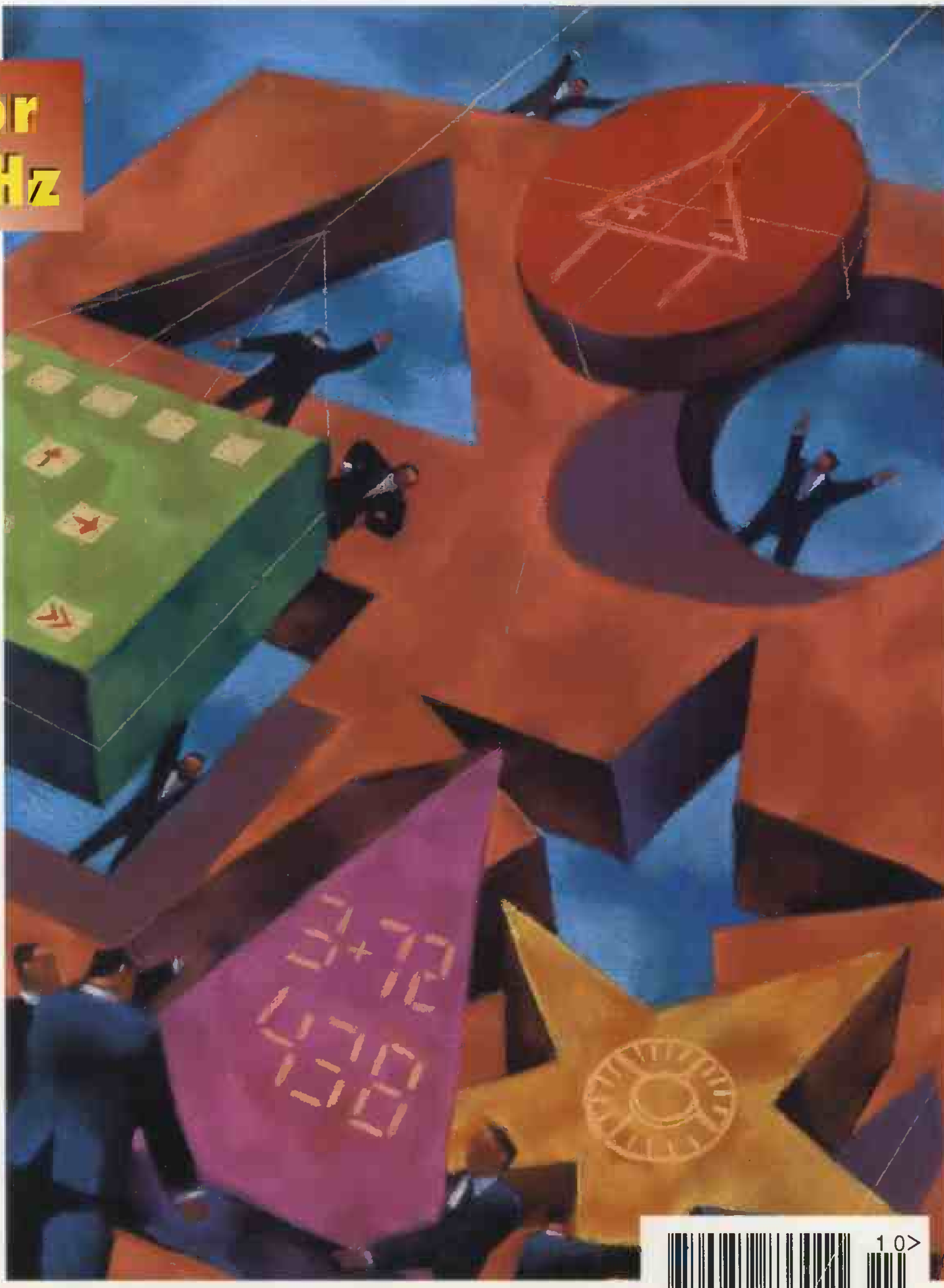
ELECTRONICS WORLD
+ WIRELESS WORLD

Denmark DKr. 65.00
Germany DM 15.00
Greece Dra.950
Holland Dfl. 14
Italy L. 8000
IR £3.30
Singapore S$12.60
Spain Pts. 750
USA $4.94

A REED BUSINESS PUBLICATION
SOR DISTRIBUTION

October 1995 £2.10



Sweeper for 0 to 200MHz

Fast 50Ω power driver

IEEE488 testing made easy

Current probe for switching mosfets

Valve audio

Analysing circuits via energy

DC circuit design

Review – Electronics Workbench

10>

CONTENTS

823 SWEEPING AT VHF
Spanning 0 to 200MHz in one range, this stand-alone sweeper provides a level of 3dBm into 50Ω with very low spurii.

832 PROBING FOR SWITCHING LOSSES
Alternative current probe for oscilloscopes – easy to implement, good performance and low cost.

835 ULTRA-FAST AMPLIFIER
Giovanni Stochino's fast and precise power amplifier for test and instrumentation drive 50Ω loads.

844 GPIB TESTING MADE EASY
Simple but effective tester for the world's most popular instrument bus – IEEE-488.

849 ANALYSING DC VIA SPICE
Owen Bishop describes how to get the best out of your circuit emulator when analysing at dc.

856 HOT AUDIO POWER
Jeff Macaulay's simple valve amplifier delivers 32W, has a power bandwidth of 5-55kHz and distorts by 0.07% at 20W.

874 VERSATILE STEPPER MOTOR CONTROL
Under PC control, Pei An's triple stepper motor driver also handles analogue and digital i/o.

879 IN A LAB ON A KEYBOARD
Allen Brown looks at the virtual electronics lab – Electronics Workbench.

890 ANALYSING CIRCUITS VIA ENERGY
A new circuit analysis method by Andrew Gibson and Bernice Dillon offers benefits over the traditional method.

REGULARS

811 COMMENT
Shifting cultures.

812 NEWS
New hope for CD standards, ccd advance, denser chips, tiny lcd, tv ghosting solution.

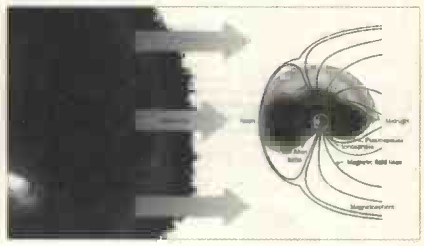
816 RESEARCH NOTES
Solar wind investigations, walls with ears, micro-robotic hinges, new optical receiver, Byzantine music.

866 CIRCUIT IDEAS
Prom and logic array in harmony, Measuring low frequencies, Non-invasive timer for battery equipment, Synchronising a crystal, Half-duplex from a pc's COM port.

884 LETTERS
Electromagnetic compatibility disarray, field hazards, bicycle dynamos, mysterious noises – problem solved?

895 NEW PRODUCTS
Pick of the month – classified for convenience.

Cover – Jamel Akib



Work investigating solar winds is reported by Jonathan Campbell in Research Notes, page 816.

Next month: Applying a new 3-terminal magnetic detector with digital output, MathPlus reviewed, developing a C++ library for geometric transforms, using the Zetex 78L05.

NOVEMBER ISSUE – ON SALE 26 OCTOBER

EW+WW READER OFFER

Digital multimeter including transistor gain tester and capable of measuring 10A dc for just £14.95 – fully inclusive. See page 864.

EDITOR
Martin Eccles
0181 652 3128

EDITORIAL ASSISTANT
Rob Allcock
0181 652 8638

CONSULTANTS
Jonathan Campbell
Philip Darrington
Frank Ogden

DESIGN & PRODUCTION
Alan Kerr

EDITORIAL ADMINISTRATION
Jackie Lowe
0181-652 3614

E-MAIL ORDERS
jackie.lowe@rbp.co.uk

ADVERTISEMENT MANAGER
Richard Napier
0181-652 3620

DISPLAY SALES EXECUTIVE
Malcolm Wells
0181-652 3620

ADVERTISING PRODUCTION
Christina Budd
0181-652 8355

PUBLISHER
Mick Elliott

EDITORIAL FAX
0181-652 8956

CLASSIFIED FAX
0181-652 8956

SUBSCRIPTION HOTLINE
01622 721666
Quote ref INJ

SUBSCRIPTION QUERIES
01444 445566

NEWSTRADE DISTRIBUTION
David G. Sanders
0181 652 8171

BACK ISSUES
Available at £2.50

ISSN 0959-8332

REED BUSINESS PUBLISHING

Shifting cultures

The Americans talk about a 'Cultural Shift' towards electronics as US college students nowadays badger their parents not for their first car, but for their first pc. Moreover, apparently they want that pc, like they used to want that first car, to be the 'hottest', in terms of raw power, they can wangle.

In the UK, if any 'Cultural Shift' is occurring, it was undoubtedly spurred along by last month's shenanigans which saw *The Times* being given away free – courtesy of Microsoft – and the Rolling Stones being paid a reported £8m to provide the backing music for the launch of Microsoft's new pc operating system.

Even chips are scoring high in the awareness stakes with ubiquitous Pentium advertising, with readers of the serious papers learning that Siemens and Fujitsu are spending a billion dollars apiece on UK-based chip plants, and with Alan Clark (of Diaries and ladykilling fame) recently telling the readers of his *Mail on Sunday* column that Japanese industrial prowess came from its strength in 'very high speed integrated circuits' which, he said, are the basis for every type of manufactured equipment.

Such events are bringing it home to many that high-tech is a big, rich industry that has spawned the 39 year-old 'richest man on the planet' – Bill Gates – and is growing like weeds.

There's only one thing wrong with all this public awareness – the companies involved, Intel, Microsoft, Siemens, Fujitsu etc are all foreign. There's no chance – since Sir Clive Sinclair's regretted departure from the forefront of the electronics scene – of any Brit or British company doing anything sufficiently stunning in electronics to capture the public imagination.

Why? It seems to be an accepted truth among the British political establishment that we simply can't hack it in electronics. Last month, the deputy prime minister Michael Heseltine was asked if he was satisfied that the UK Government spent 25 times less than the German government on collaborative European chip R&D. Heseltine replied: "We can't be a winner in every field. If you look at some areas, UK companies have a disproportionately larger share, like pharmaceuticals – a high-tech area where we are winning in the market." Clearly Heseltine did not see the high-tech electronics area as one where we are winning in the market.

"We can't be a winner in every field..."

Why not? If we can make the investments to succeed in pharmaceuticals and have world class companies like Wellcome-Glaxo, why can't we have world class companies in electronics?

Looking back over the years we can chart the milestones along the route to our present position: the closure of our leading edge chip firms in the 70s – Marconi Elliott Microelectronics and Elliott Automation; the neglect of the GEC-Philips joint venture in chips – Associated Semiconductor Manufacturers; the abandonment by our largest electronics company of the flagship R&D project of Alvey – the chip process technology research programme.

All these decisions were made by one company – GEC – whose boss Lord Arnold Weinstock is generally seen as being unenthusiastic about developing the building blocks of electronics products – chips. Can the UK's relative failure in electronics really all be put down to the attitude of one man?

David Manners

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: Distributed by Marketforce (UK) Ltd, 247 Tottenham Court Road London W1P 0AU 0171 261-5108.
Subscriptions: Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 01444 445566. Please notify change of address. Subscription rates 1 year (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 BPCC Magazines (Carlisle) Ltd, Newtown Trading Estate, Carlisle. Cumbria, CA2 7NR
Typeset by Wace Publication Imaging 2-4 Powerscroft Road, Sidcup, Kent DA14 5DT

New hope for HD-CD standards

The first steps to avoid potentially bruising battle over standards in high density CD disks have been taken with Sony and Philips agreeing to talk with rival Toshiba about creating a single standard.

Sony and Philips have been promoting their jointly developed Multimedia CD (MMCD) format but have few supporters outside of pc and cd-rom drive manufacturers. The rival Toshiba Super Density (SD) has garnered the largest amount of support with major electronics firms and Hollywood studios choosing the format in the hopes of creating a large video disk industry.

At a-recent demonstration of Multimedia CD technology at the Internationale Funkausstellung trade show in Berlin, Philips and Sony officials said that they would work toward a single standard.

Representatives of major US computer firms, organised as the Technical Working group, have been appealing for a single standard.

"We understand and share their belief that a single format should be in the best interest of the consumer," said Henk Bodt, executive vice-president Philips Electronics.

"Toward this end, recently, Philips and Sony have written to the Technical Working group expressing our desire to work toward creating a single format that ideally combines the best features of the currently proposed Multimedia CD and SD formats," he continued.

Bodt added that discussions have begun with the SD Alliance on developing a single standard.

CCD advance offers ten times the brightness levels

Matsushita Electric has developed the world's first hyper-dynamic range charge-coupled device, for which it has applied for two Japanese and two overseas patents. The device is capable of reproducing 10,000 perceptible brightness levels – 10 to 20 times that of conventional ccds. It is also capable of high resolution reproduction, either independently of or in combination with the hyper-dynamic range.

