	£800
Tektronix 2246 - 100MHz 4 channel (as new)	£995
Tektronix 2335 - 100MHz dual ch. (portable)	£750
Tektronix 465/465B - 100MHz dual ch.	from £350
Tektronix 7313, 7603, 7613, 7623, 7633, 100MHz 4 ch.	from £300
Tektronix 7304 - 250MHz 4 ch.	from £650
Tektronix 783/784 - 400MHz 4 ch.	from £750
Tektronix 7904 - 500MHz	from £850
Phillips 3206, 3211, 3212, 3217, 3226, 3240, 3243, 3244, 3261, 3262 (2ch + 4 ch.)	from £125 to £350

Other scopes available too

**SPECTRUM ANALYSERS**

Alltech 727 - 20GHz	£1250
Hewlett Packard 3580A - 5Hz - 50KHz	£995
Hewlett Packard 3582A - 25KHz analyser, dual channel	£2500
Hewlett Packard 8590A - 10MHz - 1.5GHz (as new)	£4500
Hewlett Packard 8590B - 9KHz - 1.8GHz	£4750
Hewlett Packard 8754A - Network Analyser 4 - 1300MHz	£3500
Hewlett Packard 1827 with 8559A (10MHz - 21GHz)	£3750
Hewlett Packard 4953 Protocol analyser	£2500
Marconi 2370 - 110MHz	£995
Rohde & Schwarz - SWOB 5 Polyskop 0.1 - 1300MHz	£2750
Tektronix 7L18 with 7603 mainframe (1.5-18GHz)	£3500
Tektronix 492 - 21GHz	£5500
Texscan AL51A - 1GHz	£995

**MISCELLANEOUS**

Anritsu ME538C Microwave system analyser (Rx + Tx)	£3500
Anritsu MG642A Pulse pattern generator	£1500
Anritsu ML93B/ML92B Optical power meter with sensor	£2000
Ballantine 323 True RMS voltmeter	£350
Datatab DL 1080 - Programmable Transient Recorder	£1350
E.I.P. 331 18GHz frequency counter	£850
Farnell RB 1030-35 Electronic load 1kW	£450

Farnell 2081 R/F Power meter	£350
Farnell SSG520 Sig. Gen. 10 - 520MHz	£850
Farnell TTS520 Transmitter test set	£850
Farnell SG1B Sig. Gen. interface	£225
Farnell TS70 Mill - Power Supply (70V-5A or 35V-10A)	£500
Ferroglyph RTS2 Audio test set with ATU1	£350
Fluke 9010A - Micro-system Troubleshooter (in carrying case)	£250
Gay Milano FTMIC/FTM3C - FTM - Fast transient monitor	£250
General Rad 1658 LCR Digibridge	£950
Hewlett Packard 436A Power meter + 8481A sensor	£850
Hewlett Packard 1630G - Logic Analyser (65 channel)	£250
Hewlett Packard 3403C True RMS voltmeter	£350
Hewlett Packard 3437A System voltmeter	£200
Hewlett Packard 3438A Digital multimeter	£650
Hewlett Packard 3478A Digital voltmeter, 4 wire system, 1EEE	£250
Hewlett Packard 3490A Digital multimeter	£1500
Hewlett Packard 3702B/3705A/3710A/3716A Microwave link analyser	£3500
Hewlett Packard 3711A/3712A/3791B/3793B Microwave link analyser	each £300
Hewlett Packard 3760/3761 Data gen + error detector	each £350
Hewlett Packard 3762/3763 Data gen + error detector	£250
Hewlett Packard 3777A Channel selector	£600
Hewlett Packard 3779A Primary multiplex analyser	£250
Hewlett Packard 4193A Vector impedance meter	£275
Hewlett Packard 4150A Thermal printer	P.O.A.
Hewlett Packard 5316A - Universal counter HP1B	P.O.A.
Hewlett Packard 5316B - Universal counter HP1B	P.O.A.
Hewlett Packard 5385 - Frequency counter 1GHz (HP1B) with Opts	P.O.A.
001/003/004/005	£150
Hewlett Packard 59501B HP 1B isolated D/A power supply programmer	£150
Hewlett Packard 6181C D.C. current source	£150
Hewlett Packard 7402 Recorder with 17401A x 2 plug-ins	£250
Hewlett Packard 8005B Pulse generator	£500
Hewlett Packard 8011A Pulse gen. 0.1Hz - 20MHz	£400
Hewlett Packard 8406A Frequency comb. generator	£300/£400
Hewlett Packard 8443A Tracking gen./counter with 1EEE	£400/£600
Hewlett Packard 8445B Automatic presetter	£650
Hewlett Packard 8620C Sweep oscillator mainframe	£450
Hewlett Packard 8654B 10 - 520MHz Sig. Gen.	£375
Hewlett Packard 8750A Storage normaliser	£375
Hewlett Packard 8901B - Modulation Analyser AM/FM 150KHz - 1300MHz	£3750
Hewlett Packard 8903B - Audio Analyser (20Hz - 100KHz)	£2750
J. J. Instruments CR700 - Recorder (in carrying case)	£300
Kelthly 197 20MHz with 1EEE	£400
Lycosa P373N/P375/P376/P378 Pulse generator	from £225
Marconi 2019A 80KHz - 1040MHz sig. gen.	£1850
Marconi 2022A 10KHz - 1GHz sig. gen.	£1850
Marconi 2306 Programmable Interface	£500
Marconi 2337A Automatic dist. meter	£150
Marconi 2356 20MHz level oscillator	£200
Marconi 2432A 500MHz digital freq. meter	£200
Marconi 2830 Multiplex tester	£1000
Marconi 2831 Channel access switch	£400
Phillips PM 5167 10MHz function gen.	£400
Phillips PM 5190 LF synthesizer w/HP GPIB	£800
Phillips 5390 1GHz signal gen.	£1250
Phillips PM 5519 Colour TV pattern gen.	£400
Phillips PM 5716 Pulse generator high freq. mos	£600
Phillips PM 6572 1GHz timer/counter WF 1EEE	£650
Phillips PM 8272 XYT chart recorder	£500
Racal 9301A True RMS R/F millivoltmeter	£300

Racal Dana 202 Logic analyser + 68000 disassembler	£250
Racal Dana 3100 40-130MHz synthesiser	£750
Racal Dana 5002 Wideband level meter	£650
Racal Dana 5003 Digital m/v meter	£150
Racal Dana 9000 Microprocessing timer/count. 52MHz	£250
Racal Dana 9009 Modulation meter	£225
Racal Dana 9081 Synth. sig. gen. 520MHz	£550
Racal Dana 9084 Synth. sig. gen. 104MHz	£450
Racal Dana 9242D Programmable PSU 25V-2A	£300
Racal Dana 9246S Programmable PSU 25V-10A	£400
Racal Dana 9303 True RMS/R/F level meter	£650
Racal Dana 9341 LCR datalibrary	£250
Racal Dana 9500 Universal timer/counter 100MHz	£200
Racal Dana 9917 UHF frequency meter 560MHz	£175
Racal Dana 9921 3GHz frequency counter	£450
Rohde & Schwarz BM36711 Digital Q meter	£400
Rohde & Schwarz LF42 Sweep generator 0.02 - 50MHz	£1500
Rohde & Schwarz SCUD Radio code test set	£1500
Rohde & Schwarz SMPF2 Mobile tester	£4000
Rohde & Schwarz ZPV Vector analyser	£1500
Schlumberger S.I. 4040 - Stalilock - High accuracy 1GHz Radio Test Set	£9995
Schlumberger 4923 - Radio Code Test Set	£2000
Schlumberger 2720 - 1250MHz Freq. Counter	£800
Solartron Schlumb 1170 Freq. response analyser	£250
Syatama Video 1258 Waveform analyser + 1255 vector monitor + 1407 differential phase & gain module + 1270 remote control panel	£2250
Tektronix TM503, SG503, PG506, TG501 Scope calibrator	£2200
Tektronix TM503 + AM503 + A6302 - (20A Current Probe Amp)	£995
Tektronix 834 Data comms analyser	£500
Tektronix 1411 PAL/NTSC/PAL-M signal gen. with SPG12, TSG11, TSG13, TSG15, TSG16 & SP11	£2000
Tektronix 1480 Waveform monitor	POA
Time 9811 Programmable resistance	£600
Time 9814 Voltage calibrator	£750
W&G MU3 Test point scanner	£500
W&G PCM3 Auto measuring set for telephone channels	£950
W&G P812 Level generator 200Hz-6MHz	£500
W&G SPM12 Level meter 200Hz-6MHz	£500
Watanabe WTR211 3 pin plotter	£250
Weller D80/D801 Desoldering station	£175
Weller D90 Desoldering station	£150
Willtron 352 Low freq. differential input phase meter	£350

**SPECIAL OFFERS - Phoenix 5500A Telecoms analyser, ex. demo, as new with 12 months calibration + 12 months guarantee fitted with V24 interface. A variety of interface options available - Ring/Fax for details. Navtel 9440 Protocol analyser, ex. demo, as new £8000 new - cost now £3500. Navtel 9410 PCB based protocol analyser ex. demo, as new £3000 new - cost now £1500.**

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

CIRCLE NO. 142 ON REPLY CARD

# Multi i/o via the serial port

**Providing 64 lines, this i/o interface compensates for a relatively slow serial link to the host PC by having its own 68000 family microprocessor. J. N. Ellis describes how the interface has a range of uses from switching a led to managing a control system.**

Several i/o designs taking advantage of the microcomputer's easy-to-use serial port have appeared, one as recently as June<sup>1</sup>. Many provide two eight-bit parallel ports and involve a dedicated parallel-interface chip.

This RS232 interface differs in that it provides up to eight, 8-bit ports, each programmable as an input or output, from one serial port. It incorporates a high-performance microprocessor, which makes operating it easy.

Text commands can be used directly from a terminal emulator to provide interactive control. Alternatively the interface may be programmed via a programming language on a host PC. In this case, the same text commands can be used, provided that the programming language allows access to the host PC serial port.

Since this unit operates via a standard RS232 link, virtually any type of PC with a serial port can be used. A basic operating system is available in eprom. An additional benefit of using a microprocessor is that programs – compiled 68000 machine code – could also be downloaded into ram. Alternatively, they could be programmed into rom, and used to operate the ports autonomously. This extends the scope of the interface to use as a programmable controller.

Almost 32K-byte of space, provided by a 256K-bit ram, is available to store small routines. A 1M-bit device ram providing 128K-byte could be used. In fact, decoding circuitry described will drive the full 1M-byte address space of the MC68008 in 128K-byte segments.

In principle, additional ram could be added using 1M-bit chips up to 512K-byte, but some consideration to the circuitry would be needed. While 32K is regarded as tiny these days, it is adequate for many machine-code programs.

One application for which this interface is eminently suitable is eprom programming. The multiple ports allow for two or three address ports, catering for 16 or 24-bit addressing. Another one or two ports can transfer data in 8 or 16-bit widths, and further port can provide program and verification control signals.

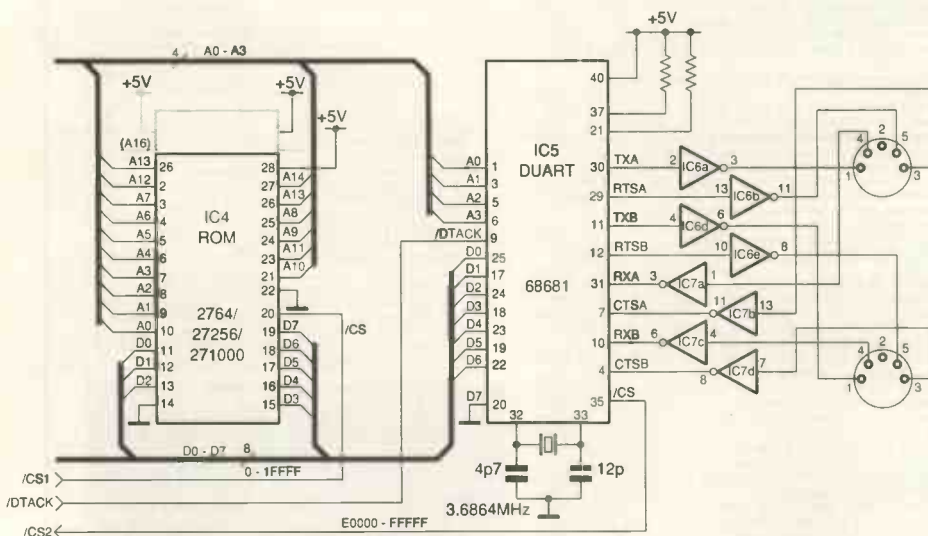
Large eproms can be programmed with this unit, but the RS232 handshaking routines will need careful design to prevent loss of data. Little extra hardware is required. A zero insertion-force socket and jumper pins for selecting the half-dozen or so non-standard pin-outs between different size eproms are needed, together with a selection of logic-controllable programming voltages, for example 12.5, 21 or 24V, or 16V for pals.

## Interfacing details

This is a straightforward microprocessor-based design incorporating the often overlooked MC68008, Fig. 1. The device is an eight-bit external-bus version of the 68000. It is able to provide much more powerful control capabilities than the 6502 or Z80, which are still often used in controllers.

A clock signal drives the processor at 8MHz, corresponding to 2MHz system clocking. A '138 decoder chip provides eight, 128K-byte address spaces which are filled

**Fig. 1.** At its most basic, this i/o interface operates 64 i/o lines from PC initiated commands communicated via RS232. Having its own 68000 family processor however, the card can become a versatile programmable controller capable of autonomous i/o.





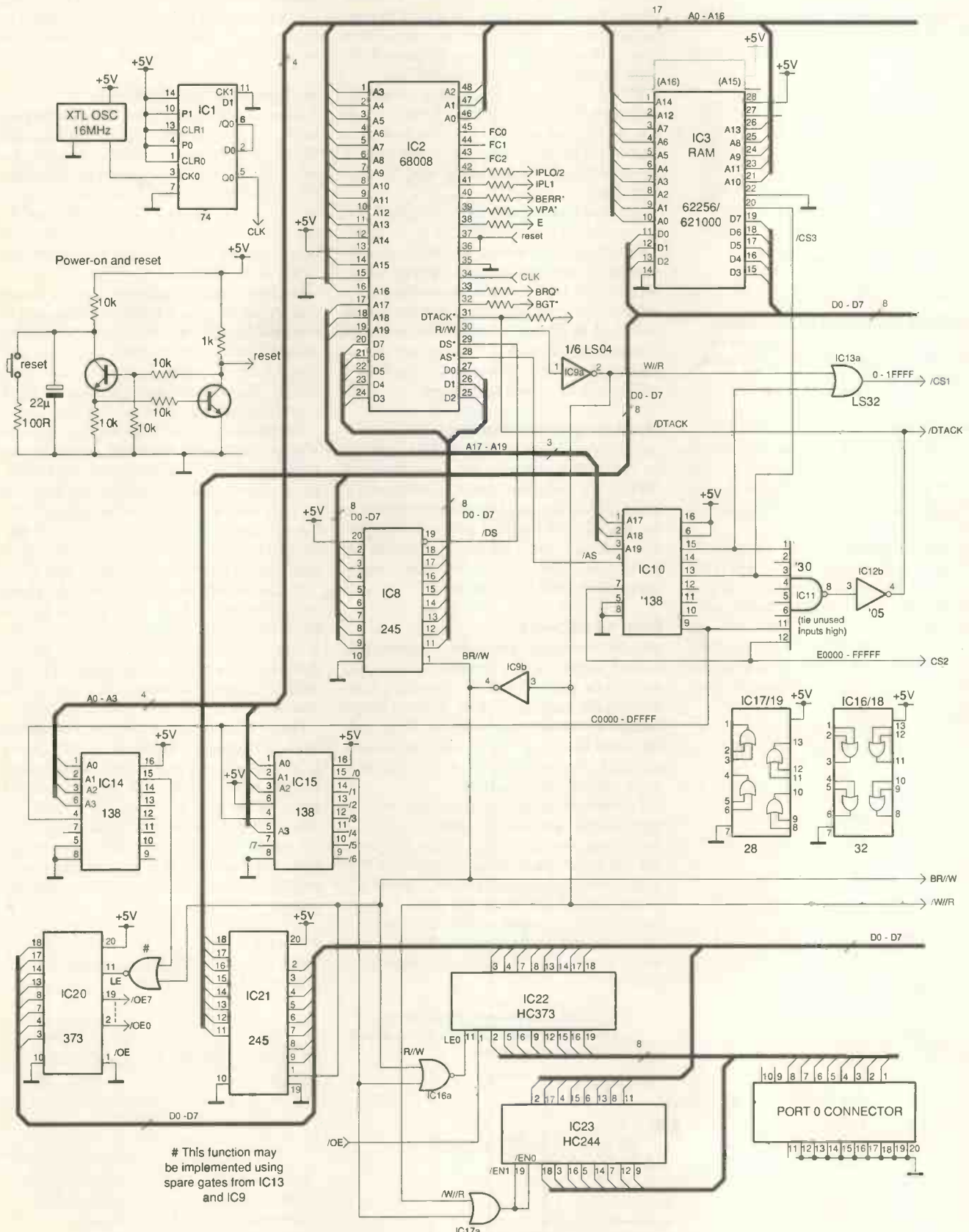
from zero upwards by a rom, at 40000<sub>16</sub> and up by ram, at C0000<sub>16</sub> and up by the i/o ports, and E0000<sub>16</sub> and up by the universal asynchronous receiver transmitter chip – a 68681.