The ccd incorporates both a new read-out structure and a new 8-phase driver. The new structure involves a signal charge read-out electrode transecting the central part of the photo diode. This has not been practical before because it mixes electrical charge signals from left and right, and produces low illumination images by requiring a long reading distance. In this ccd the problems have been solved by implanting boron in an optimal pattern in the photo diode area under the reading gate, and by a one-time heat diffusion process to produce a gently sloping potential

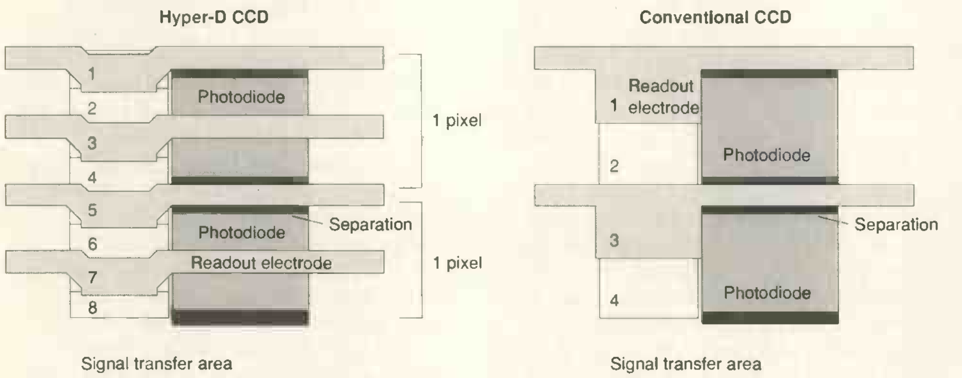


Fig. 1. New CCD read-out structure incorporating an electrode in the centre of the photo diode gives successive transfer electrodes for eight-phase driving, as opposed to conventional four-phase.

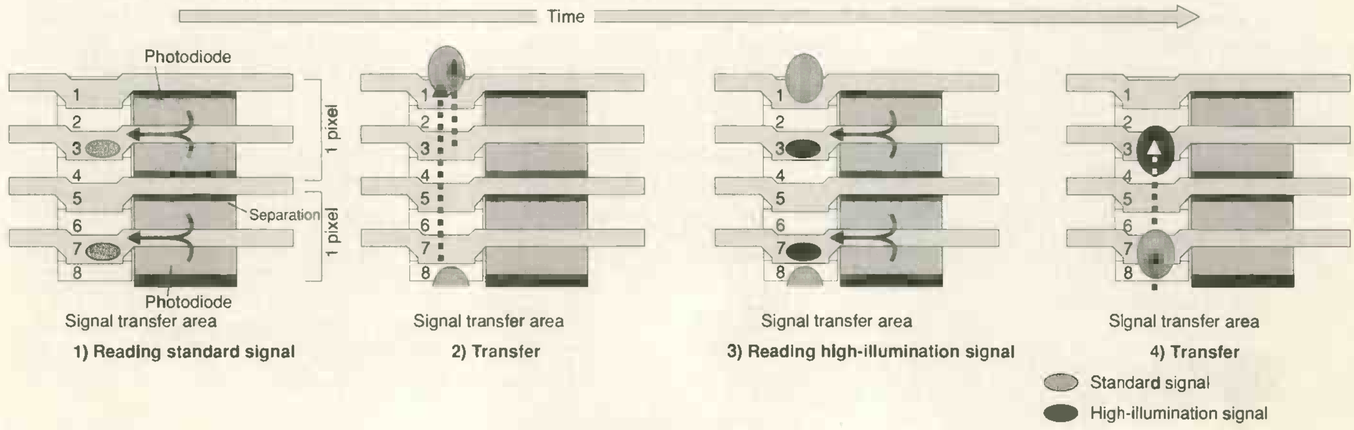


Fig. 2. Eight-phase driving enables the hyper-dynamic range – standard brightness signals are read (1) then transferred (2), followed by the brief exposed high-illumination signals (3&4), allowing up to 10,000 brightness levels.

Breakthrough heralds 16 times more transistors on an IC

Researchers at Harvard University are claiming a breakthrough in a new semiconductor production technology that will let IC designers increase the transistor count 16-fold.

Professor Mara Prentiss says the team has developed a lithography process that has produced test samples with circuits 50nm wide. The technology can be refined to produce 10nm circuit features.

The researchers are pioneering atom lithography, a technology that manipulates a stream of atoms to etch out circuits. Current lithographic techniques are starting to approach physical limits, needing new kinds of lithography.

Prentiss and other researchers working on atom lithography claim the technology offers significant benefits compared with other approaches such as e-beam and x-ray lithography. In theory, atom lithography can be used to achieve much finer resolutions.

Prentiss did not say when atom lithography technology will be ready for commercial use. The technique can create chips with transistor counts in the 100 million range and be used to speed up current designs by making them more compact.

Prentiss' team used a laser to control a well-collimated atomic-beam that etches the circuit design on the substrate. The research is funded by the US National Science Foundation and involves six research groups organised as the Consortium for Light Force Dynamics.

For more information on the Consortium for Light Force Dynamics point your web browser at http://atom-sun.harvard.edu/lightforce/

to smoothly read-out the charged signals. The 8-phase driving method applies different driving pulses independently to the eight successive transfer electrodes. This enables the capture of 10,000 brightness levels by reading out a standard signal with an independently variable exposure time of 1/60-1/15,000 second to a signal transfer area, transferring the signal to the next transfer area, and reading out the high illumination signal which has an independently variable exposure time of 1/800-1/200,000 second. High resolution is achieved by combining two sets of the eight layers of the transfer electrodes, then driving the electrode independently when transferring the electrical charge.

Potential uses for this 1/4in ccd are an electronic still camera, a 'pocket-sized' camcorder that is more advanced than current professional cameras, a camera for car navigation systems which would be robust due to the elimination of a mechanical iris, a mobile videophone, and various applications in medical and basic research.

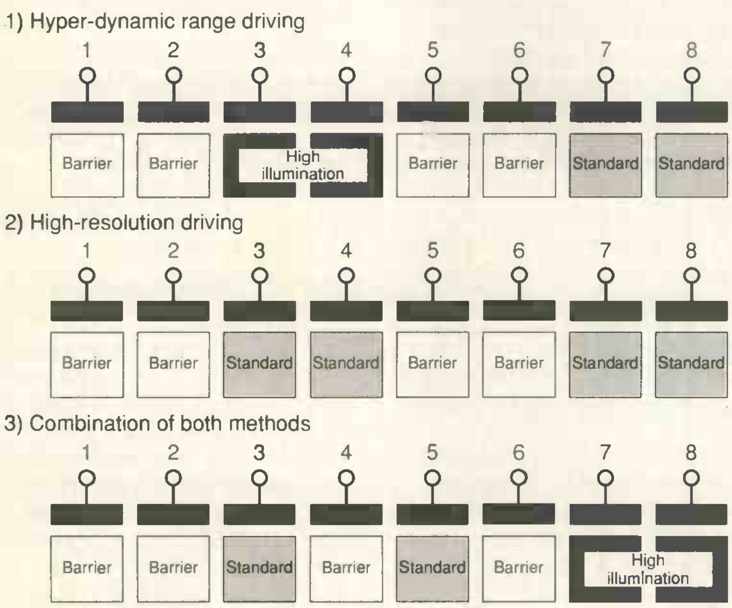


Fig. 3. Exploiting eight-phase driving to cope with differing requirements – hyper-dynamic range driving with high-illumination and standard signals (1), high-resolution driving with standard signals combined (2) and a combination of both (3).

A shrink for lcds

Full colour on a miniature lcd display has been demonstrated by the display and 2-D Optics Team at GEC Marconi led by Dr Mike Worboys. Aimed at headup displays for fire fighters and other professionals, the display combines a c-mos chip backplane with ferroelectric liquid crystals. Colour is obtained by sequentially illuminating the display with red, green and blue leds. The proof-of-concept display is 176 by 176 pixels, but the team is about to start work on a 768 by 576 pixel PAL version measuring only 8mm by 6mm. Plans for a 1280 by 24 version exist. The image has been superimposed for the benefit of the photograph.

Ghosts laid to rest

A device for rejecting tv ghost signals has been announced by Oren Semiconductor. Ghosting is the degradation in a television picture caused by the transmitted signal arriving via multiple paths.

Oren Semiconductor has been set up by the dsp company Zoran and the Singapore based Goldtron Group, and has its headquarters and design centre in Israel.

Its ghost cancelling device, the *OR43100*, consists of an adaptive equaliser controller and a large, 576-tap digital filter. The device exploits a ghost cancelling reference, gcr, signal which, in countries such as the US and Japan, is transmitted with the tv signal. Using the received gcr signal, the device calculates the necessary filter coefficients for the tv receiver to effect the necessary ghost cancellation. With its 576-tap filter, the device can reject ghost signals occurring up to 7.5μs before, and 42.5μs after the main received tv video signal.

Spencer Horowitz, Oren's director of marketing, said the device has already been adopted by Philips Consumer Electronics for its Magnavox tvs. He also confirmed its adoption "by other major consumer manufacturers".

Oren Semiconductor is developing further devices to address the emerging digital cable and terrestrial Tv standards.

IN BRIEF

Windows 95 compounds component supply problems

US pc makers are fighting for market share with major price cuts in the wake of the launch of Microsoft Windows 95, which could boost demand for semiconductors, exacerbating shortages of key components.

Over recent weeks, at least six major US pc makers have cut pc prices. Hewlett Packard is the latest company to do so – reducing prices by as much as 19%. Other companies cutting pc prices include IBM, Compaq Computer, Dell Computer and IPC Technologies.

Many pc buyers are upgrading to more powerful systems needed to run Windows 95, which requires faster microprocessors, larger hard drives and system memories. The demand is likely to worsen a shortage of d-rams.

Speed up for automotive electronics

Market analysis company BIS Strategic Decisions is predicting the total demand for automotive electronics will rise to $16.1bn by the year 1999.

Its report states that the implementation of automotive electronic systems has significantly increased in recent years. This, combined with the general recovery in key world car markets last year, resulted in a 1994 automotive electronics growth of 24 per cent.

The 1999 demand is expected to split into: power train $7.5bn, body $3.8bn, chassis $2.7bn, security $1.1bn and driver information $1bn.

Safety, security and convenience features are the main factors driving demand.

Battery boost

Mitsubishi Chemical has developed an anode material that is claimed to improve the performance of lithium ion cells.

Mitsubishi says that cell capacity is raised from 300-500mAh in more conventional cells to over 600mAh. This will allow longer battery life in mobile phones and pdas. The material is also said to improve output current capability.

The company has already established a line at its Sakaide plant in Kagawa to produce 30 tonnes of batteries per year on a test basis.

Mass production will begin in spring 1996.

Video server brings greater immediacy to news reporting

ITN is to be the first in Europe to employ Sony's digital video server technology for its news production.

The pilot system will replace current video tape systems with video servers controlled by a Sony/Oracle computer system.

The system will enable a journalist seated at a workstation to script, edit and caption stories in a form ready for broadcasting, dramatically reducing production times.

Korea boosts lcd production

The first major challenge to the Japanese monopoly in large colour flat panel displays is swinging into gear with the three Korean electronics majors, Samsung, Hyundai and Lucky Goldstar, sharply increasing production.

Car navigation system is a game

Japanese consumer electronics giant Hitachi is one of the first companies to start developing car navigation devices that can be used as game machines when taken out of the car.

The announcement of a 32bit car navigation system based around the Sega Saturn game machine was expected from Hitachi last week.

Matsushita Electric Industrial is also pursuing this line of development and its similar product is expected before the end of the year at prices around £500.

Ring with more than a hole

Dallas Semiconductor and US jewellery maker Jostens have created a ring containing a 64kbit memory chip that can hold personal information such as credit card numbers and photographs.

The $60 ring could be used like a smart card. The user would touch the ring to a data reader to download credit card or automated teller machine payment data.

Dallas is talking to potential users. Applications areas might include security, where a combination of the ring and password could be used to limit access to computer files or sectors of a building.

MICROMASTER LV PROGRAMMER

The Only True 3V and 5V Universal Programmers

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

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

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

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

Speedmaster LV £495

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

Micromaster LV £625

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

8 bit Emulator card £125

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

16 bit Emulator card £195

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

FEATURES

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

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

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

CIRCLE NO. 107 ON REPLY CARD

Jonathan Campbell

Bringing solar wind down to earth

Scientists at AT&T Bell Labs are investigating how solar activity affects long cable systems in practice, by using transoceanic cables to sense how geopotentials change with time and solar activity.

Elsewhere, much research is going into analysing solar activity and unravelling the secrets of the solar wind. But even if we can eventually understand – and predict – solar storms, their interaction with electrical and electronic systems on Earth is so complicated that we still can not be sure what actual effect a solar storm will have.

Part of the problem is that the magnitudes of earth potentials that might occur across specific power line or cable routes in a set time interval cannot be determined from first principles.

Variations in Earth's background magnetic field caused by the charged particle solar wind can induce electrical currents to flow. Normally, changes in magnetic field often appear to propagate from east to west – and magnetometers at both ends of a cable can predict the induced voltages. But in other cases the field appears to change almost simultaneously over a larger area.

The Earth's surface consists of layers of conducting and insulating materials, so the electric potentials that can be induced by a time-varying magnetic field can be quite different in different areas. The sea too, as a good conductor, has a significant effect. At the same time, statistics of magnetic fields and induced voltages all vary with local time, date and solar activity, and researchers say there appears to be more that one type of magnetic storm.

Yet these effects are vitally important to the design of long conducting systems such as power feed equipment for oceanic cables.

In the AT&T study (*AT&T Technical Journal*, Vol 74, No 3, pp.73-84), computer-based instruments are continuously monitoring cable voltages relative to the local ground, digitising the values at two second intervals and writing the data to hard disk.