Additional ram can be added at unused spaces 60000<sub>16</sub>-BFFFF<sub>16</sub>, but further address

and data buffering may be needed. Static ram keeps the design simple and avoids introducing wait states. The memory map summary is:

Address Use  
00000-1FFFF rom

20000-2FFFF rom expansion  
40000-5FFFF ram  
60000-BFFFF ram expansion  
C0000-C0007 i/o ports  
C0008 control byte  
E0000-E001F uart



7 identical i/o ports to port 0 but driven by /OE1...../OE7 from chip and /O1...../O7 from chip

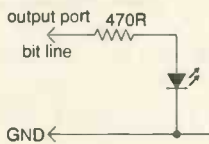


Fig. 2. In hardware terms, connecting an eight-bit d-to-a converter like the ZN428 to the interface involves little more than linking pins to i/o lines.

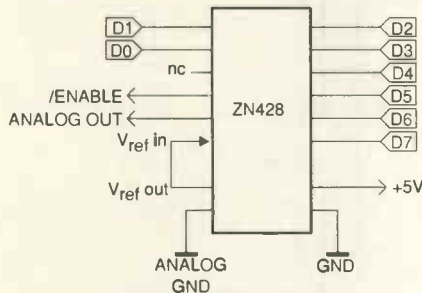
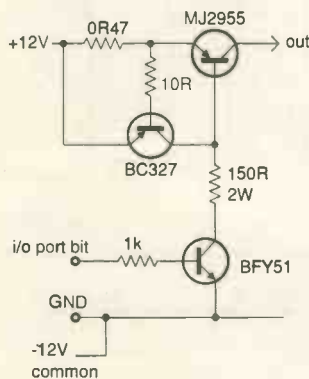


Fig. 3. Capable of delivering up to an amp at 12V, this high-side power switch incorporates current limiting for protecting the circuit in the event of an overload.

**Memory map**

Two RS232 terminals are provided by the 68681. Each RS232 socket is driven by 1488 and 1489 serial interface chips. To avoid wasting pins, DIN sockets are used as opposed to the usual 25 pin D type.

Each eight-bit, parallel i/o port comprises an HC373 latch with an LS244 buffer. Decoding these chips is performed using the R/-W line. A read activates the selected 244 buffer, while a write activates the selected latch, allowing data written to an output port to be read back. This configuration was chosen in preference to other parallel i/o ICs for three reasons – soft-



ware setting up is minimal, drive current is greater, and additional timers and control signals are unnecessary.

To allow each port to be used as an input or output, a ninth decoded HC373 latch controls each output enable pin on the eight i/o port latches. A control byte is written to a 'ninth' port address to select input or output functions on each i/o port. The bit number in this control byte corresponds to the port number of the eight i/o ports: bit 0 controls port 0, etc.

Writing a zero in a bit location allows the corresponding port to become a latched output. Writing a one to that bit turns the output latches off enabling that port to become an input, although inputs can be read from an output port.

It is not a good idea to 'force' an output port to be driven by something else as an input. Should this be essential, it can be accomplished by inserting an open-collector buffer between the latch and the input chip with a suitable pull-up resistor. If any port is required only to be an input or an output, the redundant chip need not be used. The control port is output-only, so if the control byte is needed, it will have to be copied to memory.

**Hardware considerations**

Initially, the bit rate is set to 9600baud. It can be changed by software but only through a 68000-code program. Power supplies of 5V and ±12V are needed. I considered whether to use RS232 interface chips with on-board voltage generators, but I rejected this idea as the devices are expensive. In addition, many applications need ±12V anyhow.

**Control software**

An eprom-resident controller program will receive simple ascii commands to read and write to the ports. It will also provide a rudimentary file handling system, in which the i/o routine is a separate file called io. This must be started by typing 'run io' from the terminal emulator after switching on, or sent by a program running on the host PC.

To write to a port, the command Wx,y is typed on the terminal emulator, or sent by a controlling program. Value x is the port number and y the data in hexadecimal form. The first command is usually to port 9, to set the output status of the other eight ports. Thus, to set ports 0-3 as outputs and 4-7 as inputs, the first command would be w8,f0. Port numbers are counted from zero and the command is not case sensitive.

To read from a port, the command R<x> is typed. Data is returned using hexadecimal ascii text of the form (x)=y. A menu is available, command M, with help, H, and quit, Q, to quit the i/o routine. Once quit, the minimal operating system software is in the main command mode to receive, send or run programs. It can even provide a list (dir) of programs in memory. To re-run the i/o program, just resend the command 'run io'.

**Rudimentary file transfer**

Although non-standard, the file-transfer protocol is reasonably simple. Command 'Re(ceive) <filename>' initiates receiving of a file, which should be given a filename. Filenames can be up to 32 characters, and can be anything, including spaces. The module takes text until new line characters carriage-return/line-feed, or 32 bytes – whichever is first – as the filename.

Once the filename has been received, binary data should be sent. A break should be sent to complete the file transfer. Terminal emulators usually carry out these tasks, but if not, you could write a routine to execute the 'send break'. There is no error checking and file lengths are arbitrary.

File transmission from the interface requires a 'send <filename>' command, at which point the name of the file in memory should be supplied. Transmission is initiated when the receiver indicates it is ready by issuing 'OK' through the serial link. This is to stop transmission until the host PC is ready to receive. It may have to be programmed to do this.

Programs sent as a file are run by typing 'run <filename>'. Unless control software is needed to operate the ports at speed, it is likely that normal operation through an RS232 interface via a program on the host PC will suffice. Control software must be 68000 machine code and written as PIC.

Figure 2 shows how to connect a digital-to-analogue converter. Figure 3 is a 12V power switch and Fig. 4 a mains-power switch using an opto-isolator. Logic for the i/o latches is cmos, rather than ttl, to provide a full 0-5V swing. This simplifies additional circuitry.

Examples of further drive and input circuits that could be used with this interface were published in the article mentioned in the reference.

**Reference**

Teliki, W., *Applied i/o Design for the PC*, EW&WW, June 1994, p. 452.

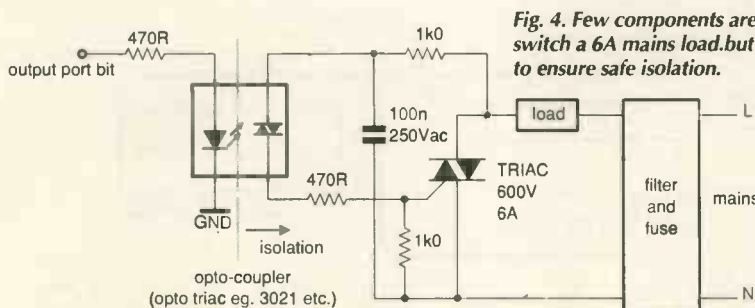


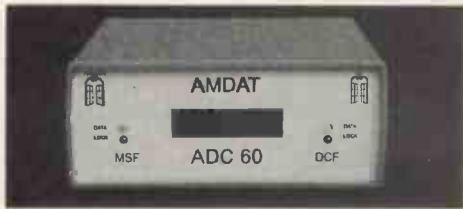
Fig. 4. Few components are needed to switch a 6A mains load, but care is needed to ensure safe isolation.

**Control software in eprom**

Operating software can be obtained by sending a 64K, 150ns eprom with cheque or postal order for £8.00 to J. N. Ellis, c/o Tavistock Electronics, Pixon Lane Industrial Estate, Tavistock, Devon. Alternatively, a programmed eprom is available for £18. Readers interested in a pcb, contact Mr Ellis.



## THE clock for your computer



The ADC-60 brings the accuracy of a time standard to your computer. It provides a data source which can be used by any system which has a serial port such as a PC, MAC or mainframe. The ADC-60 offers improved reliability by using both the British MSF and German DCF time standards. If one of the signals cannot be received the other source will automatically be used.

Other ADC-60 Features include:

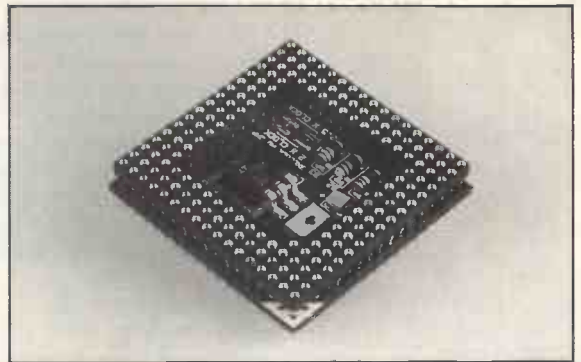
- LCD display showing current time and date together with the lock status of the unit.
- Provides GMT or Local time outputs together with the date
- Serial output in ASCII or BCD format
- Includes 2 software packages, the first is a TSR which runs under DOS, the second runs as a minimised window in Microsoft Windows

Contact us today for further information on this superb product

**AMDAT** 4 Northville Road, Northville  
Bristol BS7 0RG  
Tel: 0272 699352 Fax: 0272 872228

CIRCLE NO. 143 ON REPLY CARD

## UPGRADE YOUR 486!



ARIES Electronics Upgrade Socket (for PGA DX4), or Upgrade Adapter (for SQFP DX4), allows you to upgrade from 486 to DX4 seamlessly, thus taking advantage of its faster speed.

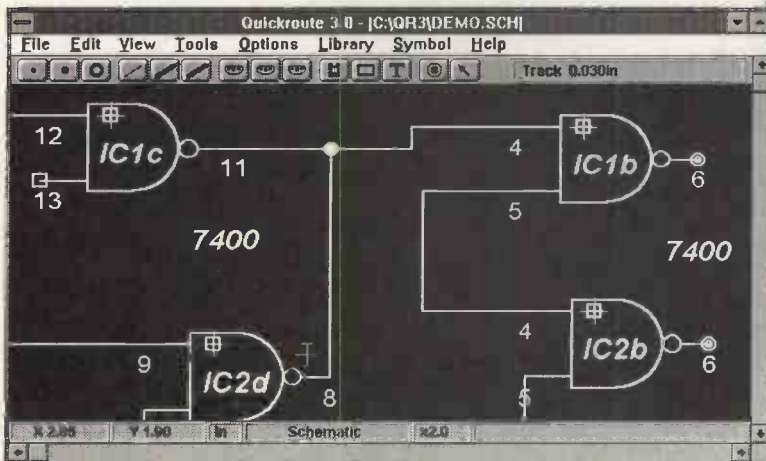
### Aries Electronics (Europe)

Unit 3, Furtho Court, Towcester Road  
Old Stratford, Milton Keynes MK19 6AQ  
Tel: +44 1908 260007 Fax: +44 1908 260008

CIRCLE NO. 144 ON REPLY CARD

## Quickroute 3.0

PCB & Schematic Design System for Windows 3.1



Announcing a new range of affordable, powerful Windows based PCB and schematic design packages from *POWERware*.

**DESIGNER** £99 \*

PCB and schematic design with all the new 'Easy-Edit' features and an Auto router!

**DESIGNER +** £149 \*

For larger PCB and schematic designs, adds Gerber and NC-Drill support.

**PRO** £199 \*

Schematic capture, with integrated rats-nest generation and auto-router. Export net-lists for design checking.

**PRO +** £299 \*

Advanced schematic capture for management of larger schematics. Gerber import facility for file exchanging.

For more details, contact  
*POWERware*, 14 Ley Lane,  
Marple Bridge, Stockport,  
SK6 5DD, UK.

\* Prices exclude VAT, post & packing

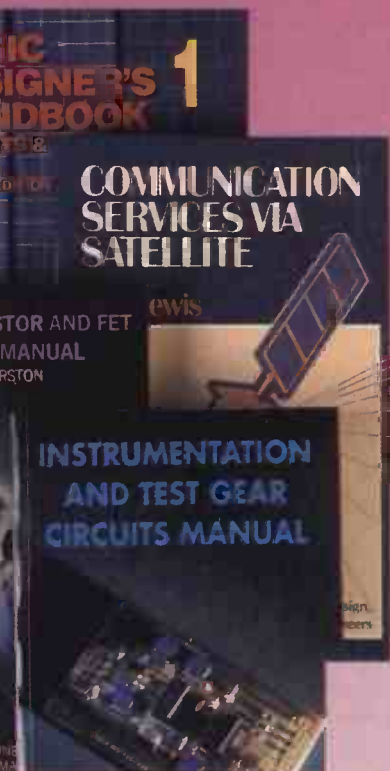
**Tel/Fax 061 449 7101**

from

**£99\***

CIRCLE NO. 145 ON REPLY CARD

# BOOKS TO BUY



In grasping electrical and electronics theory. This book has been written to help such students to understand the mathematical principles underlying their subject so that they can go on with confidence to tackle problems in practical circuits. Paperback 256 pages.  
**Price £14.95 0 7506 0924 9**

## CIRCUIT MANUALS

### Ray Marston

A series of books dealing with their subjects in an easy-to-read and non-mathematical manner, presenting the reader with many practical applications and circuits. They are specifically written, for the design engineer, technician and the experimenter, as well as the electronics student and amateur. All the titles are written by Ray Marston, a freelance electronics design engineer and international writer.

### Op-amp Circuits Manual

**Paperback 224 pages**  
**Price £13.95 0 434 912077**

### Audio IC Circuits Manual

**Paperback 168 pages**  
**Price £13.95 0 434 912107**

### CMOS Circuits Manual

**Paperback 192 pages**  
**Price £13.95 0 434 912123**

### Electronic Alarm Circuits Manual

**Paperback 144 pages**  
**Price £13.95 0 7506 00640**

### Timer/Generator Circuits Manual

**Paperback 224 pages**  
**Price £13.95 0 434 912913**

### Diode, Transistor and FET Circuits Manual

**Paperback 240 pages**  
**Price £13.95 0 7506 0228 7**

### Instrumentation and Test Gear Circuits Manual

**Ray Marston**  
Modern instrumentation and test gear circuits of value to the industrial, commercial, or amateur electronic engineer or designer make up this book. Almost 500 outstandingly useful and carefully selected practical circuits are in here. This is one book you must have if you need access to practical working circuits ranging from simple attenuators and bridges to complex digital panel meters, waveform generators, and scope trace doublers. Paperback 400 pages.  
**Price £16.95 0 7506 0758 0**

## Logic Designers Handbook

### Andrew Parr

Easy to read, but none the less thorough, this book on digital circuits is for use by students and engineers and provides an accessible source of data on devices in the TTL and CMOS families. It's a 'Designers Handbook' that will live on the designer's bench rather than on the bookshelf. The basic theory is explained and then supported with specific practical examples. Paperback 488 pages.  
**Price £25.00 0 7506 0535 9**

## Digital Audio and Compact Disc Technology

### Luc Baert, Luc Theunissen & Guido Vergult

Essential reading for audio engineers, students and hi-fi enthusiasts. A clear and easy-to-follow introduction and includes a technical description of DAT (digital audio tape). Contents includes principles of digital signal processing, sampling, quantization, A/D conversion systems, codes for digital magnetic recording, principles of error correction, the compact disc, CD encoding, opto-electronics and the optical block, servo circuits in CD players, signal processing, digital audio recording systems, PCM, Video 8, R-DAT and S-DAT. Paperback 240 pages.  
**Price £16.95 0 7506 0614 2**

## NEWNES POCKET BOOKS

A series of handy, inexpensive, pocket sized books to be kept by your side and used every day. Their size makes them an ideal 'travelling' companion as well.