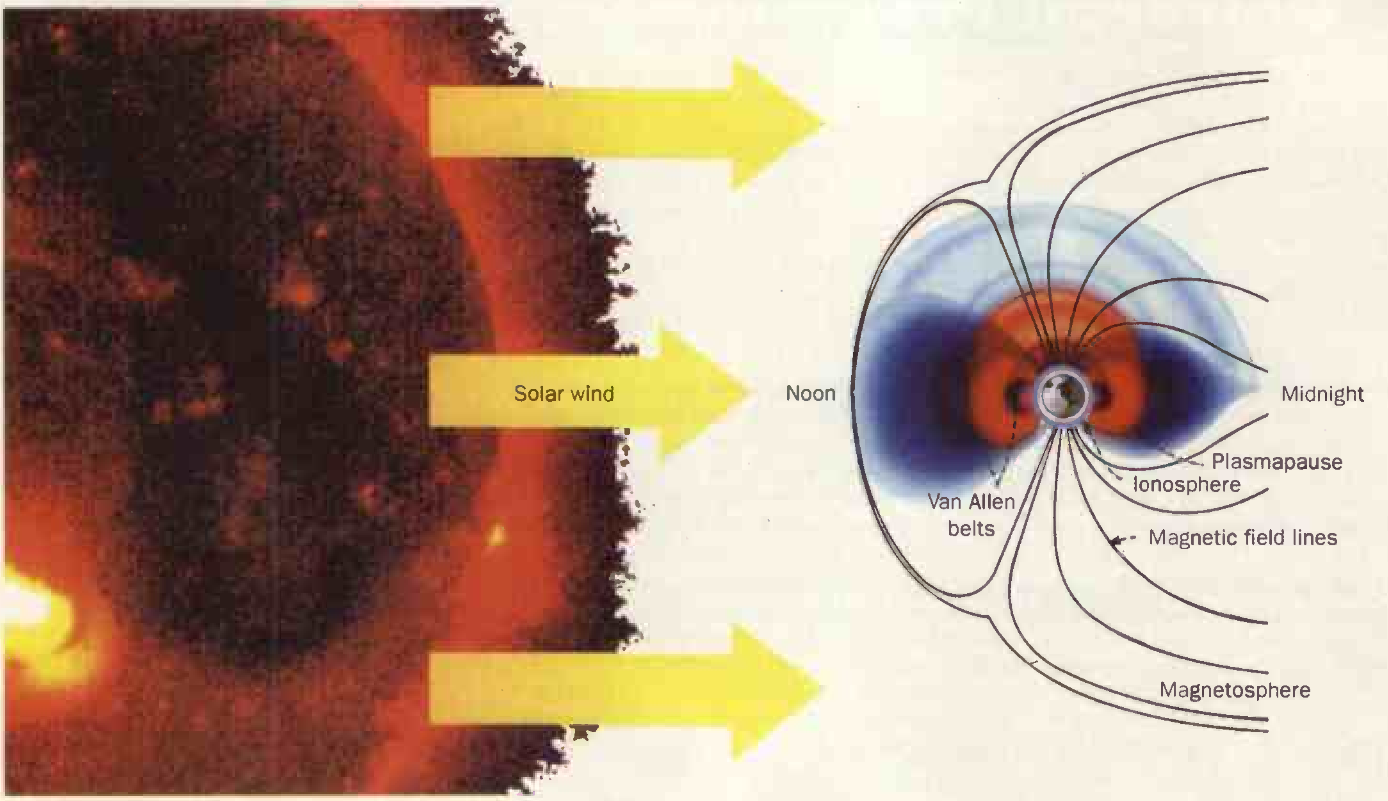
So far scientists have been finding that theoretical predictions are not able to match actual results – particularly in the case of the largest excursions.

However, the researchers say their eventual aims are both to improve predictability of observed signals and also to gain a better understanding of the mathematics of predicting non-stationary processes.

One interesting related discovery is that two of the AT&T cables being monitored, parallel and separated by about 75km in the Pacific Ocean, effectively form a large elongated Faraday loop. The net potential around the loop is induced only by variations in the component of the geomagnetic field perpendicular to the current loop.

Measurements show that this large cable loop is much more sensitive than a magnetometer to magnetic field fluctuations, giving a convenient way to measure small variations in ionospheric currents.

Emissions from the sun constantly affect the Earth. This x-ray image of the sun, made by the Japanese Yohkoh spacecraft, shows the solar corona expanding into the interplanetary medium as an ionised gas.



Now walls really do have ears

In this security-preoccupied age, cctv and infra-red sensors attached to buildings are no longer an unusual sight. Unfortunately, because they must be located in the open, they can be disabled too. But a low-power radar movement detection system that can 'see' – or should it be hear? – though walls and so be built into brickwork, suffers no such drawbacks. In addition the technology could also be useful in collecting information in terrorist attacks where hostages have been taken.

Developer of the system is Hughes Advanced Electromagnetic Technologies Center, and its workings were recently described in an interview with Lawrence Frazier, Senior Engineering Staff Specialist at Hughes Missile Systems Company (Surveillance through Walls and Other Opaque Materials *OE Reports*, No. 140, published by SPIE).

Frazier explained that, unlike conventional radar, the MDR-1A motion detection radar uses very low power. Less than 2mW goes to the antenna, as opposed to a high powered airport radar which uses 100,000W. It doesn't provide any range or angle information, only indicating if there's motion. However, it is extremely simple – the tone pitch changes when a person is moving or constant if there is no motion.

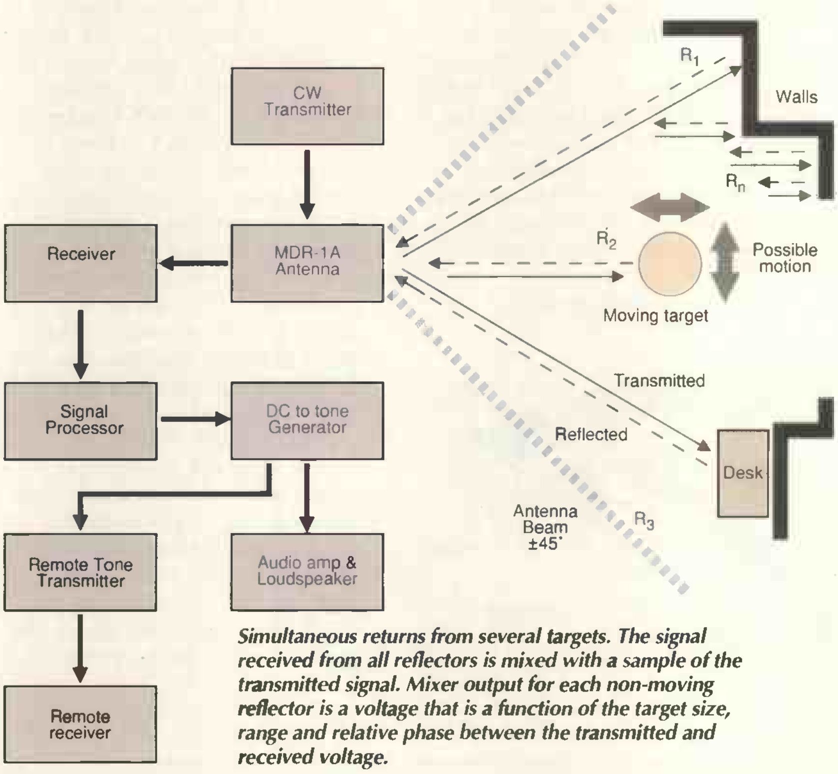
To operate, a signal is transmitted into a room, and the radar receiver senses a net voltage, representative of all the things in view. Any change, such as a movement brings about a change in the dc signal.

In the open the range is around 30m, dropping down to 10m through 15cm of steel reinforced concrete, such as a standard slab wall. Operating frequency is 915MHz and the wavelength is approximately 0.3m.

The system is not Doppler based. Instead a cw signal is transmitted. The phase of the energy coming back off each fixed reflector is summed together into a constant vector voltage. This has a voltage and phase relative to the signal that was sent out. Small phase changes of the received signal are produced by any one of the reflectors changing position.

The system is said to be so sensitive that it is capable of detecting even finger movement in a room. For all those *EW+WW* readers who might be going into their bedrooms a little more self-consciously than before, Frazier says that Hughes is very careful to whom it sells. But he does admit that some unscrupulous person could, if they wanted, obtain one.

Do you think you had better get one to check your neighbours out, before they start checking you out?



Simultaneous returns from several targets. The signal received from all reflectors is mixed with a sample of the transmitted signal. Mixer output for each non-moving reflector is a voltage that is a function of the target size, range and relative phase between the transmitted and received voltage.

Pivotal microtechnology

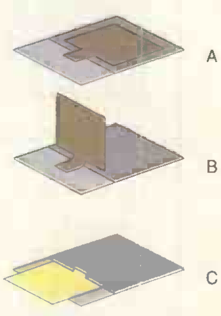
Microscale conducting bilayer hinges that can rotate and hold plate-like limbs at any position could form the basis for the design of a powerful microrobot, according to three physicists at the Linköping Institute of Technology in Sweden.

The hinges, made of a layer of polymer and a layer of gold (Controlled Folding of Micrometer-Size Structures, *Science*, Vol 268, pp.1735-1738), are used to connect rigid plates to each other and to a silicon substrate. The bending of the hinge occurs because the polymer, sitting in an electrolyte, can be tuned from insulating to metallic, with the resulting movement of ions producing a change in volume. This change translates into a rotation in the hinge in a process that can be controlled by application of a small voltage.

The Linköping team says that electrically controlled bending of the hinges allows the precise three-dimensional positioning of the plates in space. Other systems tilt the position of plates relative to a base substrate. But the Swedish approach allows controlled folding of 180° at each joint.

The hinges can apply real power too. To give an idea of their strength, the researchers say the process is equivalent to a person under water trying with one arm to move a 30m square plate – but conducting polymers are able to deliver stresses of hundreds of megapascals.

Several rigid elements can be connected with the hinges, allowing a microstructure to fold and assemble into a predetermined shape. Valves that close automatically in response to a chemical signal or change in pH is one application. But more complex folding structures could form the basis for microrobot limbs too.



Square plate paddles 90μm square being accurately positioned by 30μm hinges. Could it form the basis for a powerful microrobot?

Integrated receiver boosts optical performance

Low cost, low parasitic components that deliver high reliability and performance will be vital for the next generation of optical communications. Now work supported by DBP Telekom in Germany, has led to development of a new integrated optical receiver that could offer high current gain and inherent pulse shaping, while its structure is simpler and more bandwidth efficient than anything before proposed. The receiver integrates an InGaAs transferred-electron device having a Schottky-gate-electrode (sted), with an InGaAs metal-semiconductor-metal detector, msm – 'A new photoreceiver concept using InGaAs transferred-electron devices', D Hahn *et al*, *IEEE Journal of Quantum Electronics*, Vol 31, No6.

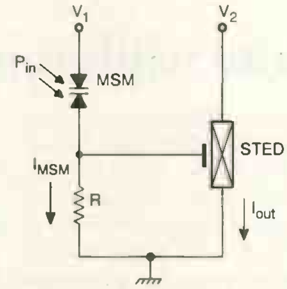
In the circuit for the integrated photoreceiver, the msm detector is biased by a voltage, V_1, chosen to yield maximum sensitivity of the device, while V_2 is set to a level just below the threshold of the sted – see diagram. An optical input pulse generates a photocurrent leading to a gate-trigger voltage for the sted across the load resistance R. The whole circuit requires only two epitaxial layers and relatively few fabrication steps.

The researchers report a dark current density of 3×10^{-5}A/cm^2 – comparable to the best values so far reported – while responsivity is 0.4A/W and capacitance at 10V is 20fF. Rise time of the temporal photoresponse is smaller than 70ps which also gives an indication of the capability to trigger the sted in the Gbit/s range.

According to Hahn and colleagues, the device should be able to demonstrate a high current gain up to 60dB and a sensitivity of –24dBm at data transfer rates of 10Gbit/s.

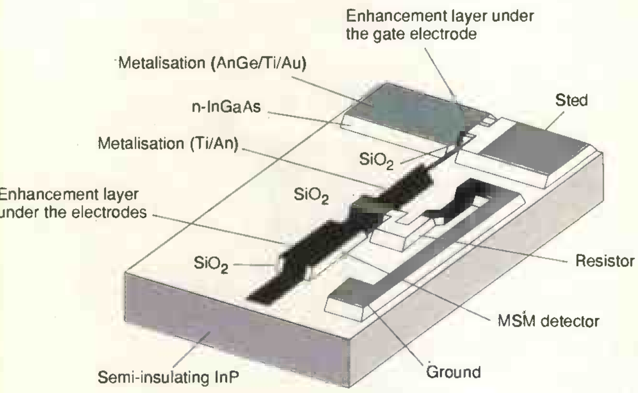
The circuit also, naturally carries out some pulse shaping of the input signal, as rise and fall times of the current drop result from domain formation and dissolution.

Because circuit implementation is so simple, it should become very easy to add a laser diode in order to realise an optical repeater.



Simple circuit forms the basis of the integrated photoreceiver.

Only two epitaxial layers and relatively few fabrication steps are required.

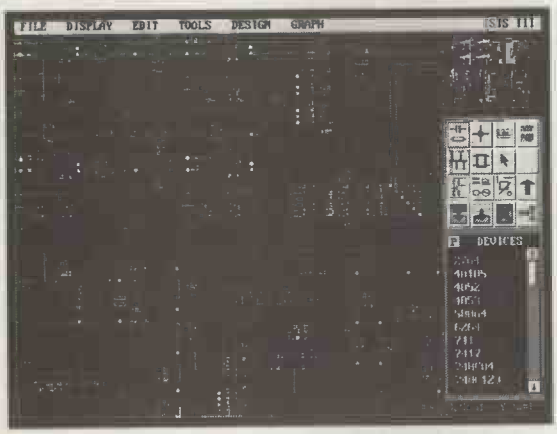


PROTEUS

NEW !