### Newnes Electronics Engineer's Pocket Book

**Keith Brindley**  
**Hardback 319 pages**  
**Price £12.95 0 7506 0937 0**

### Newnes Electronics Assembly Pocket Book

**Keith Brindley**  
**Hardback 304 pages**  
**Price £10.95 0 7506 0222 8**

### Newnes Television and Video Engineer's Pocket Book

**Eugene Trundle**  
**Hardback 384 pages**  
**Price £12.95 0 7506 0677 0**

### Newnes Circuit Calculations Pocket Book

**T Davies**  
**Hardback 300 pages**  
**Price £10.95 0 7506 0195 7**

## Newnes Data Communications

### Pocket Book

**Michael Tooley**  
**Hardback 192 pages**  
**Price £12.95 0 7506 0427 1**

## Newnes Telecommunications Pocket Book

**JE Varrall & EA Edis**  
**Hardback 400 pages**  
**Price £12.95 0 7506 0307 0**

## Newnes Z80 Pocket Book

**Chris Roberts**  
**Hardback 185 pages**  
**Price £12.95 0 7506 0308 9**

## Newnes 68000 Pocket Book

**Mike Tooley**  
**Hardback 257 pages**  
**Price £12.95 0 7506 0309 7**

## Newnes Electrical Pocket Book

**21st edition**  
**E A Parr**  
**Paperback 526 pages**  
**£12.95 0 7506 05138**

## Newnes Electric Circuits Pocket Book Linear IC

**Ray Marston**  
**Hardback 336 pages**  
**Price £12.95 0 7506 0132 9**

## Newnes Guide to Satellite TV

**D J Stephenson**  
A practical guide, without excessive theory of mathematics, to the installation and servicing of satellite TV receiving equipment for those professionally employed in the aerial rigging/TV trades. Hardback 256 pages.  
**Price £17.95 0 7506 0215 5**

## Newnes Practical RF Handbook

**Ian Hickman**  
Pressure on the RF spectrum has never been greater and it's people with knowledge and skills of RF design who are now in demand in the electronics industry to design, produce, maintain and use equipment capable of working in this crowded environment. This practical introduction to modern RF circuit design will equip you with the necessary RF knowledge and skills to enable you to compete effectively in the industry. Paperback 320 pages.  
**Price £16.95 0 7506 0871 4**

## Troubleshooting Analog Circuits

**R A Pease**  
Bob Pease is one of the legends of analog design. Over the years, he's developed techniques and methods to expedite the often-difficult tasks of debugging and

## Programmable Logic Handbook

### Geoff Bostock

Logic circuit designers are increasingly turning to programmable logic devices as a means of solving problems. This book, for the established electronics engineer, student and technician, is a thorough introduction to programmable logic. Geoff Bostock will take you to a level where you, as a designer, can take full advantage of the growing product range of ASICs and other self-programmable arrays used in computer and control systems. Paperback 256 pages.  
**Price £19.95 0 7506 0808 0**

## Understand Electrical and Electronic Maths

### Owen Bishop

People who find maths difficult often have, as a result, difficulty



troubleshooting analog circuits. Now, Bob has compiled his 'battle-tested' methods in the pages of this book. Based on his immensely popular series in EDN Magazine, the book contains a wealth of new material and advice for Digital/Analog electronics engineers on using simple equipment to troubleshoot. Paperback 217 pages.  
**Price £14.95 0 7506 16326**

**PC-Based Instrumentation and Control**

**M Tooley**  
 Do you need information to enable you to select the necessary hardware and software to implement a wide range of practical PC-based instrumentation and control systems? Then this book is for you. Paperback 320 pages.  
**Price £14.95 0 7506 1631 8**

**Electronic Circuits Handbook**

**M Tooley**  
 Provides you with a unique collection of practical working circuits together with supporting information so that circuits can be produced in the shortest possible time and without recourse to theoretical texts. Paperback 345 pages.  
**Price £24.95 0 7506 0750 5**

**Communication Services via Satellite**

**G E Lewls**  
 DBS is already with us, and will create a series of new technical problems for engineers/technicians in television and communication services. This book gives you the solutions to these problems by:

explaining how the system functions; describing several actual systems and giving several analyses and design rules. You can't afford to be without this invaluable technology update if you're a systems design engineer, service engineer or technician. Paperback 400 pages.  
**Price £25.00 0 7506 0437 9**

**Digital Logic Design**

**Brian Holdsworth**  
 As one of the most successful and well established electronics textbooks on digital logic design, this book reflects recent developments in the digital fields. The book also covers new functional logic symbols and logic design using MSI and programmable logic arrays. Paperback 448 pages.  
**Price £19. 50 0 7506 0501 4**

**The Circuit Designers Companion**

**T Willams**  
 This compendium of practical wisdom concerning the real-world aspects of electronic circuit design is invaluable for linear and digital designers alike. Hardback 320 pages.  
**Price £25 00 0 7506 1142 1**

**Credit card orders accepted by phone**  
**081 652 3614**

**Return to: Lorraine Spindler, Room L333, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS**

**Please supply the following titles:**

Qty	Title	ISBN	Price
.....	Programmable Logic Handbook	07506 0808 0	19.95
.....	Understanding Electrical & Elec Maths	07506 0924 9	14.95
.....	Op-amp Circuits Manual	0434 912077	13.95
.....	Audio IC Circuits Manual	0434 912107	13.95
.....	CMOS Circuit Manual	0434 912123	13.95
.....	Electronic Alarm Circuits Manual	07506 0064 0	13.95
.....	Power Control Circuits Manual	07506 06908	13.95
.....	Timer/Generator Circuits Manual	0434 91291 3	13.95
.....	Diode, Transistor & FET Circuits Man	07506 0228 7	13.95
.....	Instrumentation & Test Gear Circuits Man	07506 0758 0	16.95
.....	Logic Designers Handbook	07506 0535 9	25.00
.....	Digital Audio and Compact Disc	07506 0614 2	16.95
.....	Newnes Elec Engineers Pkt Bk	0 7506 0937 0	12.95
.....	Newnes Elec Assembly Pk Bk	07506 0222 8	10.95
.....	Newnes TV and Video Eng Pkt Bk	07506 0677 0	12.95
.....	Newnes Circuit Calculations Pkt Bk	07506 0427 1	10.95
.....	Newnes Data Communications Pkt Bk	07506 0308 9	12.95
.....	Newnes Telecommunications Pkt Bk	07506 0307 0	12.95
.....	Newnes Z80 Pkt Bk	07506 0308 9	12.95
.....	Newnes 68000 Pkt Bk	07506 0309 7	12.95
.....	Newnes Electrical Pk Bk	07506 05138	12.95
.....	Newnes Electric Circuits Pocket Bk	07506 0132 9	12.95
.....	Newnes Guide to Satellite TV	07506 0215 5	17.95
.....	Newnes Practical RF Handbook	07506 0871 4	16.95
.....	Troubleshooting Analog Circuits	07506 16326	14.95
.....	PC-Based Instrumentation and Control	07506 1631 8	14.95
.....	Electronic Circuits Handbook	07506 0750 5	24.95
.....	Communication Services via Satellite	07506 0437 9	25.00
.....	Digital Logic Design	07506 05014	19.50

PLEASE ADD £2.50 FOR POSTAGE  
 Add VAT at local rate .....  
 NB ZERO RATE FOR UK & EIRE .....TOTAL .....

**Business purchase:** Please send me the books listed with an invoice. I will arrange for my company to pay the accompanying invoice within 30 days. I will attach my business card/letterhead and have signed the form below.  
**Guarantee:** If you are not completely satisfied, books may be returned within 30 days in a resaleable condition for a full refund.

Remittance enclosed £ .....  
 Cheques should be made payable to **Reed Book Services Ltd.**  
 Please debit my credit card as follows:

Access/Master      Barclay/Visa      Amex      Diners

Credit Card No. \_\_\_\_\_ Exp date \_\_\_\_\_

NAME (Please print) \_\_\_\_\_

ORGANISATION \_\_\_\_\_

STREET \_\_\_\_\_

TOWN \_\_\_\_\_

COUNTY \_\_\_\_\_ POST CODE \_\_\_\_\_ COUNTRY \_\_\_\_\_

DATE \_\_\_\_\_ TELEPHONE NUMBER \_\_\_\_\_

SIGNATURE \_\_\_\_\_

T3000

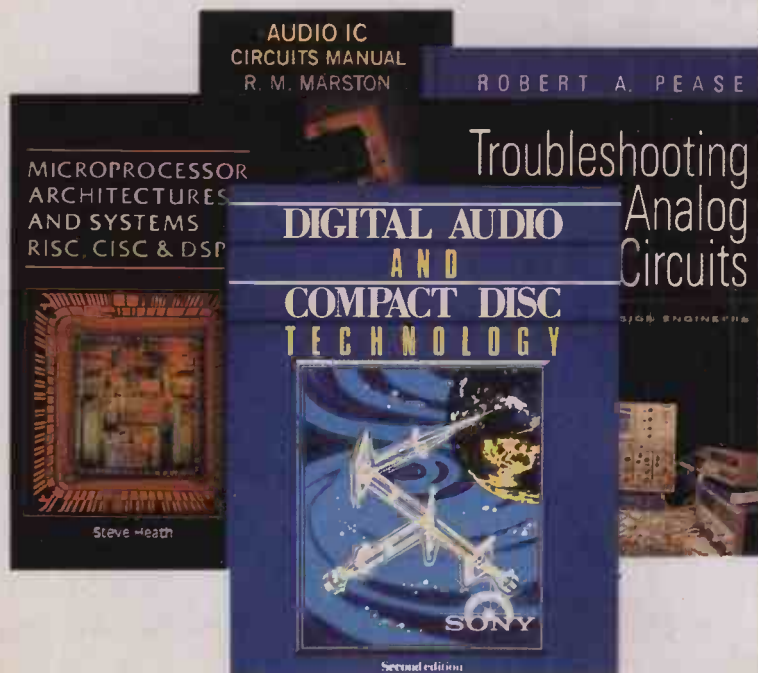
**VAT RATES**

6% Belgium, 25% Denmark, 5.5% France, 7% Gemany, 4% Greece, 4% Italy, 3% Luxembourg, 6% Netherlands, 5% Portugal, 3% Spain. FOR COMPANIES REGISTERED FOR VAT, PLEASE SUPPLY YOUR REGISTRATION NUMBER BELOW (customers outside the EEC should leave this part blank)  
 VAT NO. \_\_\_\_\_

If in the UK please allow 28 days for delivery. All prices are correct at time of going to press but may be subject to change.

Please delete as appropriate. I do/do not wish to recieve further details about books, journals and information services.

Reed Business Publishing - Registered Office - Quadrant Hse The Quadrant Sutton Surrey SM2 5AS Registered in England 151537



# APPLICATIONS

Please mention *Electronics World + Wireless World* when seeking further information.

## Wideband op-amp delivers broadcast-quality video

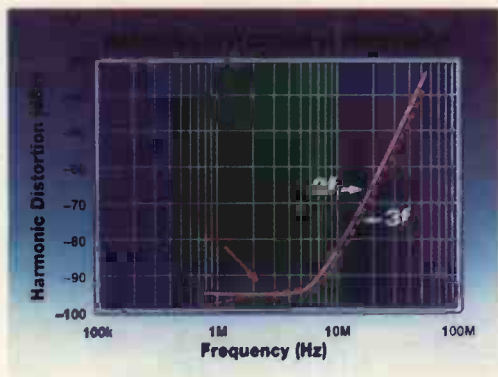
At PAL and NTSC frequencies, the OPA628 op-amp has a differential gain error of 0.015% and a differential phase error of 0.015° when driving a back-terminated 75Ω cable.

As the device data sheet describes, these specifications are made possible using a classical op-amp architecture involving true differential and fully symmetrical inputs. Separated power supply pins for the input and output stages also eliminate the effects of package and wire-bond parasitic effects.

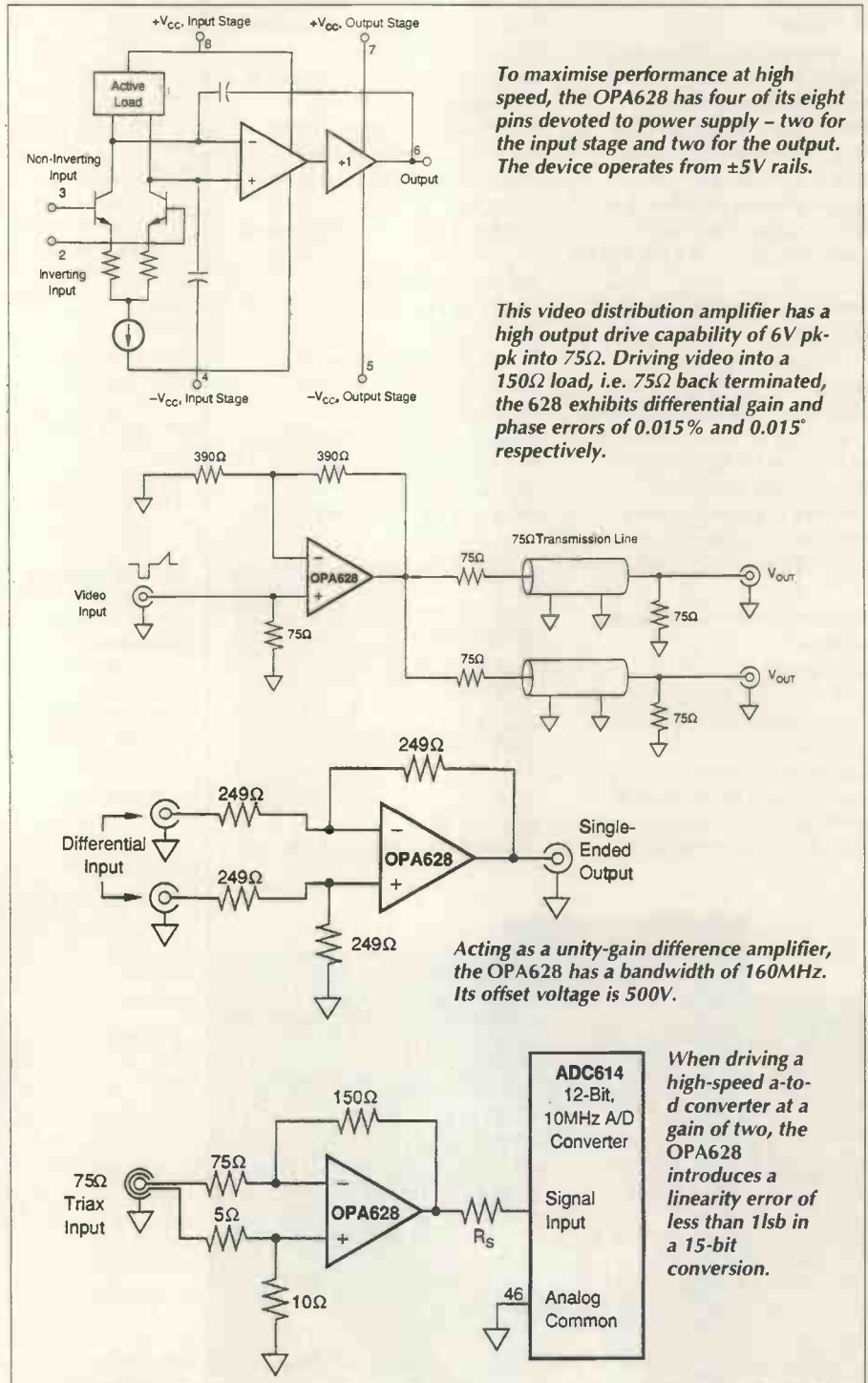
In performance terms, the device has other interesting features. These include unity-gain stability with a bandwidth to 160MHz, 90dB spurious-free dynamic range and a 2nV/√Hz noise figure. The two-tone third-order intercept is 60dB and gain is flat within 0.1dB to 30MHz.

Both Spice models and evaluation boards exist for the OPA628. The data sheet carries in-depth details of the device's performance together with discussions on many aspects including driving capacitive loads, thermal considerations, input protection and pcb layout. The three application circuits shown here are included in the note but there is no further specific information on their operation.

**Burr Brown**, 1 Millfield House, Woodshots Meadow, Watford, Hertfordshire WD1 8YX. Tel. 0923 33837, fax 0923 33979.



At unity gain, the 2f curve is roughly the same as the 3f curve shown here. Increasing gain to 2V/V causes the 2f curve to rise but the 3f curve shape and position remain virtually unchanged.





# Function generators use analogue trigonometric synthesiser

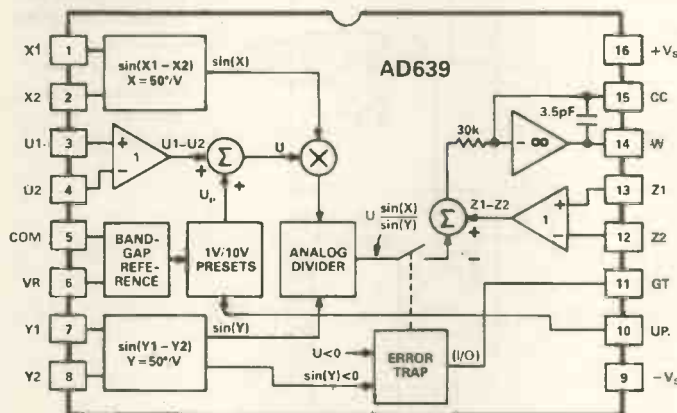
Via pin-strapping, the AD639 function generator provides all the standard trigonometric functions and their inverses. According to the device data sheet, its law conformance and total harmonic distortion surpass figures previously attained using analogue shaping techniques. Also in the data sheet are a number of application circuits. Two of them are described here, namely a gated function generator and a four-quadrant sine multiplier.

Compared with using rom look-up tables and d-to-a conversion, the device is also faster; in sine mode, bandwidth is typically 1.5MHz. Unlike other function synthesis circuits, the AD639 provides a smooth and continuous sine conformance over a range of -500° to +500°. When generating a sine wave, law conformance is within 0.02% and distortion levels of -74dB are attainable for triwave to sine wave conversion.

The device generates a basic function representing the ratio of a pair of independent sines:

$$W = U \frac{\sin(x_1 - x_2)}{\sin(y_1 - y_2)}$$

Differential angle arguments are proportional to the input voltages X and Y scaled by 50°/V. Using the 1.8V on-board reference any of the angular inputs can be preset to 90°. This provides the means to set up a fixed numerator or denominator (sin 90°=1) or to convert either sine function to a cosine (cosθ=sin(90°-θ)). Using the ratio of



Capable of generating trigonometrical functions including sin, cos, tan, cosec, sec, cot, arcsin, arccos and arctan, the AD639 can produce a sine wave with 0.02% law conformance.

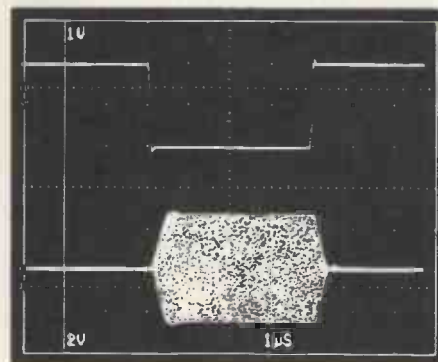
sines, all trigonometric functions can be generated.

Amplitude of the function is proportional to a voltage U, which is the sum of an external differential voltage (U<sub>1</sub>-U<sub>2</sub>) and an optional internal preset voltage, U<sub>p</sub>. Control pin UP selects a 0V, 1V or 10V laser-trimmed preset amplitude which may be used alone (U<sub>1</sub>-U<sub>2</sub>=0) or internally added to the U<sub>1</sub>-U<sub>2</sub> analogue input.

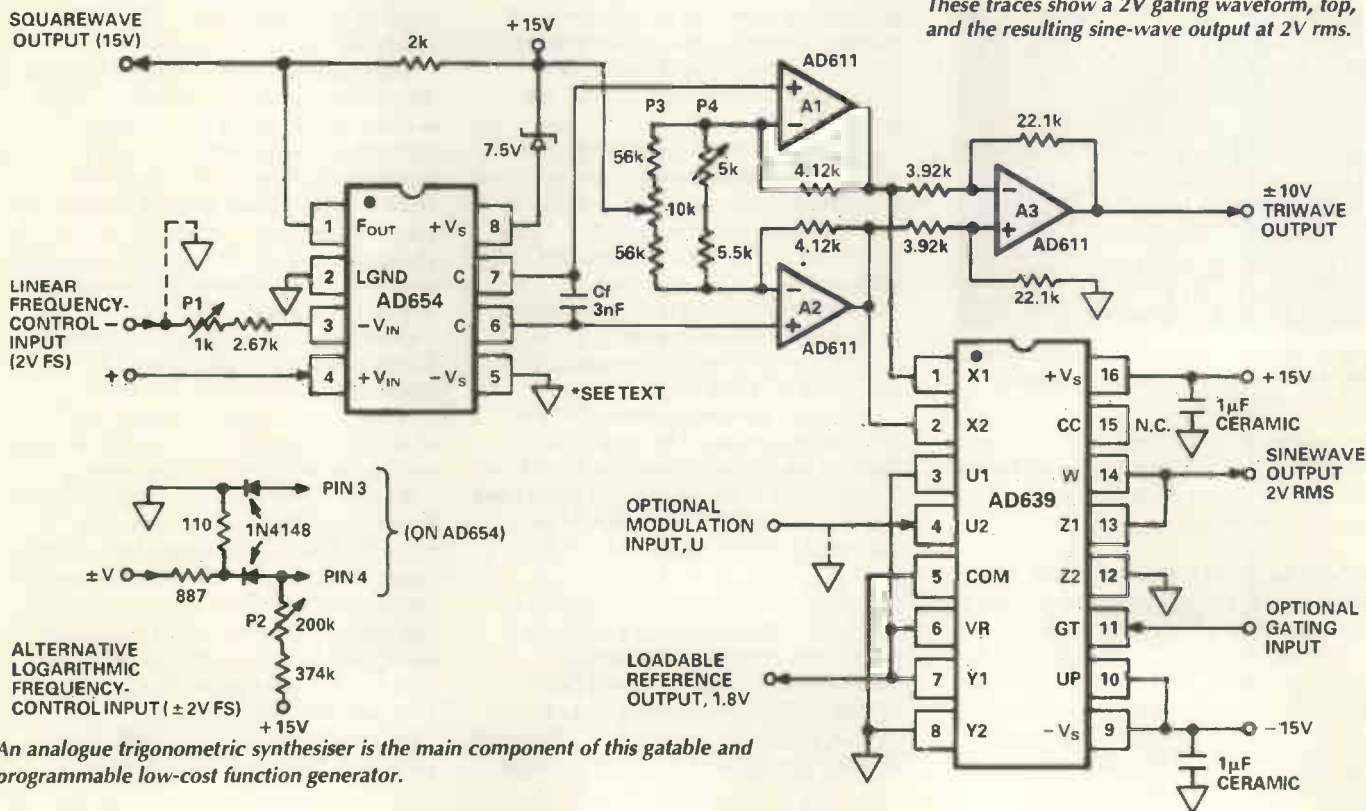
At the output, a further differential voltage Z can be added to the ratio of sines to obtain the offset trigonometric functions versine (1-cosθ), coversine (1-sinθ) and exsecant (1-secθ). A gating input is available enabling or disabling the analogue output. This pin also acts as an error flag output in situations where a combination of inputs

will cause the output to saturate or to be undefined.

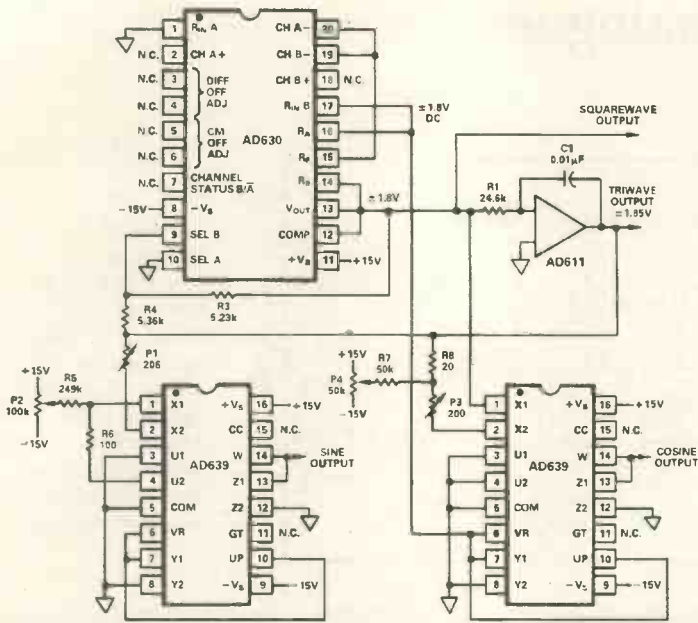
In the inverse modes, the argument can be



Output of the function generator is gatable. These traces show a 2V gating waveform, top, and the resulting sine-wave output at 2V rms.



An analogue trigonometric synthesiser is the main component of this gatable and programmable low-cost function generator.

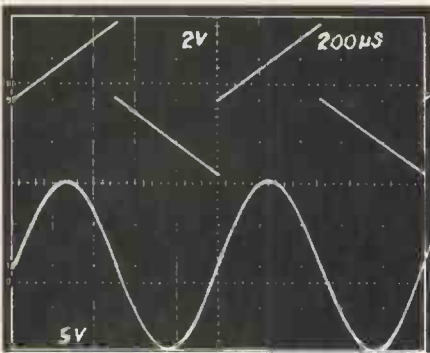


*Designing a quadrature oscillator around the AD 639 trigonometric function generator avoids many of the problems associated with integrator/sign-inverter combinations.*

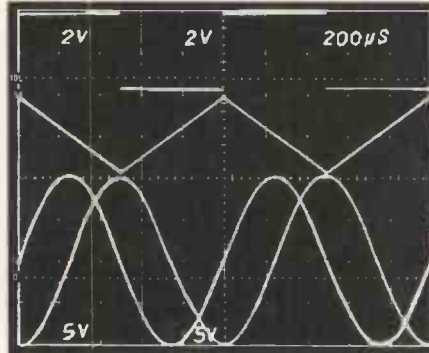
scheme provides a log-sweep response with an approximate scaling of  $10^4$  kHz (where  $V$  is in volts). The range is now from about 10Hz to 100kHz; the frequency should be set to 1kHz with  $V=0$ , using  $P_2$ . Frequency is now sensitive to variations in both temperature and the +15V supply, but stability will be adequate for many applications.

Because of the exceptionally wide angular range of the numerator function of the AD639, it is possible to generate sine wave outputs with 2, 3, 4 or 5 times the triwave frequency using cosine mode for even multiples of the sine mode for odd multiples.

For example, to multiply the output frequency by 3, use the sine function with the X input driven to 5.4V ( $\pm 270^\circ$ ). Distortion remains low; all harmonics are typically under -50dB, even for the frequency quintupling mode.



**Fig. 1.** Top waveform is the difference voltage between the triwave and squarewave. Resulting output is shown in the bottom trace.



**Fig. 2.** Timing relationships between all outputs of the quadrature oscillator.

**Sine/cosine oscillators.** Quadrature oscillators generate a pair of sinusoidal outputs displaced by  $90^\circ$ , and are invariably based on a state-variable loop comprising two integrators and a sign-inverter. This approach however needs additional circuitry to control the amplitude of the oscillation. In addition, a trade-off arises between the settling-time of this control circuitry and the distortion level, which is particularly troublesome at low frequencies. Amplitude balance of the two outputs depends on the matching of two time-constants and two tracking analogue multipliers or multiplying d-to-a converters are needed if the frequency is to be programmable.

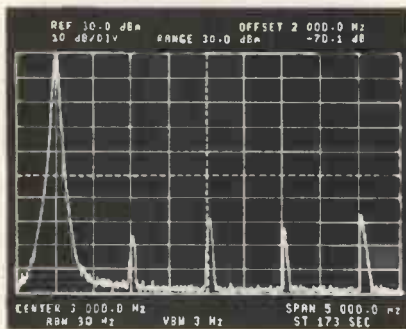
These problems are avoided using a function-shaping technique based on a triwave oscillator. Only one time-constant is required, so its frequency is more easily controlled.

Amplitude control is eliminated by using the scheme shown. The two outputs have accurate amplitudes of 10V, without the need for an external reference source. Alternatively, they can be individually controlled by external voltages, without any effect on frequency. Variable-amplitude sine and cosine outputs can be added using the Z-input to provide continuously-variable phase control of the output.

The triwave oscillator has an AD630. This device alternates the sign of the 1.8V reference from one of the AD639s to generate a square-wave output of  $\pm 1.8V$  amplitude. An integrator, formed by  $R_1$ ,  $C_1$  and the op-amp, generates the triwave.

Amplitude of the triwave is determined by the ratio of  $R_3$  to  $R_4$ , and is nominally  $\pm 1.845V$ . This is 2.5% higher than needed at inputs of the 639s, providing the adjustment range needed minimise distortion. In many applications, all adjustments can be eliminated. To do this, make  $R_2=R_4=5k\Omega$ , omit  $P_{2,4}$ ,  $R_{5,7}$ , and replace  $P_{1,3}$ , and  $R_{6,8}$  with short circuits.

Frequency is nominally  $1/4 C_1 R_1$ , and is 1kHz with component values shown. A



**Fig. 3.** Spectrum of cosine output at 1kHz for the AD639-based quadrature oscillator.

the ratio of two input signals. This allows the user to compute the phase angle between the real and imaginary components of a signal using the arctangent mode.

**Wide-range waveform generator.** This is an inexpensive signal generator, providing voltage control of frequency from 20Hz to 20kHz and a preset sine amplitude of 2.8V (within 0.1dB of 2V rms). This output may be further modulated by an input of up to  $\pm 2.8V$  to input U2, or gated off by an input of +1.5V or more to input GT; the

oscilloscope shows the gated response. If required, a further input can be summed into Z2. The sine output can be set to 10V amplitude by connecting UP to VR and grounding U1.

An AD654 is used to generate the triwave which appear across timing capacitor  $C_f$ , and is buffered, amplified and level-shifted by  $A_1$  and  $A_2$ . Using a spectrum analyser,  $P_3$  and  $P_4$  are adjusted to minimise even- and odd-harmonic distortion, respectively.

The triwave linearity is not good enough to realise the inherent capabilities of the AD639, but total harmonic distortion is in the -50dB to -60dB range.

Op-amp  $A_3$  provides further gain for a  $\pm 10V$  triwave output. The square-wave output is taken directly from the AD654 and is unbuffered. It swings between ground and +15V; if pins 2 and 5 of the AD654 are connected to -15V, this output is 30V pk-pk.

Scaling with the linear input (shown) is 10kHz/V, calibrated using  $P_1$ . Frequency can be controlled manually using a potentiometer and the V output of the AD639,  $P_1$  has sufficient trim range to provide a full-scale frequency of 20kHz with the 1.8V peak input. The alternative input



variety of methods may be used provide external control of frequency, including the use of another AD630 in series with  $R_1$ , or a multiplying d-to-a converter.

Sine output is generated using the triwave directly. Potentiometers  $P_1$  and  $P_2$  should be adjusted using a spectrum analyser for minimum odd-order and even-order harmonics, respectively. The cosine is generated by using the difference between the triwave the square-wave, as shown in the upper wave form of Fig. 1. This composite voltage first generates a sine-

function over range 0 to  $+180^\circ$ , then over the range 0 to  $-180^\circ$ , to produce the function shown in the lower wave form, which can be seen to be  $90^\circ$  out of phase with the triwave.

The complete set of wave forms available from this generator are shown in Fig. 2. Potentiometers  $P_3$  and  $P_4$  are adjusted for minimum odd-order and even-order cosine harmonics, respectively. Fig. 3 shows the cosine spectrum for a well-adjusted circuit. Due to the finite transition time back to the baseline in the drive voltage to the cosine generator, a brief spike occurs at the zero-

crossing of this output.

Frequency components will be beyond the bandwidth of the output amplifier in the AD639, and the energy contained in these spikes will not generally be troublesome. They may be further reduced, if necessary, by adding a capacitor between pins 14 and 15, to roll off the AD639 output response.

Analog Devices, Station Avenue, Walton-on-Thames, Surrey KT12 1PF. Tel. 0932 253320, fax. 0932 247401.

## Switching with igbts reduces lamp ballast size

Nearly all insulated gate bipolar transistors, igbts, are high-power devices, but there is a pair of medium-power, low-cost devices in TO-92-style packaging. These are the n-channel ZCN0545 and the p-channel ZCP0545.

The circuit is an 11W off-line fluorescent lamp ballast using two ZCN0545A igbts. Efficiency of the circuit is such that it allows the TO92-format E-line igbts to replace the TO220/TO126 bipolar or mosfets commonly used in this application. This both lowers component costs and gives a reduction in circuit size – critical in integral lamp/ballast designs.

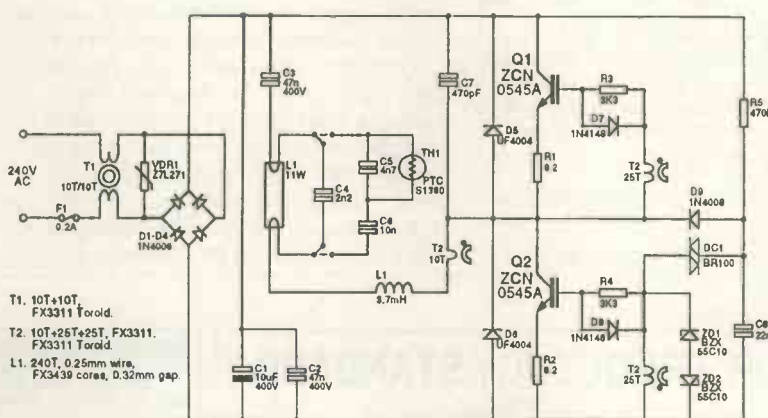
The 300ns turn-off capability of the ZCN0545A would allow operation at up to 100kHz but the working frequency of the design was set at 40kHz to minimise losses and hf interference.

By controlling the phase of the current flowing in the igbts so that cross-conduction

does not occur, switching losses have been virtually eliminated. Also the low effective  $R_{DS(on)}$  of the ZCN0545A keeps conduction losses to around 60mW in each device.

The first curves below show the voltage

and current waveforms of the igbts. Curves in the lower graph show an expanded view of the critical turn-off behaviour of the ZCN/ZCP0545A pair. Note in particular that the drain current falls to zero before the



- T1. 10T+10T, FX3311 Toroid.
- T2. 10T+25T+25T, FX3311, FX3311 Toroid.
- L1. 240T, 0.25mm wire, FX3439 cores, 0.32mm gap.

Since the ZCN igbts are efficient, they can replace TO220/126 bipolar or mos transistors and provide savings in both cost and circuit volume.

## Inside the igbt

This relatively new type of transistor has a mosfet input device followed by a bipolar amplifier. The high input resistance is ideal for direct drive from microcontrollers. In addition, igbts have a low  $R_{DS(on)}$ . For a given chip size and  $BV_{DSS}$ , the on resistance of an igbt is less than 10% that of a standard high-voltage mosfet at high current.

Like a bipolar darlington, the igbt needs a drain-source voltage of 0.7V before current flows. If the drain-source terminals are reverse biased, the drain-source diode of the input mosfet cannot conduct since the base-emitter junction of the output bipolar transistor is in series. In many applications this provides a very useful reverse blocking capability.

Switching speed is dominated by the characteristics of the bipolar transistor, which can be optimised for either speed or saturation voltage. The ZCN0545 and ZCP0545 are designed to be very fast at switching on – in less than 20ns – and their off time is less than 300ns. This makes them suitable for switching applications up to 100kHz.

Since the structure of igbts includes an scr, they have a drain current which, if exceed-

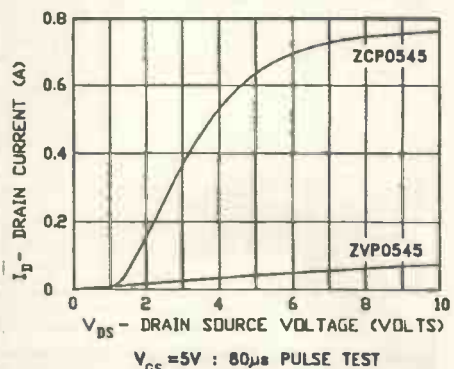
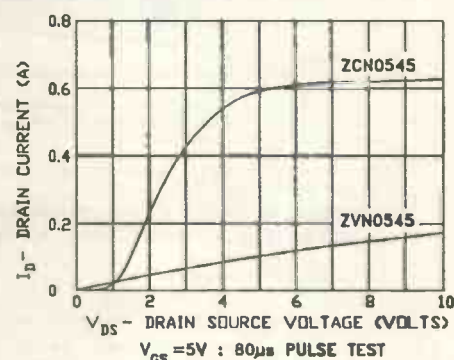
ed, will cause the device to latch up. Latchup can lead to device destruction in some applications. Consequently, the pulsed drain current rating of the igbt should not be exceeded. This rating is temperature sensitive, falling as temperature increases.