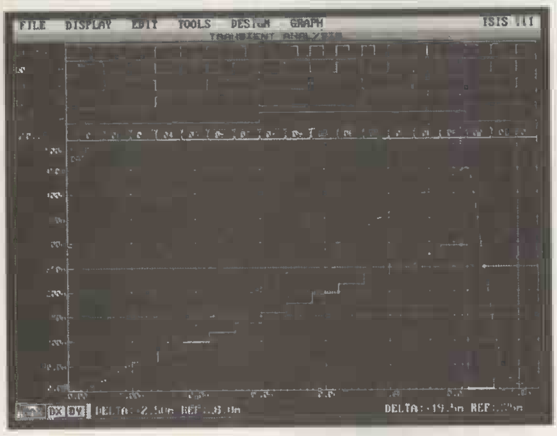
ARES III PCB Design now offers:- Polygonal (shape based) Ground Planes, 32 Bit Hi-precision database, Any Angle Rotate, Extra Layers for mechanical data, DXF Import, Padstacks and Enhanced track editing.

The Complete Electronics Design System



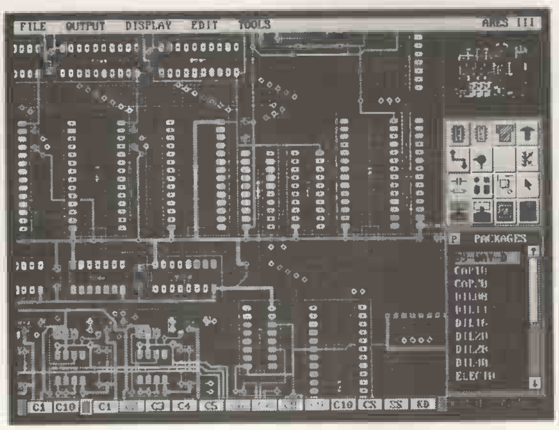
Schematic Capture

- Easy to Use Graphical Interface.
- Netlist, Parts List & ERC reports.
- Hierarchical Design.
- Extensive component/model libraries.
- Advanced Property Management.
- Seamless integration with simulation and PCB design.



Simulation

- Non-Linear & Linear Analogue Simulation.
- Event driven Digital Simulation with modelling language.
- Partitioned simulation of large designs with multiple analogue & digital sections.
- Graphs displayed directly on the schematic.



PCB Design

- Unlimited Design Capacity.
- Multi-Layer and SMT support.
- Full DRC and Connectivity Checking.
- Advanced Multi-Strategy Autorouting.
- Output to printers, plotters, Postscript, Gerber, DXF and DTP bitmaps.
- Gerber View and Import capability.

Labcenter
E l e c t r o n i c s

Write, phone or fax for your free demo disk, or ask about our full evaluation kit.
Tel: 01756 753440. Fax: 01756 752857.
53-55 Main St, Grassington. BD23 5AA.

Proteus software is for PC 386 compatibles and runs under MS-DOS. Prices start from £475 ex VAT; full system costs £1495. Call for information about our budget, educational & Windows products. All manufacturers' trademarks acknowledged.

CIRCLE NO. 109 ON REPLY CARD

Musicians need more fingers

Our well-known sequence of octaves, tones and semi-tones is not the only musical system in the world. Oriental and Arabic musicians have a choice of 36 notes in the same period occupied by our octave scale of twelve notes. Now, engineers at the National Technical University of Athens have combined both systems in a single keyboard electronic instrument for Byzantine music (eibm).

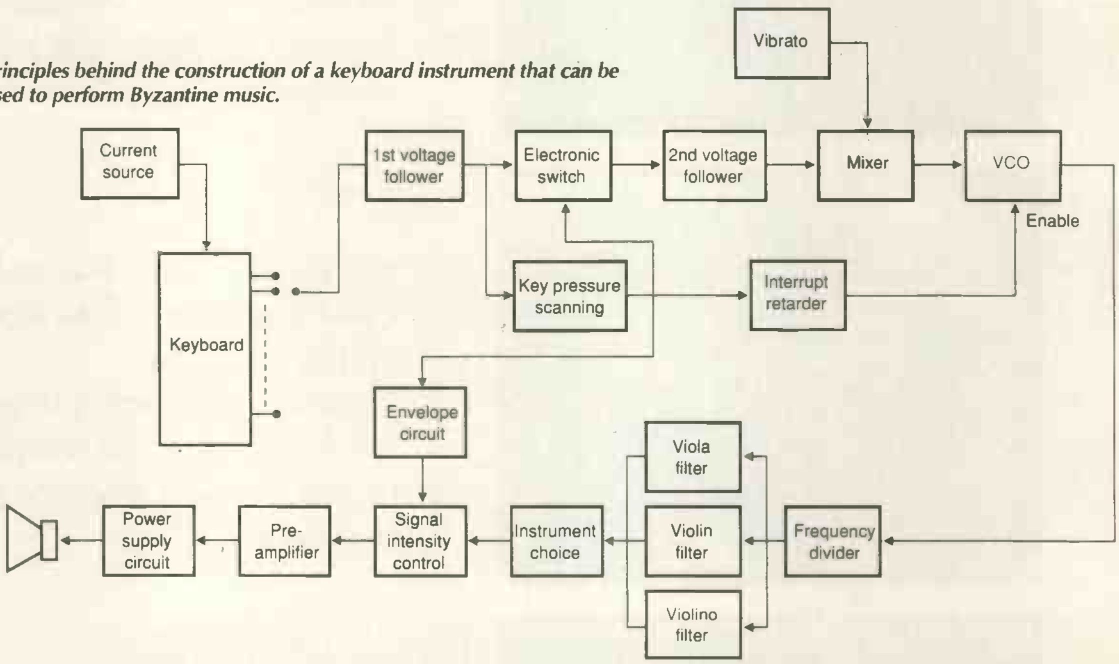
In the eibm, the semitone, normally the smallest musical partition, is divided into three new notes. To enable musicians to play these notes a keyboard has been designed (Study and Design of an Electronic Musical Instrument which Accurately Produces the Spaces of Byzantine Music, *IEEE Transactions on Consumer Electronics*, Vol 41, No 1, pp118-124) that looks like the European harmonium, except that every key has three segments. The result is that both Western and Byzantine music can be played on the same instrument.

Electronic components in the instrument include a circuit to create the envelope of the note (the shape) and a pre-amplifier – a voltage amplifier having a high input resistance – for driving the modulated output signal. There is also a power amplifier with a low output impedance for driving a speaker, various filters to simulate the sound of different instruments, and circuits to produce vibrato.

But the heart of the instrument is the oscillator, producing a regulated frequency that depends on the position of each key. A voltage-controlled oscillator is used so that when a key is pressed, equivalent to a voltage, the oscillator frequency is defined. The power supply must of course be particularly stable to provide a solid base for the reference voltages defining the frequency of the vco, but the researchers report success with their instrument and say they expect the eibm to enable creation and study of polyphony in oriental music scales and allow experimental recording of the auditory impression of different scales.

They also hope the eibm will open up the study of new sounds.

Principles behind the construction of a keyboard instrument that can be used to perform Byzantine music.



Organic development pleases tv and telecoms

A prototype opto-electronic modulator that can convert the equivalent of 15 million simultaneous phone conversations from electronic to optical form – reliably and over an extended time – has been developed following work at the University of Southern California-UCLA.

Currently, the best opto-electronic modulators have only one-third as much capacity as the new device. The tripling of conversion capacity results from substituting a newly synthesised polymer for the crystalline materials previously used in such devices.

Cable television companies, which convert electronic signals captured from satellites into the signals carried over optical cable, are large users of opto-electronic modulators. Telephone companies too, which prefer to carry signals long distance over low-loss fibre-optic cable, but which switch and process signals electronically, are potential customers.

High-capacity devices that can process up to 20GHz electronic signals conventionally use lithium niobate. But the USC-UCLA device uses an organic polymer and operates at 60 GHz – successfully converting a much wider band of electronic signals to optical ones. The 60GHz range is the equivalent of some 15,000 television channels.

The USC researchers say the wide bandwidth capacity of the device will offer advantages in design and operation of advanced 'smart' radar systems, which use arrays of antennas to transmit extremely high radio frequencies for tracking multiple targets and to avoid enemy radar jamming signals.

Tacan Corp, a manufacturer of fibre-optic components for cable television and other markets, is collaborating with USC and UCLA to develop the new devices commercially.

The USC-UCLA team is working now on a 100GHz device, and a 200GHz model might ultimately be built. ■

Sweeping to vhf

Spanning 0 to 200MHz in one range, this stand-alone sweeper provides an output level of +3dBm±1dB into 50Ω with very low harmonic and spurious content. Ian Hickman designed it in response to the recent scarcity of commercially-available alternatives.

Fig. 1. Construction of the screened enclosure for the rf unit. A die-cast box would have been more convenient, except that it is difficult to create the three partitions needed

Swept frequency generators – sweepers – were once commonplace in electronics labs. Earlier types, wobbulators, used a vibrating capacitor and consequently produced an output whose frequency varied approximately sinusoidally with time.

Nowadays, stand-alone sweepers are rare, but a sweeper is incorporated in most modern spectrum and network analysers. This design covers 0-200MHz, or any desired narrower sweep within this range. It provides an output level of +3dBm±1dB into 50Ω, with very low harmonic and spurious content.

An external attenuator may be used to reduce the level as required. Sweep speeds of 25ms for the full 200MHz sweep, down to 250s, are provided. Faster speeds are suitable for use with a basic oscilloscope, while slower speeds are provided for use with a digital storage oscilloscope.

Additionally, the sweep may be turned off. The unit may then be used to provide a cw output. Alternatively, an external audio input up to 15kHz may be connected to provide fm output. Maximum deviation available is the full 200MHz, and as the external input is dc coupled, the unit may be used as a 0-200MHz vco in a phase locked loop.

Sweeper details

A sweeper is basically a beat frequency oscillator, bfo, comprising a fixed frequency oscillator, ffo, a mixer and a voltage-controlled oscillator, vco.

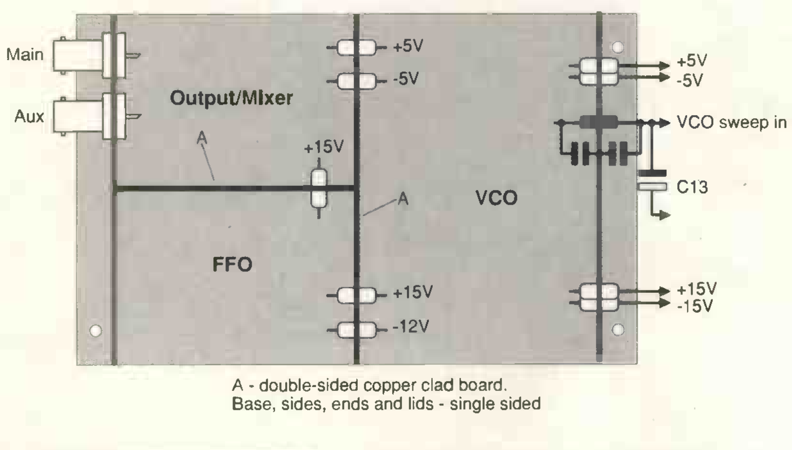
The vco can be swept from the same frequency as the ffo to some higher maximum frequency. Outputs of both oscillators connect to the mixer. Mixer output, suitably low-pass filtered and amplified, forms the sweeper output.

In addition to covering the full range 0Hz to $f_{vco(max)}-f_{ffo}$, arrangements are always included to permit the output to sweep as small a range as desired, centred anywhere within the full range.

Implementing a sweeper is greatly simplified if extensive use is made of rf ics, as opposed to discretes. Associated low-frequency circuitry, sweep generator, linearisation etc. will use ICs anyhow – the universal quad op-amp being the obvious choice.

I was prompted to develop this instrument by the appearance of the Analog Devices *AD831* low distortion mixer. Being an active mixer, it has the advantage that conversion gain can be set to any desired figure. The usual value is 0dB, compared with the typical 6.5dB conversion loss of a passive Schottky diode ring mixer.