Equivalent  $R_{DS(on)}$  of an igbt on the other hand does not change significantly with temperature. Standard mosfet resistances double as temperature is raised from ambient to the device upper limit.

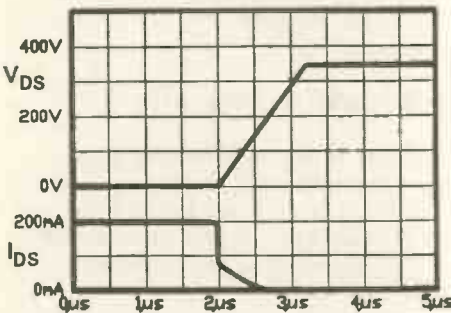
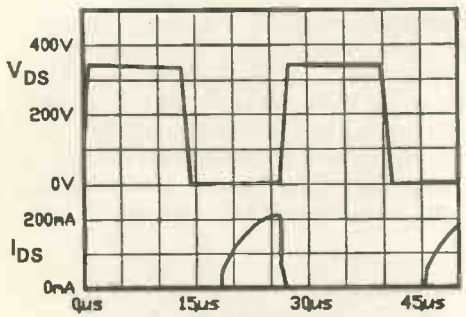
Output characteristics of the ZCN0545 and ZCP0545 igbts are illustrated on the right. These curves show typical  $I_D$  versus  $V_{DS}$  for a 5V logic level gate drive.

To indicate the improvement the igbt structure gives over standard mosfets, graphs of the typical performances of two mosfets with an identical chip size, the ZVN0545 and ZVP0545, have been plotted for comparison.

In each graph, the top curve shows characteristics of a ZC type medium-power igbt while the lower curve illustrates a similarly-sized mosfet. For a given chip area and voltage rating, on resistance of the igbt is less than 10% that of a mosfet. Upper graph is n-channel, lower p-channel.



# APPLICATIONS



Voltage and current waveforms for the fluorescent lighting ballast circuit, left, and an expanded view of critical turn-off behaviour of the IGBT used. Because drain current falls to zero before drain voltage rises significantly, switching losses are low.

drain voltage rises significantly, giving low switching losses.

Gate drive for the IGBTs come from a cur-

## Benefits of IGBTs in telephone hook switches

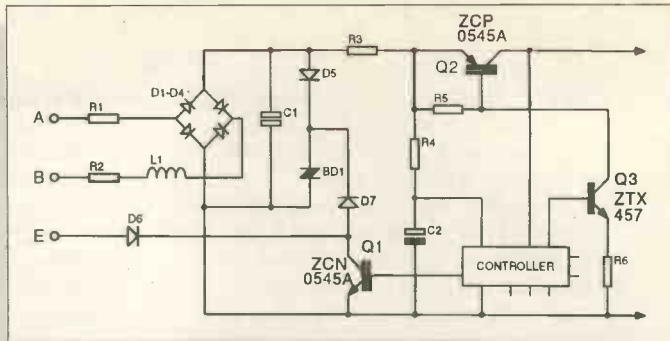
To withstand normal telephone operating voltages and lightning-induced transients, transistors with breakdown voltages of 250-400V are needed for telephone hook switches, diallers, etc. Normal currents can rise to about 150mA, or much higher on transients.

This 'feature-phone' interface shows the lower igh being used as an earth recall switch. It provides as high an input impedance as the often used mosfet but lower on-voltage at high supply currents.

Electronic hook switching is

rent transformer connected in series with the ballast inductor. This transformer controls the switching frequency of the circuit and zener diodes  $ZD_{1,2}$  set gate drive voltage for both IGBTs. A diac is used to give an initial kick to start the circuit and the transformer  $T_1$  and vdr control line borne transients and interference.

Two strike circuits can be used. The simplest - and lowest cost - is to use a single capacitor which gives the circuit an instant start characteristic. However this has the disadvantage that the lamp strikes before the heaters heat up fully, leading to tube-end blackening and some reduction of tube life when switched on and off frequently.



provided by the upper p-channel IGBT. Its controlled gate drive limits drain current during transients. Expensive p-channel mosfets or npn/pnp bipolar pairs are normally used.

Suppressors used must not

operate below 200V. Devices selected normally allow 270V worst-case peaks during transients. Having a drain-source breakdown rating of 450V, the IGBT shown simplifies design. Transient protection is aided by  $D_5$  and  $BD_1$ .

Using a two capacitor/ptc-thermistor starter combination improves matters. At turn-on, a 10nF capacitor forces a high heater current to flow until the series connected ptc warms. Resistance of the ptc increases rapidly, causing the voltage across the tube to rise until the tube strikes. Since the tube strikes only after its heaters reach working temperature, life is extended. However this starter option is more expensive and gives a noticeable turn-on delay of around 1-2 seconds.

Zetex Semiconductors, Fields New Road, Chadderton, Oldham OL9 8NP. Tel. 061 627 4963, fax 061 627 5467.

## 'OFF-AIR' FREQUENCY STANDARD



Still Only **£195+VAT** carriage extra

- \* Provides 10MHz, 5MHz & 1MHz VXCOs, oven crystals
- \* Phase locks to DROITWICH (rubidium controlled and traceable to NPL)
- \* For ADDED VALUE also phase locks to ALLOUIS (cesium controlled and traceable to OP - French eq to NPL)
- \* British designed and British manufactured
- \* Options available include enhanced receiver, sine wave outputs and 13MHz output for GSM. Prices on application.

Output frequencies - 10MHz, 5MHz, 1MHz  
Short term stability - better than  $1 \times 10^{-9}$  (1 sec)  
Typical -  $4 \times 10^{-9}$  (1 sec)  
Long term - tends to  $2 \times 10^{-12}$  (1000 sec)

### SUPERB DUAL TRACE SCOPES, TELEMEQUIP D61A, 10mV SENSITIVITY, 10uS-500mS/DIV (& x5), X-Y INPUTS, Z-MOD, INT/EXT/TV TRIGS, ETC. FROM £99

P.E. GENERATOR 12V 17A BATT CHARGE	£95	AVO VALVE TESTERS MK2, 4 & CT160	From £49
WELLS BROOKFIELD MICRO VISCOMETER	£29	"GIBSON GIRL" EMERGENCY RADIO SET	£65
JANKE & KUNKEL HI-SPEED MINI MIXER	£20	ELECTRONIC VISUALS EV4020A NTSC V/SCOPE	£395
CORE MEMORIES	From £10	FERROGRAPH RTS2 TEST SET/AUX TEST UNIT	£295
COMMODORE PETS, PRINTERS, D/DRIVES, ETC	£15 ea	PHILIPS PM5134 FUNCTION GEN 1Hz-20MHz	£149
CAMBRIDGE SCHERING BRIDGE	£35	PHILIPS PM5326 RF SIG GEN 0.1-125MHz	£395
TIME 2004 DC VOLTAGE STANDARD 0.005%	£750	PHILIPS PM5716 PULSE GENERATOR 1Hz-50MHz	£595
FLUKE 760A MULTIMETER CALIBRATOR	£249	BRADLEY 144 DC MULTIPLIER UNIT	£149
BRADLEY 171B MULTIMETER CALIBRATOR	£249	ROBIN OM200 LIGHT METER 0-50K Lux	£75
BRADLEY 191 DISTRIBUTION UNIT	£149	"XT" AT & COMPAQ COMPUTERS	From £55
HONEYWELL COLOUR GRAPHIC RECORDER	£295	LEVELL TM3B MICRO V-METER 3MHz	£85
TEKTRONIX 545 PLUG-INS, VARIOUS	£10 to £25	HP4951C PROTOCOL ANAL & 18179A RS232C/V24	POA
PLESSEY TC110 SIG GEN/ANAL 50-300 BDS	£95	HP6131C DIGITAL VOLTAGE SOURCE	POA
PRECISION STD CELL MUIRHEAD K231A TEMP	£375	GOULD 2400 4-PEN CHART RECORDER	POA
CONT	£195	LING DYN VIB GEN 406 & PA300 PWR OSC	POA
MARCONI TF2212 X-Y DISPLAY	£975	UDI2026 SONAR SCANNER SURFACE UNIT	£975
QUAD 303 STEREO POWER AMPS	£375	CITOH CX6000 6-PEN A4 PLOTTER. CENT/RS232	£135
DRAKE MN2700 MATCHING N/WORK & PS7 PSU	£95	GOULD 2400 4-PEN CHART RECORDER	£149
SCOPEX 456 6MHz SINGLE TRACE	£95	PHILIPS PM6456 FM STEREO GENERATOR	£95
SCOPEX 4D10BL S. 10MHz WITH EXTENDED LF TB	£149	MARCONI TF2300 FM/AM MODULATION METER	£195
LEADER LBO-9C ALIGNMENT SCOPE	£195	McKENZIE 70AY TEMPER/HUMIDITY RECORDER	£395
IWATSU SS5116 DUAL TRACE 10MHz	£175	FEEDBACK SS0603 1MHz SINE/SQ OSC	£125
TELEMEQUIP D1011 10MHz DUAL TRACE	£185	LCR BRIDGE WAYNE KERR CT492	£79
H.P. 8405A VECTOR V/METER 1GHz	£95	LCRQ BRIDGE AVO B151	£195
TELEMEQUIP D67A 25MHz, 2T, DEL TB	£215	LCR BRIDGE MARCONI TF2700	£145
HITACHI VC 6015 10MHz DIGITAL STORAGE	£295	LCR BRIDGE MARCONI TF2701	£125
HP1340A X-Y DISPLAYS	£149	LCR MARCONI TF1313 0.25%	£95
LEVELL TM6B MICRO V-METER 450MHz	£95	LCR COMPONENT COMPARATOR AVO C2457/5	£95

LIST AVAILABLE BUT 1000's OF UNLISTED BARGAINS FOR CALLERS. ALL PRICES EXC. OF P&P AND VAT QUALITY ELECTRONIC EQUIPMENT ALWAYS WANTED

**HALCYON ELECTRONICS**

423, KINGSTON ROAD, WIMBLEDON CHASE, LONDON SW20 8JR  
SHOP HOURS 9-5.30 MON-SAT. TEL 081-542 6383. FAX 081-542 0340

CIRCLE NO. 146 ON REPLY CARD

**WE HAVE THE WIDEST CHOICE OF USED OSCILLOSCOPES IN THE COUNTRY**

**TEKTRONIX 7000 SERIES OSCILLOSCOPES AVAILABLE FROM £200. PLUG-INS SOLD SEPARATELY**

TEKTRONIX 2465 4 Channel 300MHz Delay Sweep Cursors	£1750	TEKTRONIX CP250 Triple Output PSU 2x20V 5A Var, 5V2A Fixed	£225
TEKTRONIX 2236 Dual Trace 100MHz Delay Sweep Counter/Timer/DMM	£850	TEKTRONIX CG250 Function Gen 0.2Hz - 2MHz Sine/Sq/Tri/TTL	£180
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep	£500	TEKTRONIX CM250 Digital Multimeter 3 1/2 digit LED	£180
TEKTRONIX 455 Dual Trace 200MHz Delay Sweep	£400	H.P. 8455A DVM 6 1/2 digit True RMS AC/DC HPS	£980
TEKTRONIX N1530A Dual Trace 80MHz in 1MS/10AS As new	£500	EP/DANA 351D Microwave Frequency Counter 20Hz - 18GHz	£1000
IWATSU SS5711C 4 Channel 100MHz Delay Sweep with DMM	£500	H.P. 5341A Frequency Counter 50MHz - 1.5GHz LED	£300
TRIO CS2070 4 Channel 70MHz Delay Sweep	£450	MARCONI 2455 Digital Frequency Meter ZONE	£400
HITACHI V6501 Dual Trace 60MHz Delay Sweep	£400	RACAL/DANA 1931 Universal Counter/Timer 160MHz 9 digit	£900
TRIO PS 30217 Dual Trace 50MHz Delay Sweep	£350	MARCONI 2437 Universal Counter/Timer DC - 100MHz 8 digit	£175
TELEMEQUIP D83 Dual Trace 50MHz Delay Sweep	£260	MARCONI 2431A Frequency Counter 10Hz - 200MHz 8 digit	£150
GOULD OS1100 Dual Trace 30MHz	£160	MARCONI 2430A Frequency Counter 10Hz - 80MHz 8 digit	£125
GOULD OS300 Dual Trace 20MHz	£120	RACAL 9918 Frequency Counter 10Hz - 520MHz 9 digit	£290
GOULD OS2500 Dual Trace 15MHz	£200	RACAL 9913 Frequency Meter 10Hz - 200MHz 8 digit	£125
IWATSU SS5702 Dual Trace 20MHz	£200	RACAL 9905 Universal Counter/Timer DC-200MHz 8 digit	£150
TRIO CS1568A Dual Trace 20MHz	£200	RACAL 9904 Universal Counter/Timer DC-50MHz 7 digit	£175
GOULD CS4000 Dual Trace 10MHz Digital Storage	£200	RACAL 9901 Universal Counter/Timer DC-50MHz 8 digit	£100
H.P. 1741A Dual Trace 100MHz Delay Sweep Analogue Storage	£350	DATRON 1061A 6 1/2 digit Autocal Multimeter True RMS AC/Current	£850

**THIS IS JUST A SAMPLE. MANY OTHERS AVAILABLE**

HEWLETT PACKARD 1740A Oscilloscopes 100MHz Dual Trace Delay Sweep	only £350	H.P. 3485A 3 1/2 digit Multi-Range Current LED	£100
MARCONI 2010 Synthesized AM/FM Sig Gen 80MHz - 520MHz	£100	PHILIPS PM2534 Multi-Function DMM 3 1/2 - 6 1/2 digit GPIB/IEEE	£450
H.P. 8640B Sig Gen 20Hz - 1024MHz	£1000	SOLARTRON 7150 6 1/2 - 3 1/2 digit Multimeter with IEEE	£400
H.P. 8620C Sweep Oscillator with 8624SA 5.9 - 12.4GHz	£600	SOLARTRON 7045 4 1/2 digit Multimeter Volts/Amper/Ohms	£80
SYSTRON DORNER 1702 Syn AM/FM Sig Gen 100Hz - 1GHz	£400	WAYNE KERR 9305 Automatic Precision Bridge 0.05%	£900
RACAL 9081 Synthesized AM/FM Sig Gen 5 - 520MHz	£400	MARCONI TF2700 Universal LCR Bridge 0.1%	From £150
FARNELL SS220 Synthesized AM/FM Sig Gen 10 - 520MHz	£400	WAYNE KERR 9424 Digital Component Meter LCR	£280
MARCONI TF2008 AM/FM Sig Gen 10MHz - 510MHz Sweep Facility	£200	HEATHKIT H RLC Bridge	£80
MARCONI TF2015 AM/FM Sig Gen 10 - 520MHz	£200	BRADLEY 192 Oscilloscope Calibrator	£800
MARCONI TF2015 with Synchroizer TF2171 (lock box)	£200	WILTRON 502 Scalar Network Analyser with Detectors	£1800
PHILIPS PM5268 AM/FM Sig Gen 100kHz - 100MHz	£300	H.P. 5005A Signature Multimeter	£250
MARCONI TF2020B AM/FM Sig Gen 100kHz - 88MHz with Dig Sync	£180	FARNELL H30100 0.1 - 30 Volts, 0 - 100 Amps Metered	£800
MARCONI SANDERS 660A Microwave Sweep Disc 26.5-40GHz	£350	FARNELL TV570 0.1 - 70 Volts 5 Amps/25 Volts 10 Amps Metered	£200
H.P. 8650B Microwave Sweep Disc 26.5-40GHz	£350	FARNELL H30140 0.1 - 30 Volts, 0 - 100 Amps Metered	£200
H.P. SMITH ANTENNA type 12-602-4	£2800	FARNELL L302 0 - 30 Volts, 0 - 5 Amps Metered	£125
MARCONI TF2033 Automatic Distortion Meter	£700	MARCONI (WEM) TF213A D - 30V 1A, 0 - 15V 2A, 0 - 7.5V 4A Metered	£150
SAYROSA Automatic Modulation Meter type 25Z	£125	W.P. 1551A 4 - 30V 1A, 0 - 15V 2A, 0 - 7.5V 4A Metered	£150

**SPECTRUM ANALYSERS**

H.P. 8555A D01 - 22GHz	£5000	BRANDENBURG Model 472R +/- 2KV Metered	£200
H.P. 8530A Sig Gen 20Hz - 210MHz	£4500	FEEDBACK FG500 Signal Gen 0.01Hz - 100kHz	£80
H.P. 3580A LED 5Hz - 50MHz	£1000	LYONS P5071H Pulse Gen PWT 1Hz - 5KV 10 microseconds	£175
AMRITSU MS528 with Tracing Generator 10MHz - 1700MHz	£1500	FARNELL P6101 Pulse Gen 100Sec (1 Sec 1Hz)	£125
POLARAD 641-1 10MHz - 18GHz	£1500	LINDOS LA1 MK2B Audio Analyser	£500
ARND AC6281 with AC2211 1MHz - 1500MHz	£1500	ORION BPS01 Audio Analyser	£350
H.P. 1411 with 8558B & 8552B 500MHz - 1250MHz	£1200	PHILIPS PM5518 Colour TV Pattern Generator	£1250
H.P. 1411 with 8553B & 8552A 10MHz - 110MHz	£800	RADFORD L004 Low Fd/Oscillator	£300
MARCONI TF2370 30Hz - 110MHz	£1000	RADFORD L0M52 Low Distortion Measuring Set	£300
H.P. 8444 & 8443 Tracing Generators. Available from H.P. 1411 Main Frames only. Good Tubes	£225		

**NEW EQUIPMENT**

NAMEC OSCILLOSCOPE HM1005 Triple Trace 100MHz Delay Timebase	£847
NAMEC OSCILLOSCOPE HM1004 Dual Trace 50MHz Delay Sweep	£653
NAMEC OSCILLOSCOPE HM203 7 Dual Trace 20MHz Component Tester	£362
NAMEC OSCILLOSCOPE HM205 3 Dual Trace 20MHz Digital Storage	£653

All other models available - all oscilloscopes supplied with 2 probes

**BLACK STAR EQUIPMENT (P&P all units £5)**

APOLLO 10-100MHz Counter/Tmr Ratio/Period/Time Interval etc	£222
APOLLO 100-100MHz (As above with more functions)	£325
METRO 100 FREQUENCY COUNTER 100MHz	£119
METRO 600 FREQUENCY COUNTER 600MHz	£195
METRO 1000 FREQUENCY COUNTER 1GHz	£189
METRO 500 FUNCTION GEN 0.1Hz-500MHz Sine/Sq/Tri	£119
ORION COLOUR BAR GENERATOR PAUL/Video	£229

OSCILLOSCOPE PROBES Switchable x1 x10 (P&P £3) & 8 VIBRATION SYSTEM (P&P £10) Other B & K Equipment available

**Use Equipment - Guaranteed - Guaranteed. Manuals supplied if possible.**  
This is a VERY SMALL SAMPLE OF STOCK. SAE or Telephone for lists. Please check availability before ordering.  
CARRIAGE all units £16. VAT to be added to Total of Goods and Carriage.