The data sheet for this active mixer, housed in a 20 lead plastic leaded chip carrier, claims a 500MHz bandwidth for both the rf and local oscillator ports. Some of the graphs show typical performance extending to 600MHz. Knowing that the larger more reputable IC manufacturers tend to give conservative fig-



A - double-sided copper clad board.
Base, sides, ends and lids - single sided

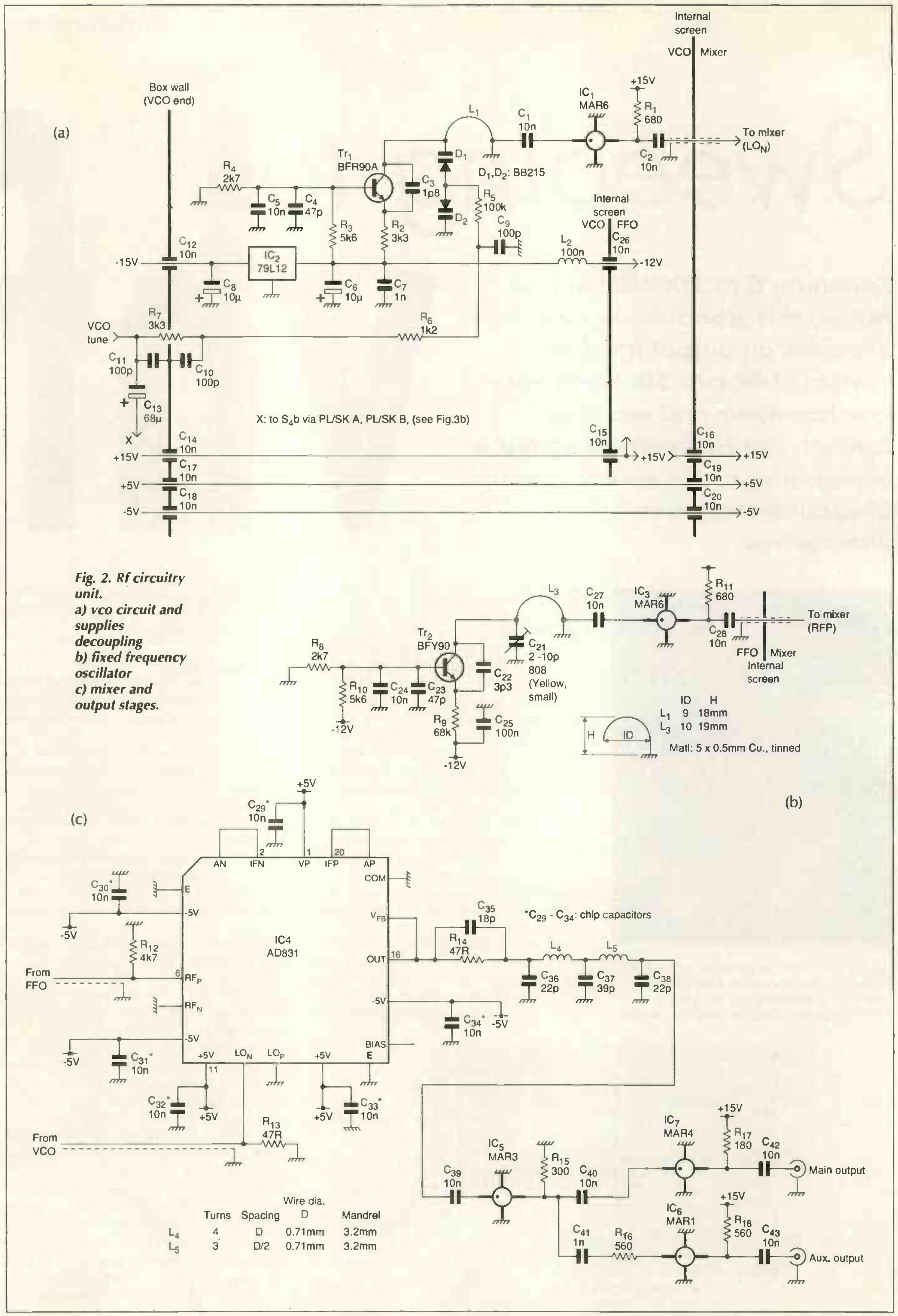


Fig. 2. Rf circuitry unit.
a) vco circuit and supplies decoupling
b) fixed frequency oscillator
c) mixer and output stages.

ures in their data sheets, I decided to aim at a design providing an output frequency range covering 0-200MHz. For reasons explained later, this implies a fixed-frequency oscillator at just over 400MHz and a vco covering from there up to just over 600MHz.

Rf criteria

As the rf section was clearly going to be the most tricky, design and construction of this section was tackled first. A fully screened construction was obviously essential, so I initially considered a die-cast box. However, I soon abandoned the idea since three separate and completely screened internal compartments were required for the two oscillators and the mixer/output. Partitions are not easily implemented in a die-cast box.

For the prototype, a enclosure was fabricated out of copper-clad pcb. Single sided was used for the base, four sides and three lids, while double sided board formed the internal partitions, **Fig. 1**.

Each lid sits just below the top of its compartment, supported on stops soldered to the compartment wall. With its copper side uppermost, when the rf unit is complete, each lid is soldered to the walls of its compartment. I recommend that you tack it at one central point only on each of its four sides, as you are sure to want to remove it again sometime.

Enclosure seams, by contrast, are soldered along their whole length. For ease of access, initially, just the base, sides and central partition were assembled. The short partition and ends were fitted only when the three sections were all basically functional, the lids only when final testing was complete.

This approach illustrates one of the differences between general analogue circuit design and rf design, which tends to be overlooked by the newcomer to rf. At rf, mechanical design has to be considered before the circuit is worked out in detail

VCO details

The vco was designed first, accommodated in the largest of the three compartments. It, and the remaining rf circuitry, are shown in **Fig. 2**. In my prototype, the vco used the same inductor as the fixed-frequency oscillator. As a result, it covers the required tuning range, but with not much to spare at the top end. The bottom end however extended down to around 300MHz – hence the different vco inductor specification shown in the diagram.

Output from each oscillator was taken from a tap near the earthy end of the inductor, to ensure low loading on the oscillator. This does not significantly affect its operating Q, which, especially in the case of the vco, is much lower than I would like.

Outputs are amplified to about –10dBm, and connect to the mixer via miniature 50Ω coaxial cable. Each cable is taken into the mixer compartment under a notch in the intervening partition. At this point, the outer sleeve was locally stripped, and the coax screen soldered to the partition.

Similarly, to prevent leakage of rf energy from one compartment to another, power rails are taken through 10nF feed-through capacitors. These are also used to bring the supplies into the vco end of the rf unit. But a different arrangement – shown in Fig. 2 – is needed to bring in the vco tuning voltage.

Drive from the vco is applied to the local-oscillator input. In the *AD831*, this input feeds an internal limiting amplifier before being applied to the mixer cell. This results in the mixer performance being unaffected by variations in the level of local-oscillator drive as the vco sweeps across the band.

Since the rf port is a linear input, the waveform of the mixer if output reflects that of the rf input. The fixed-frequency oscillator is designed for low output harmonics. The following amplifier also operates way below the 1dB compression point. As a result, the mixer intermediate frequency output also exhibits a low harmonic content. An *MAR4* IC, with its +11dBm, 1dB compression point, ensures that at the sweeper's modest +3dBm output, the harmonic content remains low.

Extensive use is made of convenient and reasonably priced 'Mini-Circuits' rf amplifier ICs, available from various distributors. In addition to the *MAR4* providing the main +3dBm output, an *MAR1* provides a –13dBm auxiliary output. This is well buffered from the main output and can be used to drive a frequency meter.

Low-frequency circuitry

Compared to the rf section, the sweeper's low frequency circuitry is not critical. In the case of the prototype it was all accommodated on a stripboard. This was supported horizontally on brackets at the rear of the case, above the mains transformer and the rf unit.

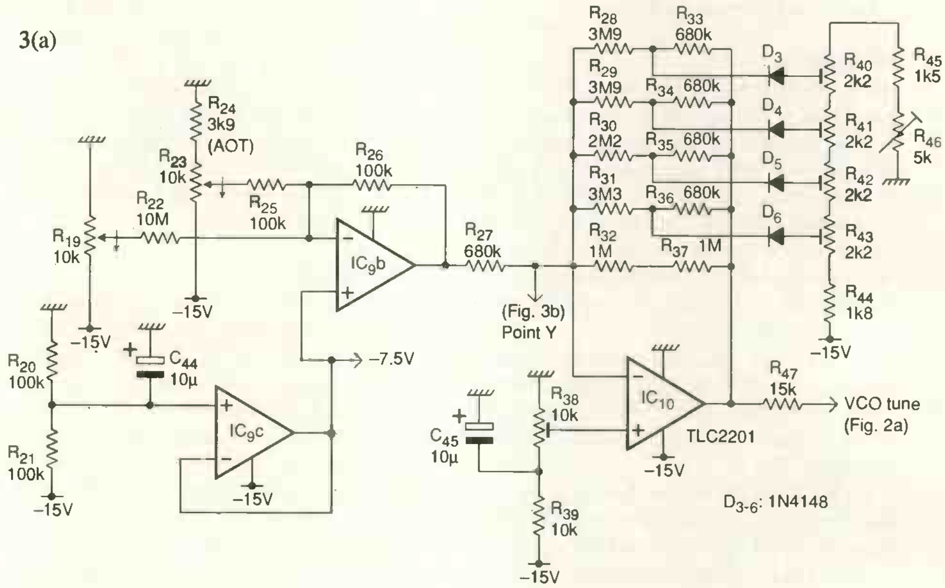
Connections between this board and the rf unit were made via an 8-way 0.1in pitch Molex plug and socket. These were mounted at the left rear of the stripboard, above the rf unit.

In front of the 8-way connector, a 15-way Molex plug and socket provided all the necessary connections to the front panel controls and the 'bnc ext' fm input and 'trigger' output sockets. The whole instrument was mounted in a case 305×159×133mm high.

The suite of stabilised supplies were mounted at the right hand side of the stripboard, above the 20V+20V 25VA mains transformer.

Figure 3a) shows the centre frequency setting circuitry IC_{9B}, with 10kΩ coarse and fine

3(a)



3(b)

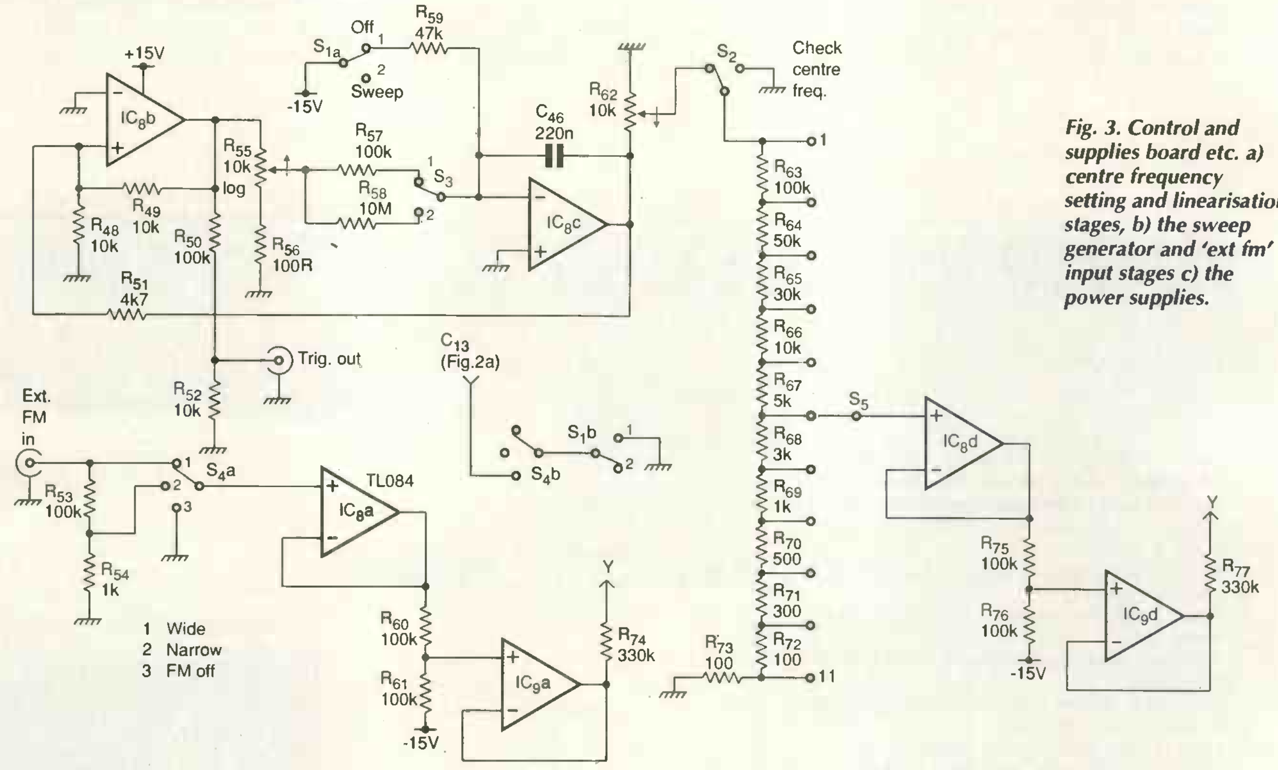
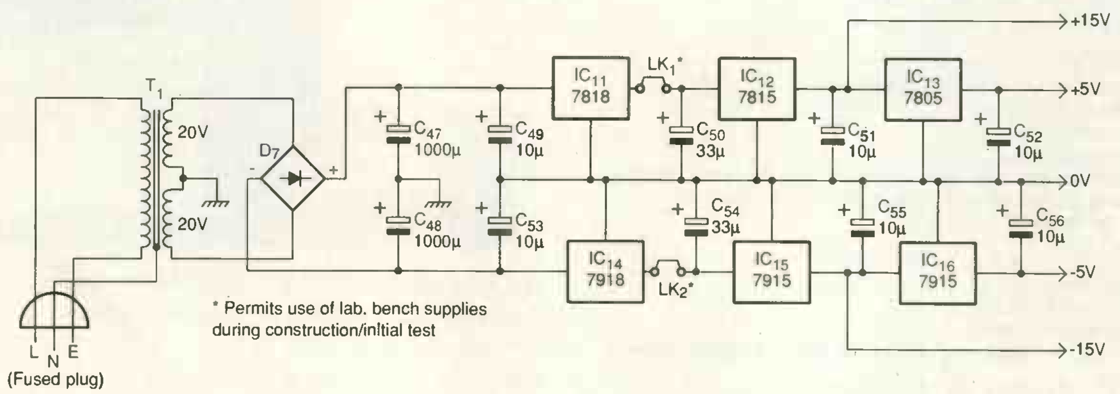


Fig. 3. Control and supplies board etc. a) centre frequency setting and linearisation stages, b) the sweep generator and 'ext fm' input stages c) the power supplies.

3(c)



controls, together with the vco drive amplifier IC_{10}. A *TLC2201* was chosen for IC_{10}, since its cmos output stage can swing to within millivolts of either rail. This allows the vco to be tuned up to a top frequency just in excess of 600MHz.

For ease of adjustment, both the 10kΩ potentiometers were ten-turn types. A select-on-test resistor R_{24} was fitted at the earthy end of the coarse tuning control R_{23}. Its tuning range – in cw mode with sweep disabled – was limited to just below 0Hz, in fact about –10MHz.

Note that both IC_9 and IC_{10} operate between 0V and –15V rails. This ensures that the varactor diodes in the vco can never become forward biased. IC_{10} incorporates a linearisation network around its feedback resistor.

Figure **3b)** shows remaining control circuitry. Principally, this comprises the sweep generator IC_{8B} and *c* – operating on +15 and –15V rails – sweep-width buffer IC_{8D} and level translator IC_{9D}.

The sweep generator produces a triangular voltage, not a sawtoooth. Note also that the highest vco frequency results when the tuning voltage is at –15V and that IC_{10} is inverting. Consequently, when displaying the discriminator characteristic of an fm receiver on an oscilloscope for example, the oscilloscope should be triggered at the start of the positive-going half of the triangular waveform.

Signal selection and i/o

A suitable timebase speed should be selected to display the whole of the frequency sweep. With the values shown in Figure3b), the wiper of sweep speed variable control, R_{55}, at the top of its travel and sweep speed switch S_3 in position 1, the sweep time is about 25ms. Thus a sweep speed of 2ms/division, adjusted to 2.5/div with the oscilloscope's timebase speed *VAR* control, will be suitable.

Alternatively, a front panel output socket can provide a suitably scaled version of the sweep voltage from IC_{8C}, for application to the oscilloscope's X input, in XY mode. Progressively slower sweep speeds may be set by means of R_{55}. Position 2 of S_3 provides sweep speeds slower by a factor of 100, for use with digital storage oscilloscopes in 'roll' mode.

A buffer and level translator are provided for the 'ext fm' input, IC_{8A} and IC_{9A}. Figure **3c)** shows the power supplies, which uses *78/79XX* series IC regulators, fitted with heatsinks.

Non-linear ramp for a linear output

A linear sweep voltage or ramp is produced by the sweep generator, but applied directly to the vco this will not result in a linear frequency sweep. The sweep linearisation network around IC_{10} shapes the ramp into a non-linear form which is the inverse of the vco tuning voltage/frequency characteristic, resulting in a linear frequency sweep.

Necessary adjustments to the linearisation are most conveniently made while displaying the full 0-200MHz sweep, with the aid of 10MHz 'birdie' markers. These can be produced by feeding the output of the sweeper to one input of a passive schottky diode double balanced mixer, and narrow 10MHz spikes to the other.

Mixer output is then displayed on an oscilloscope. I tried this arrangement, but it proved unsuccessful, partly due to the poor risetime of the 10MHz squarewave obtained from a 10Hz-10MHz video generator. But even below 100MHz, where birdie markers were obtained, their amplitude was very small.

In principle, the linearisation network could be set up without the sweep, using the centre frequency setting control R_{23}. But in practice this proves impossibly cumbersome. So I set up a special harmonic mixer, **Fig. 4**. This used the 10MHz squarewave already mentioned, but with its edges sharpened up by a test circuit that I had used previously[1].

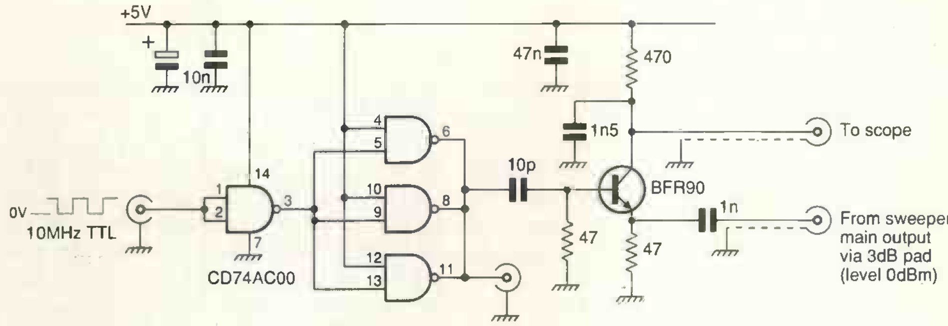


Fig. 4. Harmonic mixer used to provide birdie markers, to facilitate the adjustment of the frequency sweep linearisation.

Checking the sweep

Figure 5a) shows output of the harmonic mixer, lower trace, during a positive-going varactor tuning voltage sweep, upper trace, corresponding to a falling frequency sweep. The sweep extends from 10MHz to –80MHz, i.e. to the point where the vco frequency is 80MHz below the fixed-oscillator frequency.

Note the absence of a birdie marker at 0Hz. This photograph was taken before fitting any linearisation around IC_{10}, and the decreasing tuning sensitivity with increasing frequency is clearly visible.

In the design stage of the sweep circuitry I felt that five breakpoints should be ample to achieve an acceptable degree of linearisation. Provision for these were made in the circuit of Fig. 3a). When it came to setting up the linearisation, never one to use two resistors where one will do, I tried the effect of using just three of the breakpoints. Adequate linearity was not achievable, but the addition of a fourth breakpoint as in Fig. 3a) achieved a good degree of linearity, Fig. **5b)**. This shows the vco tuning voltage, top trace, and the output of the harmonic mixer, bottom trace, showing birdie markers at 10MHz intervals from 0Hz-200MHz.

As viewed on the oscilloscope, the fit is not quite perfect, though this does not show too clearly in the diagram.

However, as the trace is expanded from the 20MHz/div shown, by means of coarse sweep width control S_5 to say 1MHz/div, any deviation from perfect linearity becomes more noticeable. For this, fine sweep width R_{62} is wound fully clockwise.

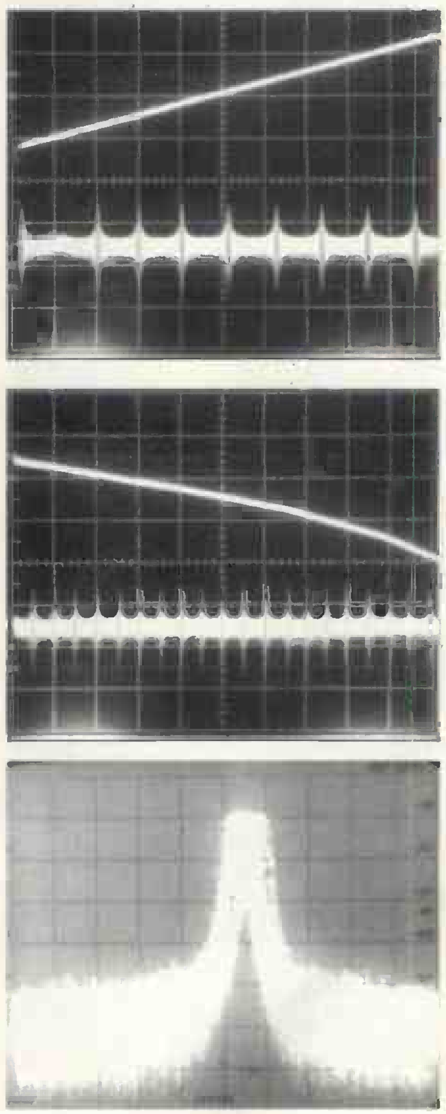


Fig. 5a) Sweep voltage (upper trace) and birdie markers output from the harmonic mixer (lower trace) as frequency sweeps from 10MHz through zero to –80MHz. 5b) Linearised sweep from 0 to 200MHz. 5c) Output in 'cw' mode, ref.level +10dBm, 10dB/div. vertical, centre frequency 100MHz, 5kHz/div. horizontal, I.F. bandwidth 1kHz.

It is therefore worthwhile taking the extra trouble to use all five breakpoints. Resistors $R_{40\text{-}43}$ set positions of the individual breakpoints, while R_{46} permits adjustment of where the first breakpoint occurs. Resistors $R_{28\text{-}31}$ set the strength of each breakpoint. These were 5MΩ potentiometers during the setting up, being replaced with the nearest E12 values when linearity had been achieved. A final tweaking of the positions of the breakpoints was then carried out.

Owing to the non-linear gain of IC_{10}, following linearisation, if its non-inverting input were returned to –7.5V, its output would swing further in the negative-going direction than in the positive when a sweep voltage was applied. To counter this, it is returned to a somewhat lower voltage, set by R_{28}. Whatever sweep setting is selected, the sweep may be turned momentarily by means of the check centre frequency switch S_2 – a biased toggle.

Again, due to the non-linearity of IC_{10}, the 'centre frequency' does not correspond to midscreen on the oscilloscope display, but to a point about two divisions to the right of this. As the sweep width is reduced, the display will expand off each side of the screen, points to the right of 'centre frequency' moving to the right, points to the left moving leftwards.

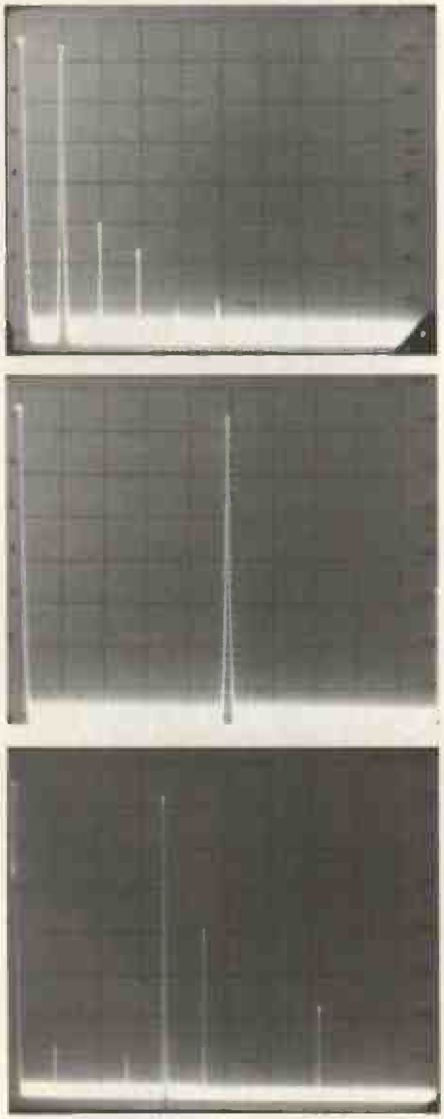


Fig. 6a) Showing the sweeper main output, in CW mode, set to 20MHz. Note the low level of the second and third harmonics. (Span 0-200MHz, ref.level +10dBm, 10dB/div. vertical.), b) As a), but output set to 98MHz. c) Main output at 180MHz, showing spurious responses ,see text. Settings as a) except span 0-500MHz.

Switching functions

Switch S_1 provides a choice of sweep on – position 2 – or sweep off, and serves two purposes. In the off position, C_{13} is switched into circuit, preventing any ac noise on the vco tune line reaching the varactor – provided 'ext fm In' is set to off at S_4. This reduces linewidth of the rf output substantially, Fig. **5c)**.

Towards the end of the six seconds exposure required by the oscilloscope camera the frequency starts to wander up by a few kilohertz. Apart from this it can be seen that the linewidth is not greatly in excess of the analyser's 1kHz intermediate-frequency bandwidth, although noise 'shoulders' appear at only some 40dB below the output. For this, a centre frequency of 100MHz, 5kHz/div horizontal with a reference level of +10dBm, 10dB/div vertical were used.

Broadband noise floor is about –70dB, compare Fig. **5c)** with Fig. **8a)**, which covers a 1MHz span, as against a 50kHz span.

Note that to use cw mode, it is necessary to set 'fine display width' R_{62} to minimum and S_5 to position 11. This is because in the 'sweep-off' position, S_1 causes IC_{8C}'s output to rise to +15V, which would set the vco to maximum frequency.

The other use for S_1 is when using a dso in 'roll' mode as the display. Setting S_1 to 'sweep off', i.e. cw mode, sets the vco to maximum frequency and the trigger-out level positive. The digital storage oscilloscope may now be set to 'roll' mode, with positive triggering.

On returning S_1 to the sweep position, output will sweep down to minimum frequency and then back up to maximum. At this point the trigger output goes positive again, halting the dso acquisition. If a suitable sweep speed was selected with R_{55} and S_3, to match the dso's time/div in 'roll' mode, the screen will display the result of one complete frequency sweep from minimum to maximum.

The linewidth or close-in noise of the instrument is much worse than that of a signal generator, but this is normally the case with sweepers, or any other bfo type instrument. In other respects, performance is very good.

Performance at rf

Figure 6a) shows output at 20MHz with a span of 0-200MHz, ref.level +10dBm, 10dB/div. From this, you can see that the second-harmonic is over 40dB down and the third-harmonic nearly 50dB down on the output, which is around +3dBm. Even at 100MHz, Fig. **6b)**, second-harmonic is nearly 40dB down, while higher harmonics are of course out of band. Level flatness of the main output is within ±1dB over 2-200MHz.

These photographs were actually taken with the unit in 'cw' mode, but the harmonic performance is of course identical in sweep mode.