**STEWART OF READING**

110 WYKEHAM ROAD, READING, BERKS RG6 1PL  
Telephone: (0734) 268041. Fax: (0734) 351696  
Callers Welcome 9am-5.30pm Monday to Friday (until 8pm Thursday)

CIRCLE NO. 147 ON REPLY CARD



# Pocket sized Logic Analyser for your PC



## NEW SLA-16 Logic Analyser

- Low cost, High Performance 16 Channel Logic Analyser
- Connects to PC serial port, ideal for desktops or notebooks
- Supplied with easy to use software, power supply and cables
- High Speed - up to 50 MHz sampling
- Internal & external clock modes
- 8K Trace Buffer

Special Introductory Price

**SLA-16 £ 189.00**  
for limited period only

Normal List Price £ 219.00

PICO TECHNOLOGY



Pico Technology Ltd. Broadway House, 149-151 St Neots Road, Hardwick, Cambridge. CB3 7QJ  
TEL: 0954 - 211716 FAX: 0954 - 211880



Phone or FAX for sales, ordering information, data sheets, technical support. All prices exclusive of VAT

CIRCLE NO. 148 ON REPLY CARD

## RF EQUIPMENT

### WIDEBAND AMPLIFIERS

TYPE 9301 100KHz-500MHz. NF 2dB at 500MHz. Gain 30dB. Output 12.5dBm, 18 mW. 50 ohms .....	£175
TYPE 9302 10MHz-1GHz. NF 2dB at 500MHz. Gain 30dB. Output 12.5dBm, 18mW. 50 ohms .....	£175
TYPE 9008 Gasfet. 10MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Output 18dBm, 65mW. 50 ohms .....	£175
TYPE 9009 Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Output 20dBm, 100mW. 50 ohms .....	£195

### WIDEBAND LINEAR POWER AMPLIFIERS

TYPE 9246 1 watt output. 100KHz-175MHz. 13dB gain .....	£240
TYPE 9248 1 watt output. 100KHz-300MHz. 10dB gain .....	£260
TYPE 9306 1 watt output. 10MHz-1.2GHz. 15dB gain .....	£360
TYPE 9249 4 watts output. 100KHz-300MHz. 17dB gain .....	£420
TYPE 9247 4 watts output. 1-50MHz. 13dB gain .....	£260
TYPE 9051 4 watts output. 20-200MHz. 13dB gain .....	£260
TYPE 9176 4 watts output. 1-50MHz. 26dB gain .....	£395
TYPE 9177 4 watts output. 20-200MHz. 26dB gain .....	£395
TYPE 9173 20 watts output. 1-50MHz. 17dB gain .....	£450
TYPE 9174 20 watts output. 20-160MHz. 10dB gain .....	£450
TYPE 9271 40 watts output. 1-50MHz. 16dB gain .....	£795
TYPE 9172 40 watts output. 20-160MHz. 10dB gain .....	£795
TYPE 9660 60 watts output. 25-75MHz. 17.5dB gain .....	£950

### UHF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range 250-470MHz	
TYPE 9123 500mW input, 5 watts output .....	£385
TYPE 9124 2-3 watts input, 25 watts output .....	£545
TYPE 9126 8 watts input, 50 watts output .....	£1645

Prices are ex-VAT & ex-P&P.

### TELEVISION LINEAR POWER AMPLIFIERS

RF output powers available from 1/2 watt to 150 watts. GASFET LNAs 5 MHz-2GHz. Two-stage. High Q filters. Masthead or local use. TYPE 9006 Freq: 5-250MHz. B/W up to 40% of CF. Gain 10-40dB variable. 50 ohms. NF 0.6db .....	£135
TYPE 9004 Freq: 250-1000MHz. B/W up to 10% of CF. NF 0.7dB. Gain 25dB. 50 ohms .....	£185
TYPE 9304 Freq: 1-2GHz. B/W up to 10% of CF. NF 0.7dB. Gain 20dB. 50 ohms .....	£250
TYPE 9035 Transient protected mains power supply for above preamplifiers .....	£65
TYPE 9010 Masthead weatherproof unit for preamplifiers .....	£18

### PHASE LOCK LOOP FREQUENCY CONVERTER

TYPE 9115 Up/down converter. I/p & o/p frequencies 20MHz-2GHz. B/W up to 50MHz. NF 0.7dB. Gain 60dB variable. O/p up to 10mW, +10dBm. AGC .....	£750
--	------

### PHASE LOCK SIGNAL SOURCES 20-2000 MHz

TYPE 8034 Freq. as specified in the range 20-250MHz. O/p 10mW .....	£250
TYPE 9036 Freq. as specified in the range 250-1000MHz. O/p 10mW .....	£350
TYPE 9038 Freq. as specified in the range 1-2GHz. O/p 10mW .....	£420
TYPE 9282 FM up to ±75KHz max. Freq. as specified in the range 30-2000MHz. O/p 10mW .....	£465

### TELEVISION TRANSMISSION MODULES

TYPE 9169 Voltage tunable T/V modulator. Bands I or III or IV or V. O/p 50mW. Sound channel .....	£395
TYPE 9269 PLL T/V exciter. Single channel. Bands I, III, IV or V. O/p 10mW .....	£750
TYPE 9115B PLL T/V transposer. Up to 10 adjacent chs in bands I, III, IV or V. O/p 10mW .....	£750

## RESEARCH COMMUNICATIONS LTD

Unit 1, Aerodrome Industrial Complex, Aerodrome Road, Hawkinge, Folkestone, Kent CT18 7AG

Tel: 0303 89 3631

Fax: 0303 89 3838

CIRCLE NO. 149 ON REPLY CARD

# CIRCUIT IDEAS

SEND YOUR CIRCUIT IDEAS TO THE EDITOR, ELECTRONICS WORLD, QUADRANT HOUSE, THE QUADRANT, SUTTON, SURREY SM2 5AS

Do you have an original circuit idea for publication? We are giving **£100** cash for the month's top design. Other authors will receive **£25** cash for each circuit idea published. We are looking for ingenuity in the use of modern components.

## £100 WINNER

### One chip air-flow monitor

An 800Ω thermistor has combined negative and positive temperature coefficient and can therefore accept voltage excitation; the lamp filament prevents thermal runaway, but allows sensitivity to heat dissipation in the air stream.

With normal flow, the thermistor

possesses high resistance and passes a low current to node 11 of the 3046 transistor array. The triple current mirror therefore turns off the output transistor. If air-flow drops, the temperature rises, reference current and current through the monitor increase and the output transistor conducts and saturates.

The supply voltage and load resistor  $R_c$  should be chosen to provide the required output levels; limits for the 3046 are 15V and 10mA collector current. Trim reference current to take account of varied ambient temperature.

**John A Haase**  
Fort Collins  
Colorado  
USA

*Air-flow monitor provides a two-level indication.*

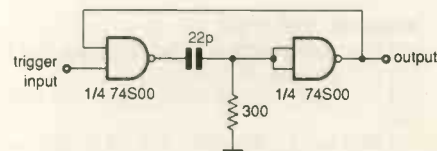
### Monostable flip-flop pulses down to 10ns

Since there is no monostable member of the 74S series of ttl logic, a monoshot comparable in speed with the rest of the family must be made from gates. This circuit produces pulses less than 10ns wide and with 2.5ns transitions.

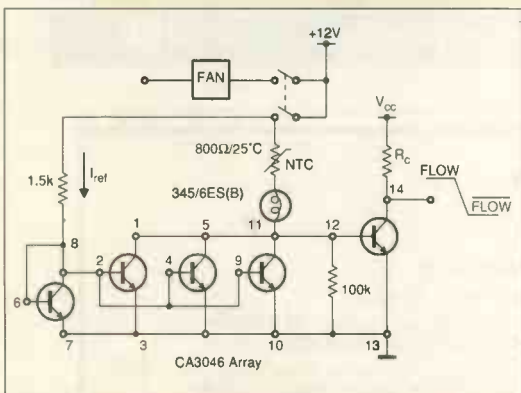
The falling edge of a 7ns pulse to the first gate triggers the circuit to give the 10ns output when  $R=300\Omega$  and  $C=22pF$ . This is rather better than the performance of ecl monoshots, which give a minimum output pulse width of 10ns.

The two spare gates could be used to invert input and output or in a second circuit.

**I K and S R Kaul**  
Bhabha Atomic Research Centre  
Bombay  
India



*Spare pair of two-input Nand gates performs the function of the monostable flip-flop missing from the 74S ttl series.*



## YOU COULD BE USING A 1GHz SPECTRUM ANALYSER ADAPTOR!

Got a good idea? Then this Thurlby-Thandar Instruments TSA1000 spectrum analyser adaptor could be yours.

Covering the frequency range 400kHz to over 1GHz with a logarithmic display range of 70dB  $\pm$ 1.5dB, it turns a basic oscilloscope into a precision spectrum analyser with digital readout calibration.

Recognising the importance of good design, TTI will be giving away one of these excellent instruments every six months to the best circuit idea published in the preceding period until further notice. This incentive will be in addition to our £100 monthly star author's fee together with £25 for all other ideas published.

Our judging criteria are ingenuity and originality in the use of modern components with simplicity particularly valued.



## Guitar fuzz box uses radio chip

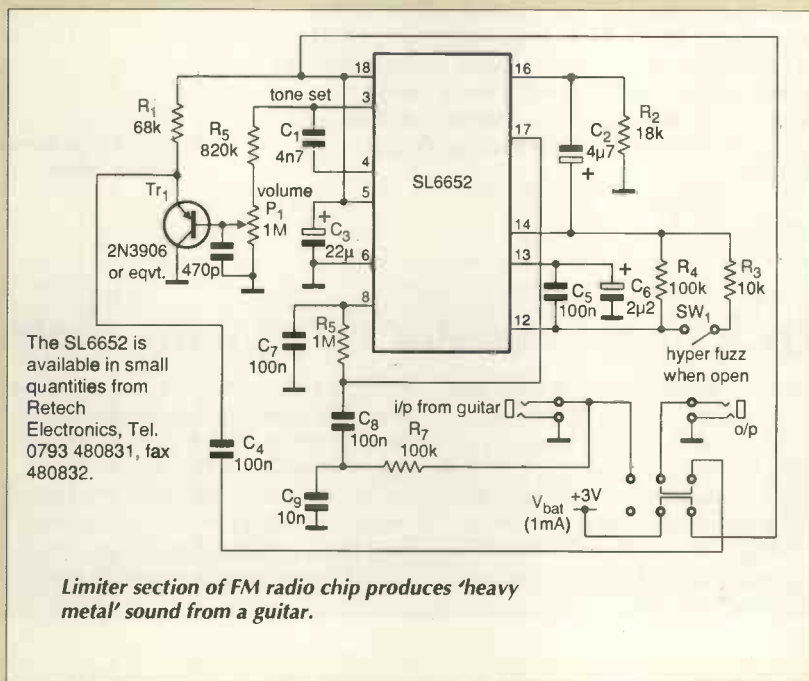
Fuzz boxes to produce the 'heavy metal' sound from guitars rely on limiting the input signal to generate odd harmonics. GEC Plessey's SL6652 is a low-power IF/AF circuit meant for fm cellular radio, naturally containing a good limiter.

The circuit shown needed no special screening or layout and gave good results without any decoupling problems, the only initial drawback being a harshness in the sound. Resistor  $R_7$  and  $C_9$  solved that problem and two professional guitarists have approved the results. In this application, the SL6652 draws about 1mA so two AA batteries last a long time.

To use the circuit, turn the fuzz box volume control to minimum and slowly increase the volume, while strumming the guitar, until the correct drive level for the amplifier is obtained. The guitar volume control now functions as a 'sustain' control.

As regards the hyper-fuzz switch – try it and see!

**Dave Mapleston and Steve Newton**  
GEC Plessey Semiconductors



## Triggered sawtooth generator from a phase-locked-loop IC

One phase-locked loop IC generates triggered linear sawtooth waveforms, referred to ground, of constant amplitude and positive-going. Alternative methods involve several ICs and multiple power supplies.

In the absence of a trigger pulse, the vco section of the pll holds pin 7 at ground, a current  $I_C$  appearing at pin 6, determined by the value of  $R_4$  and the voltage at pin 9. This current through  $R_{5,6}$  sets the voltage on pin 6

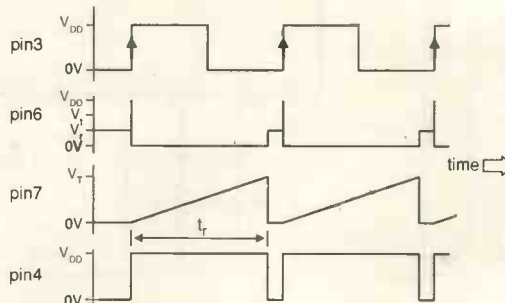
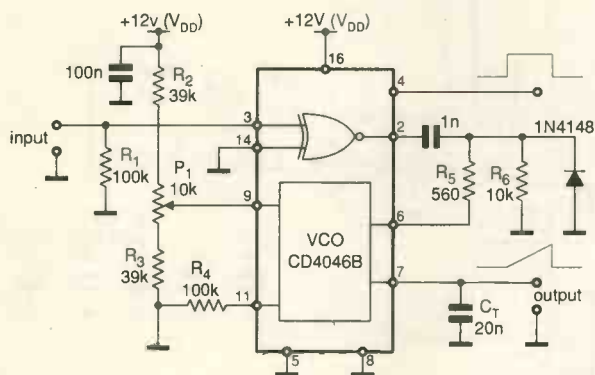
lower than  $V_T$ , the transfer voltage of the vco inverters.

Trigger pulses are buffered by the ex-or phase comparator and increase the pin 6 voltage to change the state of the vco flip-flop, in which condition pin 6 is now grounded and  $I_C$  now appears at pin 7, where it charges  $C_T$ . When the charging ramp on pin 7 reaches  $V_T$ , the flip-flop again changes state and the capacitor discharges into pin 7. The circuit is now stable until the next

trigger pulse. The vco output at pin 4 goes high during the ramp.

Ramp duration is around 1ms for these values, but can be set to last from a few microseconds to several seconds by varying  $C_T$ ,  $R_4$  and the voltage on pin 9.

**M S Nagaraj**  
ISRO Satellite Centre  
Bangalore  
India



Single-IC, wide-range triggered sawtooth generator produces a linear, ground-referred ramp from microseconds to seconds in duration. Timing is shown on the right.

## Low battery-voltage indicator

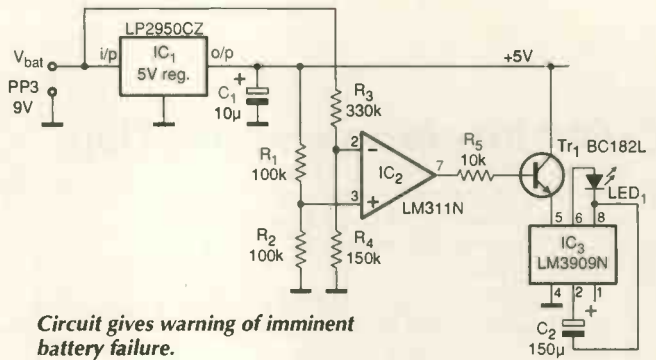
In circumstances in which battery failure might lead to loss of data – for example, in field data logging – this device will warn of impending doom by means of a flashing led.