Another important criterion of any signal generator, including sweepers, is the level of spurious outputs. These are an unfortunate fact of life, wherever two or more oscillators and a mixer are involved. They can be explained with the aid of Fig. **6c)**, which covers 0-500MHz, ref. level +10dBm, 10dB/div. vertically.

Output at 180MHz is the main output at a level of +3dBm nominal. The output at 360MHz is its second-harmonic, which is still considerable, despite being in the stopband of the post mixer low-pass filter. The three other outputs are spurious responses, or spurii.

To simplify the explanation, assume the fixed oscillator is at 400MHz, so that its second harmonic is at 800MHz. To produce a 0-200MHz output, the vco must cover 400-600MHz. As the vco frequency approaches 600MHz, it will beat with the second harmonic of the fixed oscillator. This beat frequency falls to 200MHz as the vfo frequency reaches 600MHz.

This is a 'two/one' response, i.e. twice the fixed-oscillator frequency, ffo, minus the vco frequency. The other two/one response, 2×vco–ffo is out of band at all times. For this reason, the fixed frequency is set very slightly higher than 400MHz. In the prototype, measurement showed it to be 406.6MHz.

With the aid of a frequency meter and spectrum analyser, this is easily deduced from the measured frequency f_x of the wanted output. Here, it coincides with the two/one response so vco–ffo and 2×ffo–vco both equal f_x. This means that the two/one response never goes below 206.6MHz, i.e. it remains out of band at all times.

The two smallest outputs are higher order spurious responses; fortunately such responses get smaller the higher the order. The output at 133.4MHz is a three/four response, as can be deduced from the fact that it moves 30MHz for every 10MHz that the wanted output moves. As a result, it must involve the third harmonic of the vco.

Given the main output is 180MHz , the third harmonic of the vco will be 3(180+406.6), which is 1759.8MHz. The fourth harmonic of the fixed oscillator is 1626.4MHz, so the 133.4MHz output – which is over 60dB below the main output – is the 3×vco–4×ffo response. As the main output is tuned up or down, this spurious response moves in the same direction. Eventually, as the frequency is reduced, it disappears out of band below 0Hz, never to return.

The other spurious response, at 46.6MHz, moves at twice the rate of the main output,

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

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

K1100 AUDIO DESIGN 80 WATT POWER AMPLIFIER.

This fantastic John Linsley Hood designed amplifier is the flagship of our range, and the ideal powerhouse for your ultimate hifi system. This kit is your way to get uK performance at bargain basement prices. Unique design features such as fully FET stabilised power supplies give this amplifier World Class performance with startling clarity and transparency of sound, allied to the famous HART quality of components and ease of construction.
Useful options are a stereo LED power meter and a versatile passive front end giving switched inputs, with ALPS precision Blue Velvet low-noise volume and balance controls. Construction is very simple and enjoyable with all the difficult work done for you, even the wiring is preterminated, ready for instant use!. All versions are available with Standard components or specially selected Super Audiophile components at £29.60 extra per channel, plus ú2.40 if you want to include Gold Plated speaker terminals.

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

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

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

K2100 Complete Kit. £109.50
K2100SA Series Audiophile version with selected audiophile components. £112.46
A2100SA Series Audiophile version, factory Assembled. £149.46
K3565 "Andante" Power Supply Kit to suit "Chiara". £85.42
A3565 Power Supply, Factory Assembled. £128.42
CM2100 Construction Manual. £2.50
SPECIAL OFFER. Both units together, Kit Form. £184.92
Factory Assembled and Tested. £267.88

"Andante" SERIES 20VA AUDIOPHILE POWER SUPPLIES

Specially designed for exacting audio use requiring absolute minimum noise, low hum field and total freedom from mechanical noise this unit is a logical development from our highly successful 1550 series.
Utilising linear technology throughout for smoothness and musicality makes it the perfect partner for any module requiring fully stabilised ±15v supplies.
Two versions are available. K3550 has 2 ±15v supplies and a single 15v for relays etc. and can be used with our K1400 preamp and our K1450 RIAA pickup preamp, as well as other useful modules soon to be introduced. The K3565 is identical in appearance but only has the ±15v lighter current supply for use with the K1450 RIAA pickup pre amplifier or "Chiara" headphone amplifier.

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

ALPS *"Blue Velvet"* PRECISION AUDIO CONTROLS.

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

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

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

TECHNICAL BOOKSHELF

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

"THE ART OF LINEAR ELECTRONICS."

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

"DIGITAL AUDIO AND COMPACT DISC TECHNOLOGY" 0-7506-0614-2 .... £17.95*
INTRODUCING DIGITAL AUDIO CD, DAT AND SAMPLING. ISBN 1870775 22 8 .... £7.95
"THE ART OF SOLDERING" 0-85935-324-3. 0 .... £3.95
"TOWERS' INTERNATIONAL TRANSISTOR SELECTOR" 0-572-01062-1. .... £19.95*
"AUDIO" F.A.Wilson. BP111 .... £3.95
"HOW TO USE OSCILLOSCOPES & OTHER TEST EQUIPMENT" R.A.Penfold. BP267. .... £3.50
"THE LOUDSPEAKER DESIGN COOKBOOK" Vance Dickason. (4th Edn.) 0-9624-191-7-6 .... £22.95*
ELECTROSTATIC LOUDSPEAKER DESIGN AND CONSTRUCTION Ronald Wagner BKT6 .... £18.95
"AN INTRODUCTION TO LOUDSPEAKERS & ENCLOSURE DESIGN" V. Capel. BP256 .... £2.95
"LOUDSPEAKERS FOR MUSICIANS" BP297 .... £3.95
"THE HART PRINTED CIRCUIT BOARD CONSTRUCTION GUIDE." £2.50

VALVE & EARLY CLASSIC BOOKS

THE VTL BOOK David Manley BKVT1 .... £17.95
LOUDSPEAKERS; THE WHY AND HOW OF GOOD REPRODUCTION. G.Briggs. 1949 0-9624-1913-3. .... £8.95
MULLARD TUBE CIRCUITS FOR AUDIO AMPLIFIERS BKAA27 .... £13.95
"THE WILLIAMSON AMPLIFIER." 0-9624-1918-4. .... £6.95
AN APPROACH TO AUDIO FREQUENCY AMPLIFIER DESIGN. GEC 1957, 1-882580-05-2 .... £18.95
AUDIO ANTHOLOGIES, articles from Audio Engineering. Six voumes covering the days when audio wasyoung and valves were king!. BKAA3/1 to 6. All .... £13.95 each.
"A SIMPLE CLASS A AMPLIFIER" J.L.Linsley Hood M.I.E.E. 1969. RLH12. .... £2.50

Postage on all books, unless starred, is only ú1.50 per book, maximum ú4.50 for any number, any size!. Starred items are heavy books costing .... £2.50 to send.
No waiting!. All listed books are normally in stock!.
SPECIAL OFFER. All book orders over £15 will receive a **FREE** John Linsley Hood monograph entitled "Digital versus Analogue, Black Disks or Silver?"

SPECIAL OFFER
PRECISION Triple Purpose TEST CASSETTE TC1D.

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

HC80 Replacement Stereo Cassette Head.

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

SOLDERING

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

HART SUPER AUDIOGRADE SILVER SOLDER.

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

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

QUALITY AUDIO KITS | 24 hr. SALES LINE (01691) 652894 | ALL PRICES INCLUDE UK/EC VAT

HART ELECTRONIC KITS LTD.
1 PENYLAN MILL
OSWESTRY, SHROPSHIRE
SY10 3AF

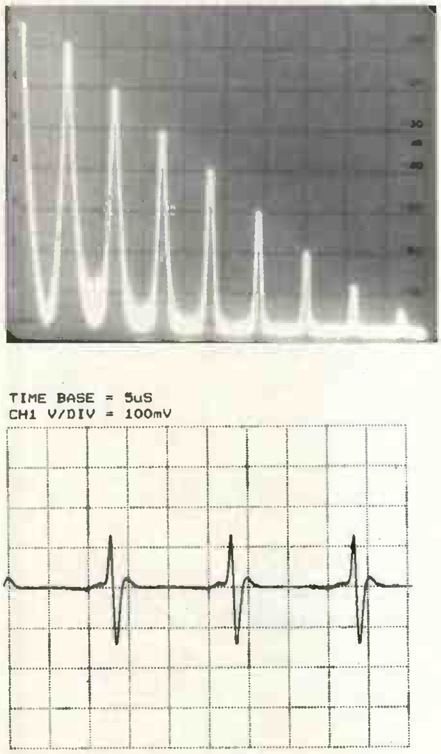


Fig. 7a). Main output of the sweeper in 'cw' mode, set to 600kHz. ref. level +10dBm, 10dB/div., span 0-5MHz. b) Waveform of the main output of the sweeper in 'cw' mode, set to 65kHz. The two oscillators run at the same frequency except when slipping a cycle every 16μs.

and in the opposite direction. Similar reasoning to the above identifies it as a two/three response, namely 3×ffo–2×vco. Since it travels in the opposite direction from the main output, their frequencies can coincide: this happens at a frequency of 135MHz.

A spurious output that can occur very close to an expected response can be most embarrassing, but fortunately its level is around 60dB down on the main output.

Low-frequency performance

Another criterion of a good sweeper is how low a frequency it can be tuned to before the two oscillators begin to affect each other, eventually locking up to the same frequency. **Figure 7a)** shows the main output set to 600kHz with a reference level of +10dBm, 10dB/div vertical scaling and a span of 0 to 5MHz.

Note the numerous harmonics, the second being only 10dB below the main output. This is due to the two oscillators affecting each other, as a result of the inadequate isolation between them.

One oscillator tends to keep in step with the other until the disturbance from its undisturbed phase becomes excessive, when it suddenly slips a cycle. This is shown in the time domain in Fig. **7b)**, where the frequency has been reduced still further to about 65kHz. At this frequency the power in the fundamental was greatly reduced, and a host of harmonics up to very high orders present. Forgetting the frequency for the moment, electronic organ buffs will recognise the waveform as similar to that of a trumpet stop. Any attempt to tune the two oscillators closer together simply resulted in their locking up to the same frequency.

Figure 7 results were taken during the development of the rf unit, before all of the screening was fitted. In the finished instrument, lock-up did not occur until the offset was below 25kHz, or a mere 125 parts per million of the frequency of the two oscillators. This attests to the efficacy of the screening arrangements, the rf to local-oscillator port isolation of the *AD831* mixer and the reverse isolation of the *MARx* series amplifiers. As a result, the sweeper is usable down to 1MHz, even at 500kHz, the harmonics are still over 25dB down, though the output level has fallen to just over 0dBm, due to the size of the various coupling capacitors.

Modulating the sweep

Figure 8a) is an example of the sweeper output when used in the external fm input mode with the fm input switch set to 'narrow'. The centre frequency is 100MHz and the horizontal scale 100kHz /div. Reference level and vertical scale are +10dBm and 10dB/div, as usual. It shows the output frequency modulated at 1.5kHz with a peak deviation of ±75kHz, the maximum deviation in the broadcast fm standard.

Individual fm sidebands are visible but blurred. This is due to the lack of an exact relationship between modulating frequency, maximum deviation and sweep repetition frequency of the spectrum analyser, over the exposure time required by the oscilloscope camera.

Figure **8b)** is another example of the instrument in use, this time in 'sweep' mode. The top trace shows the discriminator output of a portable transistor radio – an *ITT KB Junior Super* am/fm model dating from the 1970s. The oscilloscope settings were 0.2V/div and 2ms/div. The sweeper was set to sweep 3MHz during 20ms. No direct connection between the set and the sweeper was necessary, stray pick-up sufficing.

Resultant output is shown on the upper trace. The discriminator characteristic is about the width one would expect for a mono receiver, but the peaks are slightly asymmetrical and the central portion of the characteristic is not quite a linear as it might be – clearly after so many years, the set is in need of realignment. The lower trace shows the effect of excessive sweep speed.

The fm broadcast standard allows for a ±75kHz deviation at a maximum modulating frequency of 15kHz, and this corresponds to a maximum rate of change of frequency of 7139Hz/μs.

In the lower trace of Fig. b), the 3MHz sweep width has been increased to 75MHz, and the oscilloscope timebase speed to 200μs/div. The rate of change of frequency is now over 9.3kHz/μs, or over ten times the maximum specified rate. The result is that the discriminator output is grossly distorted and reduced in amplitude. This demonstrates that when using a sweeper, the sweep rate selected must be appropriate to the bandwidth of the circuit under test.

There are many other uses for a sweeper. Used with a return loss bridge, for example, it performs much the same job as a scalar network analyser. I hope to be exploring some of these in a future article. ■

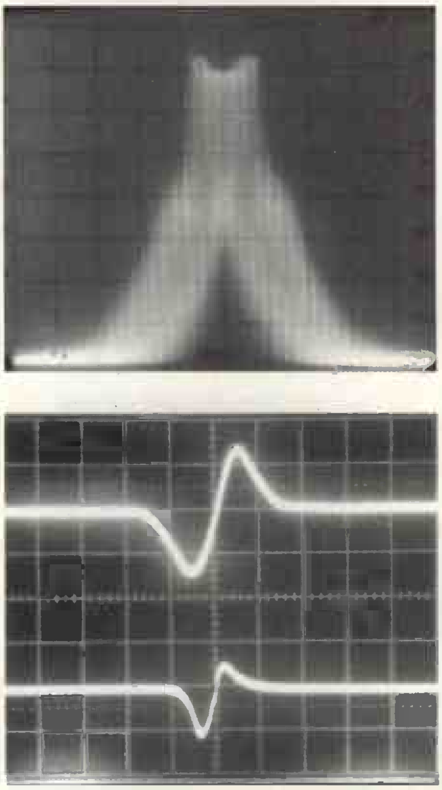


Fig. 8a) Main output of the sweeper in fm mode, showing modulation at 1.5kHz with a peak deviation of 75kHz. ref. level +10dBm, 10dB/div., centre frequency 100MHz, 100kHz/div. b) Output of the discriminator circuit of a transistor radio, upper trace (0.2V/div., 2ms/div.) with a suitable sweep rate. Distorted output, lower trace, when sweep speed is excessive (0.2V/div., 200μs/div.)