Regulator  $IC_1$  powers the circuit from the 9V battery, drawing a very low quiescent current, and supplies a reference voltage via  $R_{1,2}$  to the comparator. If the battery-derived input to the comparator falls to the threshold voltage set by  $R_{3,4}$ , 8.15V with these values,  $Tr_1$  turns on and enables the led flasher oscillator  $IC_3$ , its flash rate being set by  $C_2$  (2.3Hz in this case). Changing  $R_3$  to a  $1M\Omega$  variable component allows any battery voltage to be monitored. Circuit current consumption is 1.5mA and 2.5mA when the led flashes; micropower devices would reduce this considerably.

**Kamru Miah**

CSL

Slough



Circuit gives warning of imminent battery failure.

## Bench filter evaluator with tuning control

Cascading the two halves of a National Semiconductor *MF10* dual cmos switched-capacitor filter IC makes a bench instrument to evaluate the effects of varying the frequency of a prototype filter section before committing yourself to a final design.

This instrument is effectively a state-

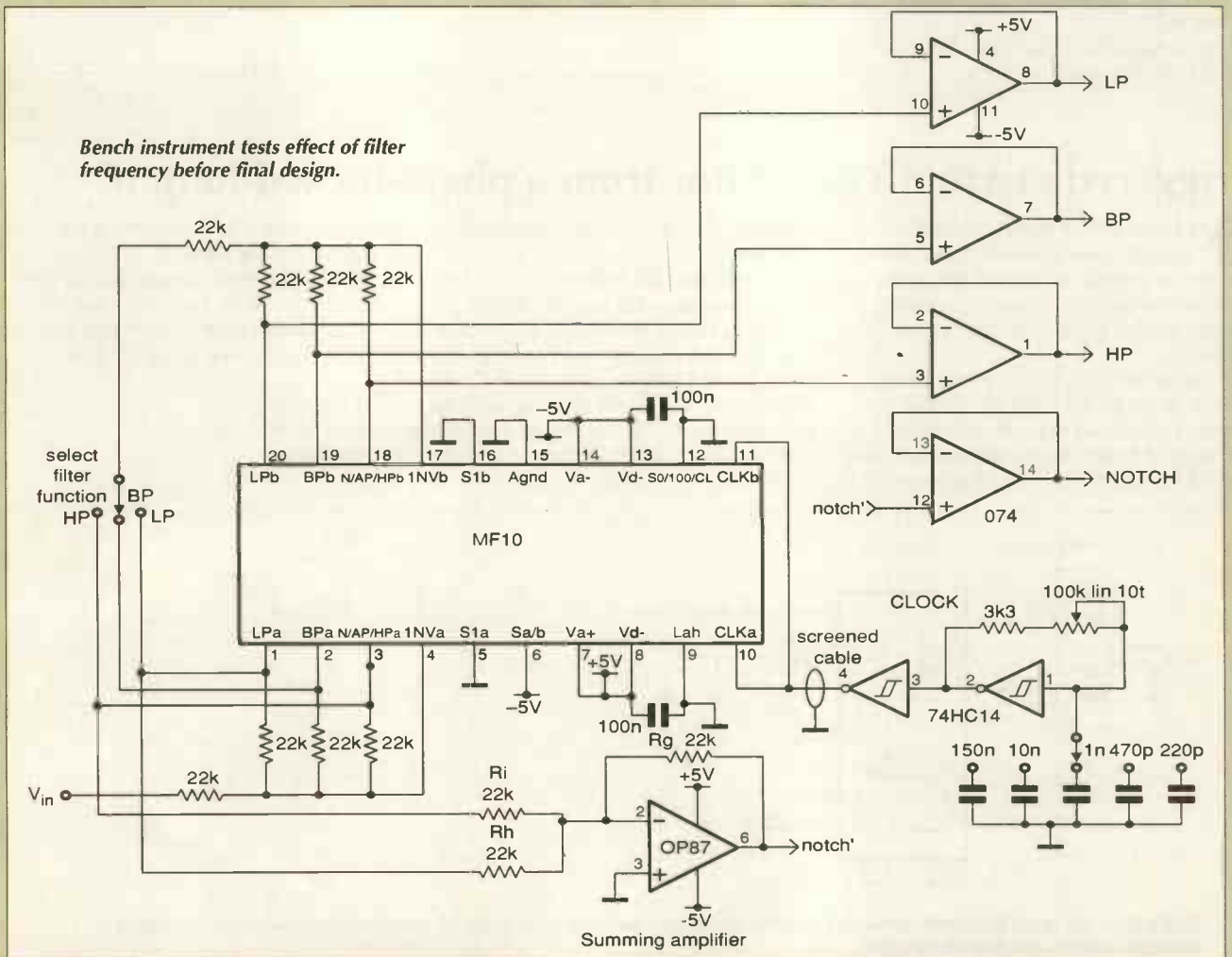
variable filter giving the characteristics of low-pass, band-pass and high-pass types with 80dB/decade slopes. A summing amplifier combines high and low-pass sections to give a 40dB/decade notch filter. Clock frequency is variable from 0.83Hz to 14.7kHz in five ranges and it would be simple to drive pins 10 and 11

directly with an external clock, via an internal/external switch.

Centre or break frequency is  $f_o = f_{clk}/100$ , which is also the notch frequency. Outputs are buffered by the four op-amps.

**P J Hale**

University of Humberside Hull



Bench instrument tests effect of filter frequency before final design.



## Automatic gain-adjusting bridge amplifier

When a measuring bridge is near balance, amplifier gain must be high to cope with the small bridge signal. When out of balance, however, the large gain is unnecessary and could lead to instability, so that a dynamic setting of gain is the ideal.

In Fig. 1, the diodes in the feedback loop of a bridge difference amplifier increase their resistance at low signal levels, increasing the amplifier gain. If feedback resistance is  $R + \delta R$ ,  $\delta R$  being the change in diode resistance, then amplifier gain is expressed as  $1 + 3\delta R/4R$ . A practical circuit using the INA 105, with  $R = 25k\Omega$ , is shown in Fig. 2.

The circuit in Fig. 3 uses the same approach to increase the low-signal gain of the classic three-op-amp instrumentation amplifier, in this case an AD524.

**Kamil Kraus**  
Rokycany  
Czech Republic

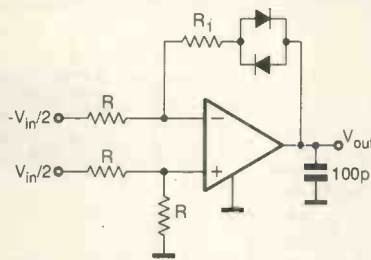


Fig. 1. At low input levels, the feedback diodes have higher resistance, increasing the gain of a bridge amplifier near balance.

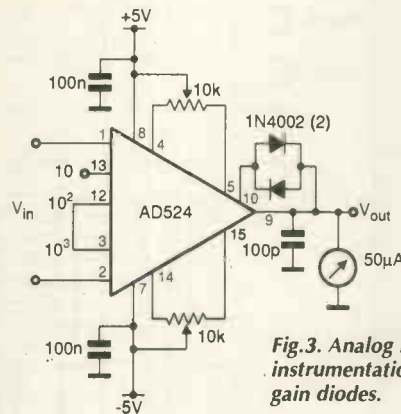


Fig. 3. Analog Devices's AD524 three-op-amp instrumentation amplifier with the dynamic-gain diodes.

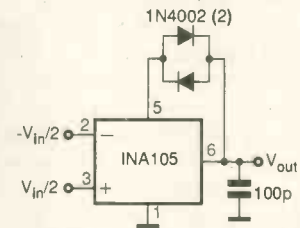


Fig. 2. Practical circuit using the approach of Fig. 1

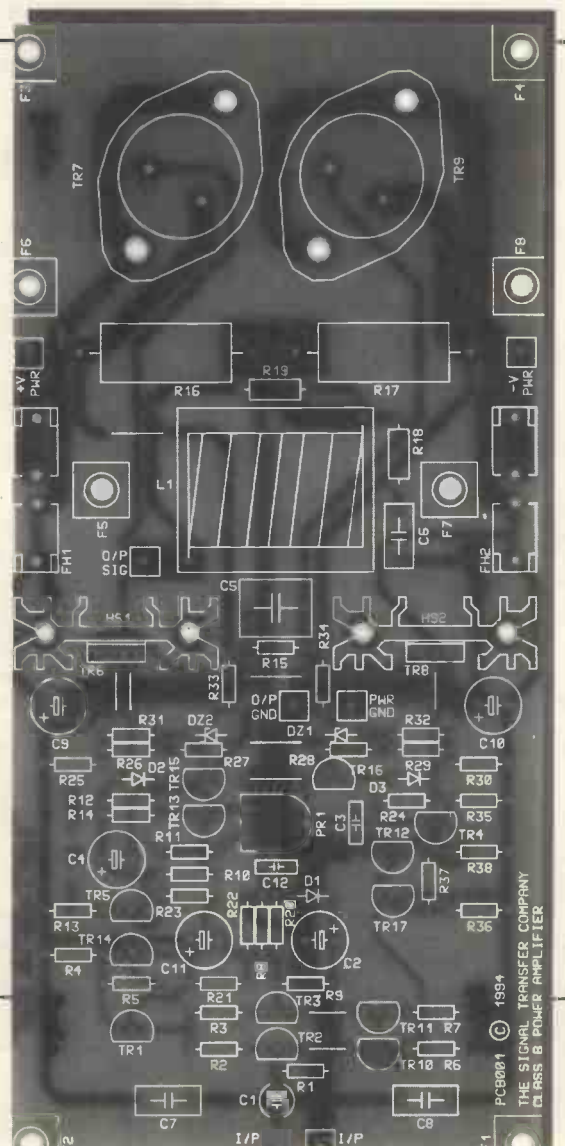
## PCBs for Douglas Self's power amplifier series

Circuit boards for Douglas Self's high-performance power amplifier are now available via *EW+WW*.

Detailed on page 139 of the February issue, Douglas Self's state-of-the-art power amplifier is the culmination of ideas from one of the most detailed studies of power amplifier design ever published in a monthly magazine. Capable of delivering up to 100W into 8Ω, the amplifier features a distortion figure of 0.0015% at 50W and is designed around a new approach to feedback.

Designed by Douglas himself, the fibreglass boards have silk-screened component IDs and solder masking to minimise the possibility of shorts. Sold in pairs, the boards are supplied with additional detailed constructional notes.

Each board pair costs £45, which includes VAT and postage, UK and overseas. Credit card orders can be placed 24 hours on 081-652 8956. Alternatively, send a postal order or cheque made payable to Reed Business Publishing to *EW+WW*, The Quadrant, Sutton, Surrey SM2 5AS.



## A better feeling about channel selection

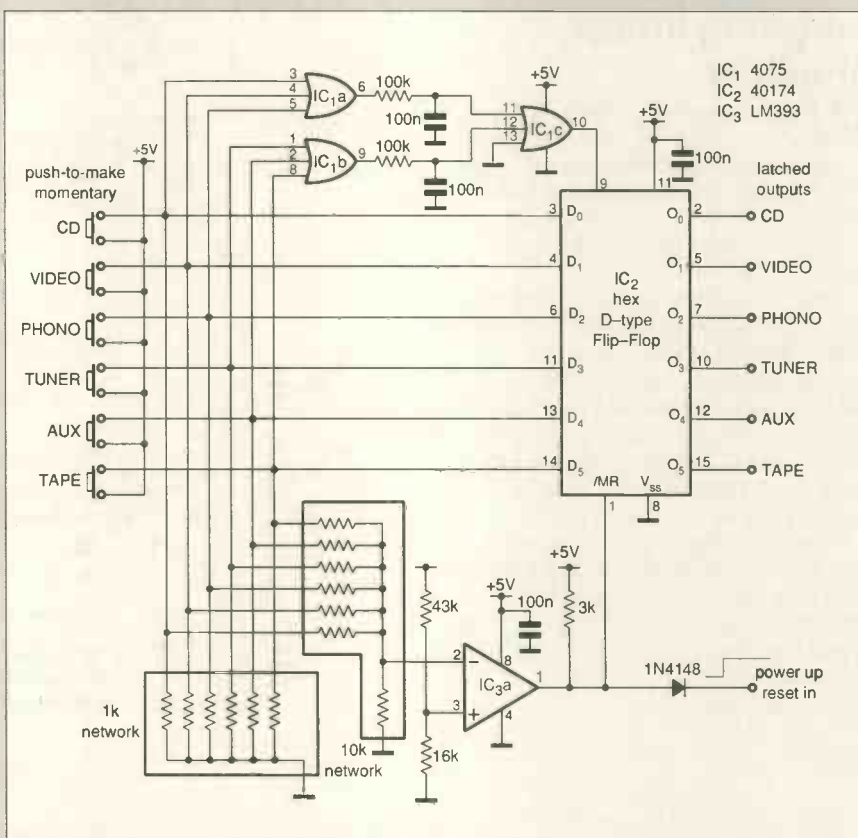
The row of mechanically ganged push-button switches sometimes used for channel selection in audio amplifiers and television receivers is effective, but lacking in the feel of quality. This circuit arrangement uses momentary-action, light-touch switches without complicated circuitry.

Pressing any switch causes IC<sub>1</sub> to emit a clock pulse to IC<sub>2</sub> and latch it, the relevant output from IC<sub>2</sub> going high. However, if more than one switch is pressed, the output of IC<sub>3</sub> is low to inhibit all outputs and act as a mute.

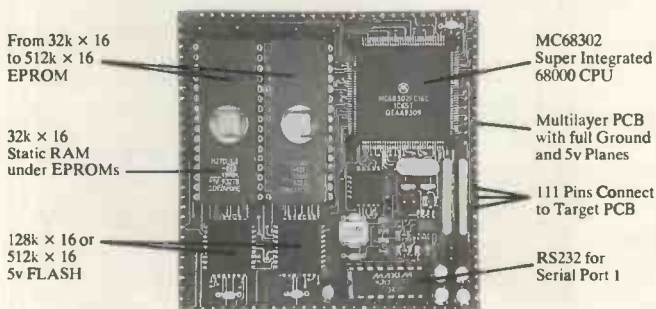
The outputs could be buffered and used to drive relays, perhaps also illuminating indicator leds to confirm the selection.

*A P Scrimgeour  
London N4*

*Momentary-contact, unganged switches replace the mechanically ganged type to provide a lighter touch.*



## The EM68 68000 Embedded OEM Module



### Powerful, Practical and Sensibly Priced

**The CPU** is Motorola's 16 bit 68302, a highly integrated 68000 processor running at 16Mhz. This processor has 3 full high speed serial ports operating in UART, HDLC/SDLC, BISYNC or DDCMP modes. It also has DMA channels. Interrupt controller, 28 parallel I/O lines 2 16 bit timers with compare and capture, Watchdog timer and low power (standby) modes. (We can supply the MC68302 Data Book.)

**The Memory** Up to 1M byte of EPROMs - 1M byte of FLASH EPROM and 64k Bytes of static RAM.

**The EM68** Expandable to 16M byte, the EM68 is constructed on a Multilayer PCB with full power and ground planes and has a small 7.62cm<sup>2</sup> footprint.

Prices range from £255.50 (1 off - 1M Byte FLASH) down to £95.00 (100+ No FLASH)

Our Catalogue lists products based on the 64180, 80C31, Dallas 80C320, 80C552, 80C188 processors, and a wide range of peripheral modules, A/D, D/A, Serial, Opto, Relay, Transistor drive, Stepper drive, Thermocouple etc. with power supplies, backplanes and cases. Request a copy today.

**Devantech Ltd**  
INDUSTRIAL ELECTRONIC CONTROLS

Units 2B-2C, Gilray Road,  
Vinces Road Industrial Est,  
Diss, Norfolk IP22 3EU, UK.  
Tel: +44 379 644285  
Fax: +44 379 650482

CIRCLE NO. 150 ON REPLY CARD

## ADVERTISERS PLEASE NOTE

For all your future  
enquiries on  
advertising rates,  
please contact

**Malcolm Wells on:  
Tel: 081-652-3620**



# CLASSIFIED

TEL 081 652 3620

FAX 081 652 8956

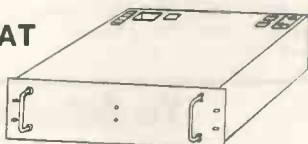
## ARTICLES FOR SALE

19" Rack Mounting Switch Mode Power Supply  
By FARNELL INSTRUMENTS F2667  
P.O. [B.T.] 164  
MONARCH 250C SYSTEM

990 WATTS MODULAR CONSTRUCTION

+5 volt 48 Amp  
+12 volt 8 Amp + Ringer Module Capable of Ringing  
12 Telephone Bell Loads  
-12 volt 5 Amp  
-50 volt 8 Amp  
Dimensions H125 D500 W485mm Weight 13.5KG  
BRAND NEW IN ORIGINAL PACKING

PRICE £199.00 + VAT  
UK Mainland  
Carriage £12 +VAT



**R. Henson Ltd.**

21 LODGE LANE  
LONDON N12 8JG  
TEL: 081-445 2713/0749  
FAX: 081-445 5702

## ARTICLES WANTED

### WE WANT TO BUY !!

**IN VIEW OF THE EXREMELY  
RAPID CHANGE TAKING PLACE  
IN THE ELECTRONICS  
INDUSTRY, LARGE QUANTITIES  
OF COMPONENTS BECOME  
REDUNDANT. WE ARE CASH  
PURCHASERS OF SUCH  
MATERIALS AND WOULD  
APPRECIATE A TELEPHONE  
CALL OR A LIST IF AVAILABLE.  
WE PAY TOP PRICES AND  
COLLECT.**

**R.HENSON LTD.**

21 Lodge Lane, N.Finchley,  
London N12 8JG.  
5 Mins, from Tally Ho Corner.  
**TELEPHONE**

081-445-2713/0749  
FAX 081-445-5702.

### VALVES AND CRTs

ONE MILLION ITEMS IN STOCK INCLUDING MAGNETRONS,  
KYLSTRONS, VALVE SOCKETS FOR AUDIO RECEIVING  
TRANSMITTING, OBSOLETE BRANDS SUCH AS MULLARD, GEC A  
SPECIALITY. ALSO HUGE STOCKS OF RUSSIAN AND SOVTEK ITEMS.  
ASK FOR OUR 40-PAGE VALVE CATALOGUE OR CRT CATALOGUE.

### VALVES WANTED FOR CASH

ESPECIALLY KT66, KT77, KT88, PX4, PX25, VALVE HI-FIs e.g. QUAD,  
LEAK, GARRARD 301. IF POSSIBLE SEND WRITTEN LIST.

**BILLINGTON EXPORT LTD**

1E GILLMANS IND EST, BILLINGSHURST, SUSSEX RH14 9EZ

CALLERS STRICTLY BY APPOINTMENT ONLY

TEL: 0403 784961 FAX: 0403 783519

MINIMUM ORDER £50.00 PLUS VAT

### WANTED

High-end Test, Communication &  
Computer Equipment. Top prices paid.

Please send or fax your offer to:

Steigerwald GmbH  
Neusserstrasse 9, 80807 Munich  
South Germany

Tel: 01049 89 3615833  
Fax: 01049 89 3615899

### WANTED

High-end Test Equipment, only  
brand names as Hewlett-Packard,  
Tektronix, Rhode & Schwarz,  
Marconi etc. Top prices paid.

Please send or fax your offer to:

**HTB ELEKTRONIK**

Alter Apeler Weg 5,  
27619 Schiffdorf, West Germany

TEL: 01049 4706 7044  
FAX: 01049 4706 7049

### WANTED

Test equipment, receivers, valves,  
transmitters, components, cable  
and electronic scrap and quantity.  
Prompt service and cash.

**M & B RADIO**  
86 Bishopgate Street,  
Leeds LS1 4BB  
Tel: 0532 435649  
Fax: 0532 426881

### WANTED SCRAP

**Printed Circuit Boards**

We are by far the best buyers of PCB's  
CASH OR CHEQUE AVAILABLE

**Computer Salvage** OPERATORS  
**Specialists** Est. 1985 OF THE UK'S  
TEL: 0635 552666 NATIONAL  
FAX: 0635 582990 PCB BANK

### WANTED

Receivers, Transmitters, Test  
Equipment, Components, Cable  
and Electronic, Scrap, Boxes,  
PCB's, Plugs and Sockets,  
Computers, Edge Connectors.  
**TOP PRICES PAID FOR ALL TYPES OF  
ELECTRONICS EQUIPMENT**

A.R. Sinclair, Electronics, Stockholders.  
2 Normans Lane, Rabley Heath, Welwyn,  
Herts AL6 9TQ. Telephone: 0438 812 193.  
Mobile: 0860 214302. Fax: 0438 812 387  
Telephone: 0763 246939

### TOP PRICES PAID

For all your valves, tubes,  
semi conductors and IC's.

Langrex Supplies Ltd,  
1, Mayo Road, Croydon, Surrey  
CR0 2QP

TEL: 081-684 1166  
FAX: 081-684 3056

### TURN YOUR SURPLUS TRANSISTORS, ICS ETC, INTO CASH

Immediate settlement.

We also welcome the opportunity to  
quote for complete factory clearance.

Contact:

COLES-HARDING & CO, Unit 58,  
Queens Road, Wisbech, Cambs. PE13 2PQ

ESTABLISHED OVER 15 YEARS  
Buyers of Surplus Inventory  
Tel: 0945 584188 Fax: 0945 475216

FOR SALE HP7908 Mainframe with three 64000 terminals. Offers.  
Tel: 031 333 2468.

9956

# CLASSIFIED

TEL 081 652 3620

FAX 081 652 8956

## ARTICLES FOR SALE



### **Cooke International** SUPPLIER OF QUALITY USED TEST INSTRUMENTS

ANALYSERS, BRIDGES, CALIBRATORS,  
VOLTMETERS, GENERATORS, OSCILLOSCOPES,  
POWER METERS, ETC. **ALWAYS AVAILABLE**

ORIGINAL SERVICE MANUALS FOR SALE  
*COPIES ALSO AVAILABLE*

EXPORT, TRADE AND U.K. ENQUIRIES WELCOME,  
SEND LARGE "A3" S.A.E. + 50P POSTAGE FOR LISTS  
OF EQUIPMENT AND MANUALS.

ALL PRICES EXCLUDE VAT AND CARRIAGE  
*DISCOUNT FOR BULK ORDERS SHIPPING ARRANGED*

OPEN MONDAY-FRIDAY 9AM-5PM

### **Cooke International**

ELECTRONIC TEST & MEASURING INSTRUMENTS  
Unit Four, Fordingbridge Site, Main Road, Barnham,  
Bognor Regis, West Sussex, PO22 0EB

Tel: (+44) 0243 545111/2

Fax: (+44) 0243 542457

EQUIPMENT & ACCESSORIES PURCHASED

## ARTICLES WANTED

### **PURCHASE FOR CASH**

**SURPLUS - OBSOLETE - REDUNDANT - EXCESS** stocks of  
electronic, electrical components/accessories, part processed and/or  
finished products. Please submit preliminary information or lists for  
immediate response to:

**K.B. COMPONENTS, 21 Playle Chase, Gt Totham,  
Maldon, Essex CM9 8UT  
Telephone 0621-893204. Facsimile 0621-893180.**

## FREE CLASSIFIED

WANTED Very old Philips television. Jac  
Janssen, Hoge Ham 117D, NL-5104 JD  
Dongen, Netherlands. Tel: +311623  
18158. Fax: (office) +3113 624664.

**RADFORD DISTORTION MEASURING  
SET Series 3.** I need some spare  
parts. Please write to me. Stefano Fax N.  
0039.2.3566188.

**FOR SALE MOTOROLA 68030RC25,**  
68882RC25 Weitek 3164 and Brooktree  
BT458KG80, all PGA package, all at £10  
each. Tel: 0234 219756.

WANTED: "Micro Professor" teaching  
aid made by Acer. Your price paid. Tel:  
0838 200304.

**HEWLETT PACKARD MANUALS**  
WANTED HP5300B, HP5306A,  
HP5307A. Also HP test gear. Call 0703  
813844.

**ANALYSER 141T 1200Mhz manuals**  
£750. Marconi 110MHz TF2370 manuals  
£650. Marconi synthesised V.L.F.  
receiver Sub-Assy £150. TEK 434 Scope  
£150. 0344 27869.

**SWAP FOR RF Vector Impedance  
Meter?** TF868, TF1313A LCR Bridges,  
TEK 551, TEK555 (+ Plug ins), +  
HP185C scopes. HP165 Oscillator, R210  
receiver, 074632-479.

**To Advertise Here  
Please contact:  
Malcolm Wells on:  
Tel: 0181-652 3620  
Fax: 0181-652 8956**

## INDEX TO ADVERTISERS

	PAGE		PAGE
Alternative Distribution UK	821	Kestral Electronic Components	821
Amdat	863	Keytronics	841
Anchor Surplus Ltd	828	Lab Center	799
Antex Electronics	805	Laplace Instruments	817
Aries Electronics	863	M&B Electrical	851
BK Electronics	805	M&B Radio (Leeds)	847
Bull Electrical	836	MQP Electronics	831
Cambridge Microprocessor Systems Ltd	848	Number One Systems	805
Carston Electronics	847	Pico Technology	871
Chelmer Valve Company	825	Powerware	863
Citadel Products Ltd	IFC	Premier EDA Solutions	832
Crash Barrier Ltd	817	Ralfe Electronics	880
Danbar Sales Company	845	Research Communications	871
Dataman Designs	BC	Robinson Marshall (Europe) Ltd	833
Devantech Ltd	876	Seetrex Ltd	849
Display Electronics Ltd	854	Smart Communications	794
Glazertron Ltd	812	Stag Programmers	IBC
Halcyon Electronics Ltd	870	Stewart of Reading	870
Hately Antenna Technology	848	Surrey Electronics	831
Henry's Audio Electronics	825	Technology Sources Ltd	845
ICE Technology Ltd	801	Telnet	859
Integrated Measurement Systems	825	The Low Power Radio Assoc.	831
John Morrison	812	Those Engineers Ltd	845
Johns Radio	797/853	Tsien Ltd	849
JPG Electronics	821	Ultimate Technology Ltd	823





# COMMUNICATIONS

Permanent and contract opportunities for engineers and technicians in Systems, Networking, Design Development, Software, Test, Service, Installation and Commissioning.

**We supply the best to the best !**

**We understand your true value**

**Cliveden Consultancy Services plc**

**92 Broadway,**

**Bracknell, Berks, RG12 1AR.**

**Tel 0344 489489. Fax 0344 489505.**

*Offices in London, Manchester, Southampton, Stevenage, Crawley, Brussels*

## **CLIVEDEN**

### **Technical Recruitment**

**Cliveden Consultancy Services plc**



Established 1977.

FRES MEMBER.

Managing Director: Roger Howard C. Eng. M.I.E.E.

### SPECTRUM ANALYSERS



ANRITSU TR4133A 100kHz-20GHz synthesized spectrum analyser	
IFRA 7550 1GHz portable analyser w tracking gen opt	£4500
IFR A8000 2.6GHz version of above	£6250
HP3580A 5Hz-50kHz audio spectrum analyser	£1500
HP3582A dual-channel 25kHz analyser	£3500
HP8568B 1.5GHz High-performance	£10000

### MARCONI INSTRUMENTS

2019 AM/FM synthesized signal generator 80kHz-1GHz	£1750
2019A as above, improved spec	£1950

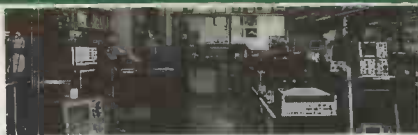


2022D synthesized signal generator	£1950
2438 520MHz universal counter/timer	£200
2828A/2829 digital simulator/analyser	£1000
2955 mobile radio test set	£3000
2955A + 2960 cellular adapters... various configurations...	call
6059A signal source 12-18GHz	£750
6460/6420 power meter 10MHz - 12.4GHz 0.3uW - 10mW	£350
893B audio power meter	£350
OA2805A PCM regenerator test set	£750
TF2910/4 non-linear distortion (video) analyser	£1000
TF2914A TV insertion signal analyser	£1250
TF2910 TV interval timer	£500

## RALFE ELECTRONICS

36 EASTCOTE LANE S HARROW, MIDDLESEX HA2 8DB  
TEL 081-422 3593 FAX 081-423 4009

NOW  
IN  
40th  
YEAR



DISTRIBUZIONE E ASSISTENZA, ITALY: TLC RADIO, ROMA, (06)871 90254

### TEST EQUIPMENT

ANRITSU ME518A pcm portable error rate test set	£2500
BRUEL & KJAER 2511 vibration meter set/1621 filter	£2250
BRUEL & KJAER 2307 level recorder	£1000
BRUEL & KJAER 2317 portable level recorder	£1850
BRUEL & KJAER 1618 band pass filter	£750
BRUEL & KJAER 3513 portable vibration analyser	£3500
BRUEL & KJAER 2515 vibration analyser	£5000
AVO RM215L-2 insulation & breakdown tester	£650
DATRON 1065 digital multimeter	£750
DRANETZ 626 mains disturbance analyser/2 x PA-6001	£750
DRANETZ 606-3 line disturbance analyser	£275
FLUKE 1720A TEE instrument controller	£500

### SPECIAL THIS MONTH ONLY: HP8673C

synthesised signal generators covering from 50MHz-18.6GHz, AM/FM/PM. Full HP/IB control. Supplied in 'as new' condition with current HP calibration. List is over £59,000. We have two to sell this month only, for £9,950 each.

RACAL 9082 synthesized AM/FM sig' gen/ 5-520MHz	£600
RACAL 9300 RMS voltmeter - 80dB to +50dB	£325
RACAL V-STORE 16, 16-chan instrumentation recorder	£9000
RACAL-DANA 9302 RF milli-voltmeter 1.5GHz	£450
RACAL-DANA 9303 level meter, digital	£1000
ROBERTS & ARMSTRONG l/c-cable end-cut measure unit	£500
TEKTRONIX J16 digital photometer	£250
TEKTRONIX 1503C/03/04/05/06 TDR cable tester	£3250
WAYNE KERR 3245 precision inductance analyser	£3000
WAYNE KERR B905 automatic precision bridge	£950

### HEWLETT PACKARD



331A distortion meter	£200
339A distortion meter	£1500
3400A voltmeter 10Hz-10MHz	£250
3335A synthesizer/level generator with option 01	£2500
3336A level generator	£2000
352A transmission test set	£1000
3586A selective level meter	£2500
415E swr meter	£350
4274A multi-frequency (100Hz-100kHz) LCR component meter	£4000
4275A multi-frequency LCR component meter	£5000
432A/478A microwave power meter 10MHz-10GHz	£400
432A/R486A uwave power meter 26.5-40GHz (waveguide)	£600
5370B universal time-interval counter	£2500
6253A dual power supply 0-20V 0-3A twice	£225
6825A bipolar power supply/amp -20 to +20vdc 0-1A	£350
70300A tracking generator plug-in unit	£2000
70907A external mixer for 70000-ser spectrum analyser	£1750
7035B X-Y single pen analogue chart recorder	£350
8011A pulse generator 0.1Hz-20MHz	£500
8112A pulse generator	£2500
816A slotted line 1.8-18GHz with carriage 809C & 447B	£500
8350B sweep generator main-frame	£2250
8405A vector voltmeter, voltage & phase to 1000MHz	£950
8620C sweep generator, many plug-in units available	£call
8671A synthesized signal generator 2-6.2GHz	£2500

URGENTLY REQUIRED - HIGHEST CASH PRICES PAID FOR 8568B, 8753A B/C, Spectrum/network analysers, 8590 1/2/3 portable analysers. Please call us if you have high-end capital equipment being under-utilised.

PLEASE NOTE: ALL OUR EQUIPMENT IS NOW OPERATION-VERIFICATION TESTED BEFORE DESPATCH BY INDEPENDENT LABORATORY

We would be pleased to handle all grades of calibration or NAMAS certification by same laboratory at cost price. All items covered by our 90-day parts and labour guarantee and 7-day 'Right to Refuse' (money back) warranty.

ALL PRICES SUBJECT TO ADDITIONAL VAT AND CARRIAGE

CIRCLE NO. 151 ON REPLY CARD

# ELECTRONIC UPDATE

Contact Malcolm Wells on  
081-652 3620

A regular advertising feature enabling  
readers to obtain more information  
on companies' products or services.

mqp

UNIVERSAL PROGRAMMING SYSTEM 2000

Models S2200 and S2400



Gang and Set Programmers for 24, 28 & 32 pin EPROMs, EEPROMs, FLASH, Emulators and OTPs up to 8M bit.

The system 2000 is an ideal programmer for the production environment. Fast programming results in high throughput and rigorous verification leads to improved quality control. Single key functions and checks against misoperation facilitates its use by unskilled staff.

**MQP ELECTRONICS LTD.**

Tel: 0666 825146

Fax: 0666 825141

CIRCLE NO. 152 ON REPLY CARD

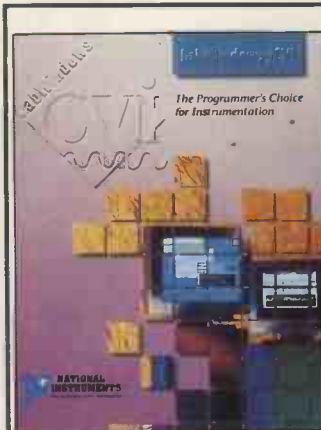
### LabWindows/CVI Brochure

The LabWindows/CVI Brochure, from National Instruments, explains how users can build instrumentation applications on Windows PCs and Sun SPARCstations using the ANSI C programming language and LabWindows/CVI data acquisition, analysis, and presentation libraries.

**NATIONAL INSTRUMENTS**

For further information  
FREEPHONE 0800 289877

CIRCLE NO. 153 ON REPLY CARD



OLSON

FUSED SUPER SLIM MAINS DISTRIBUTION PANELS WITH DOUBLE POLE SWITCHED SOCKETS



OLSON ELECTRONICS LIMITED is a leading manufacturer in the field of mains distribution panels of every shape and size to suit a variety of needs. For use in Broadcasting, Computing, Data Communications, Defence, Education, Finance, Health etc. All panels are manufactured to BS5733. BRITISH AMERICAN, FRENCH, GERMAN CEE22/IEC and many other sockets. Most countries catered for.

All panels are available ex-stock and can be bought direct from OLSON.

**Olson Electronics Limited**

Tel: 081 885 2884

Fax: 081 885 2496

CIRCLE NO. 154 ON REPLY CARD



### ENGINEERING & SCIENTIFIC PC

The new 230 page 1994 PC-LAB catalogue covers an extensive range of PC-based data acquisition, measurement, control, and interface plug-in cards plus supporting software packages for engineering & scientific applications. Also includes 19" rack mounting industrial PCS, custom OEM PC chassis and associated sub-systems.

Please contact integrated measurement systems for a free catalogue copy.

Tel: (0703) 771143

Fax: (0703) 704301