Reference

1. Hickman, I, 'CFBOs, delivering speed at any gain?', *EW+WW* Jan. 1993, pp 78-80, reproduced in the 'Analog Circuits Cookbook', Butterworth-Heinemann 1995, ISBN 0 7506 2002 1.

831

Probing *for switching losses*

Current probes can be expensive. Developed for analysing switching losses in power mosfets, this alternative solution, designed by A Durrant and G Whitfield, costs next to nothing.

A R Durrant Bsc is with the School of Science, Engineering & Computing, Reading College of Arts and Technology and Dr G R Whitfield is at the Dept of Cybernetics, University of Reading.

Here we will show that is possible to design an ac current probe small enough to fit around the leg of a power mosfet at very low cost. Our design has the advantage that the layout of the circuit under test is not disrupted when the probe is inserted.

Defining the problem

Power supply designers are forever under pressure to increase efficiency. There are many types of losses associated with switched mode power supplies. When dealing with voltages in the order of 200V, switching losses in mosfets are a major source of dissipation. Designers find that any successful technique for speeding up switching edges should be incorporated into their designs. Circuit layout is particularly important in order to minimise series inductance. Poor layout can cause dangerous voltage spikes.

The unit we developed achieves 20ns edges when switching 200V. Plots in **Fig. 1**, show the similarity between a measurement made with a *Tektronix P6021* probe, and the low cost alternative outlined here. Peak current is in the order of 16.5A. This speed was achieved by very careful layout together with a low-impedance drive circuit.

To measure switching losses it was necessary to insert an ac current probe in series with one of the switching transistors. The only way to do this was to lift the drain connection to the pcb, and add 5cm of wire to accommodate the *Tektronix* probe. Unfortunately extra inductance caused by the wire produced large voltage spikes on the drain of the transistor. Had the supply voltage been turned up to 200V, it would almost certainly have destroyed the transistor.

A probing solution

I decided to make the current probe small enough to fit around the leg of the transistor so as not to disturb the layout. This allowed a comparison to be made between the probe and its *Tektronix* counterpart to ensure that it was performing correctly.

The initial design, **Figs 2, 3**, used a toroidal ferrite core with an outside diameter of 13mm, an inside diameter of 6mm, and a thickness of 3.5mm, wound with 25 turns. The transistor leg passes through the centre of the core.

Clearly it was important that proper impedance matching was considered. Two metres of 50Ω coax was used which was terminated with 50Ω at each end. At the oscilloscope end, a simple 50Ω termination was used, while at the toroidal core end, two 100Ω resistors were soldered close to the core.

Current passing through the transistor leg is divided by 25 due to the turns ratio and applied across 25Ω – 50Ω at the current probe

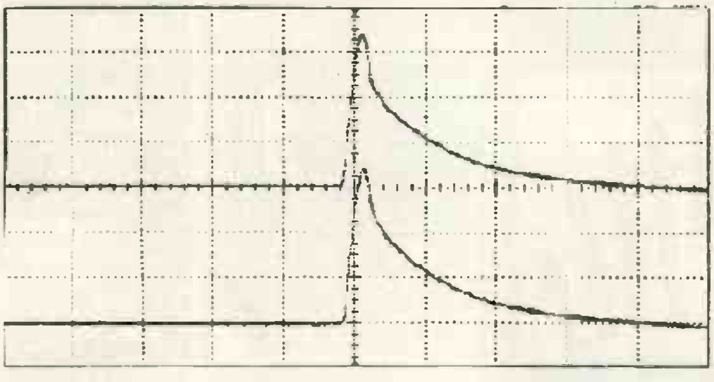


Fig. 1. (left) Comparison between measurements made via Tektronix P6021, top trace, and the low-cost alternative, bottom trace, show little difference in performance with scaling at 100ns/cm versus 5A/cm.

Fig. 2. Winding the toroid as prescribed and placing the semiconductor leg through it results in a 1:25 transformer which, in parallel with the 50Ω resistor, feeds the coaxial cable to the oscilloscope.

end, in parallel with the 50Ω line impedance. Therefore a current of 1A passing through the transistor leg would develop a voltage of 1V at the oscilloscope input. In order to minimise inter-winding capacitance, the 25 turns are wound in one layer.

Characteristics of the toroidal core used were relatively unimportant. Calculations were done to ensure the probe would not saturate. The probe would be unlikely to be subjected to more than 50A, and the switching time would not be greater than 100ns. Since 1A passing through the probe would develop 1V on the secondary winding, then the same could be said for 50A. The peak flux density may be calculated.

$$E = N\frac{d\phi}{dt} = NA\frac{dB}{dt} \therefore$$

$$dB = \frac{E.dt}{N.A} = \frac{50\times100\times10^{-9}}{25\times3.5\times3.5\times10^{-6}} = 16.3mT.$$

Clearly there was no chance of saturation.

Inductance of the secondary winding was 680mH. With 50V developed across the secondary winding, for 100ns, the magnetising current would be,

$$di = \frac{Vdt}{L} = \frac{50\times100\times10^{-9}}{680\times10^{-6}} = 7.3mA.$$

If a conservative 0.25T was used as a maximum before saturation took place, then the maximum volt-second product may be calculated,

$$E.dt = N.A.dB = 25\times3.5\times3.5\times10^{-6}\times0.25 = 76.5\mu Vs.$$

Since 1V output represents 1A measured then the maximum current second product that the probe could cope with is 76.5mAs.

Down sizing

A smaller version of the probe is even more useful where a very tight layout has been used. The probe shown in **Fig. 4** was made using 25 turns of 0.2mm wire wound on a 4mm core, namely a *Siemens B64290-A36x1*. Core dimensions are outside diameter 4mm, inside diameter 2.4mm, and height 1.6mm. The core has an A_l value of 13nH/N^2 and is made from K1 material, which is reasonably linear up to 0.25T.

Maximum current-second product is therefore 8mAs. Again the probe was unlikely to be subjected to more than 50A, so provided the edge of the waveform is less than 8mAs/50=160ns, then it would not saturate. Inductance of the secondary winding is 13nH×25^2=8.1mH, so the magnetising current when measuring 50A at 160ns would be 0.98A – about a 2% error in the measurement.

The probe was used to measure current spikes in a mosfet full bridge circuit, and in particular to investigate the effect of turning off the built-in diode within the mosfet. **Figure 5** shows the circuit arrangement. Duty cycle is arranged so that current in the load moves from left to right, such that when Tr_1 turns off, the output current is maintained by the built-in diode of Tr_3. When Tr_1 turns back on again, a large current spike appears in both Tr_1 and Tr_3 in an effort to turn off the built-in diode of Tr_3.

Figure 6a shows a large spike of current in Tr_1 and Fig. **6b** shows a similar current spike in Tr_3. Spikes in both transistors are similar in magnitude, indicating that the built-in diode requires considerable energy to turn off. With a load current and forward diode current of less than 1A, the built-in diode is causing a current to flow of some 16A. Large current spikes caused by the built-in diode can be destructive to mosfets[1]

Cost considerations

At the time of writing, the cost of a *P6021* current probe is £683. The cost of the home-made current probe is virtually zero. We do not suggested that this design equals the performance or convenience of the *Tektronix* probe – the *P6021* is rated at 500mAs. However we do suggest that if switching edges are to be examined, then a probe can be quickly and easily constructed to give accurate results for a negligible cost – without disrupting circuit layout. ■

Further reading

Pelly, BR, 'The do's and don'ts of using power Hexfets', International Rectifier, Application note 936A, 1983.

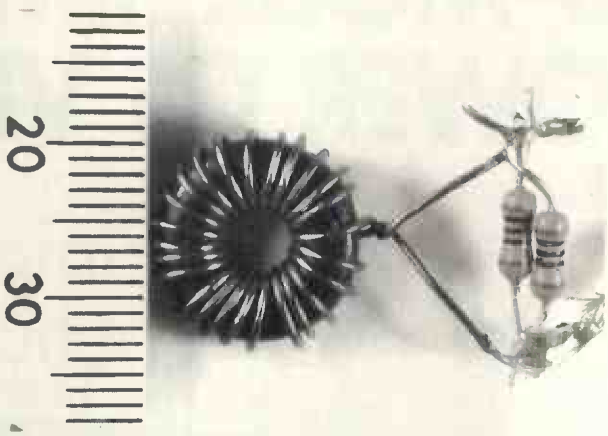


Fig. 3. Prototype probe functioned well, but was a bit on the large side for some applications.

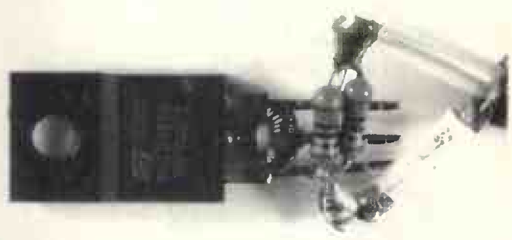


Fig. 4. Redesigning the arrangement using a 4mm core rendered the probe even less disruptive.

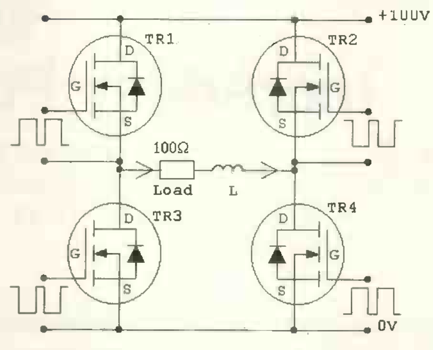
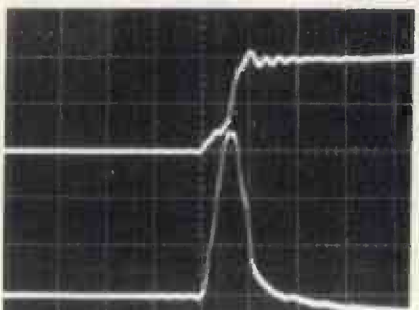
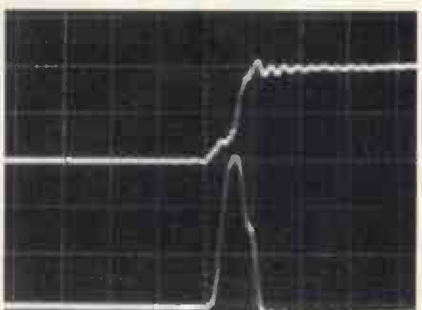


Fig. 5. Power mosfet switching circuit used to test performance of the probe. Duty cycle is arranged so that current in the load moves from left to right.

Fig. 6. In a) a large spike of current in Tr_1 of Fig. 5 is evident. Shot b) shows a similar spike in Tr_3.


(a)


(b)

834

Ultra-fast amplifier

Giovanni Stochino demonstrates new techniques for driving up the speed of high-performance 50Ω power amplifiers for precision test and measurement.

This work deals with maximising speed in voltage-feedback amplifier architectures. Nevertheless, most of the arguments and the techniques presented here also apply to current-feedback amplifiers.

When an amplifier is overdriven by a large signal pulse or square wave with a fast enough rise/fall time, the output is generally not capable of following the input immediately, **Fig. 1**. Output slews at a finite rate, determined by internal currents and capacitances. Note that amplifiers incorporating inductors are not considered in this discussion.

Slew-rate is a term used to designate the maximum rate of change of the output voltage V_o, formally written as,

$$SR = \frac{dV_o}{dt}\bigg|_{max} \qquad (1)$$

and expressed usually in volts-per-microsecond, i.e. V/μs.

Generally, the concept of slew rate limiting can be extended to all nodes of the amplifier. In this context, the maximum rate of change of the voltage V_n at the generic node n is given by,

$$SR(n) = \frac{dV_n}{dt}\bigg|_{max} = \frac{I_n}{C_n} \qquad (2)$$

where C_n is the equivalent total node capacitance to ground and I_n is the maximum positive or negative current available at the same node for charging or discharging C_n.

As shown in Fig. 1, positive $SR(+)$ and negative $SR(-)$ slew rates are usually different, mainly due to the fact that positive/negative currents available at the node are different.

It is important to stress that a non-linear phenomenon is being considered here. During slewing, the amplifier is overdriven at some point in its circuitry, therefore the output is unable to follow the input.

In Fig. 1, the sinusoidal signal superposed to the step input voltage is not present at the output during slewing times T_r and T_f. This phenomenon is the major cause of transient intermodulation distortion in audio amplifiers.

Slew rate and power bandwidth

Power bandwidth is defined as the maximum frequency at which full output swing – i.e. close to the supply rails – can be obtained without severe distortion.

Consider a sinusoidal voltage $V_0(t)$, which equals $V_p\sin(\omega t)$. The rate of change requested to the output is,

$$dV_0(t)/(dt)\big|_{max} = \omega V_p\cos(\omega t) \le 2\pi f V_p.$$

Knowing maximum slew rate of the amplifier, the highest frequency, f_{max}, or power bandwidth, that can be linearly reproduced at full swing can be calculated from,

$$f_{max}=SR/(2\pi V_p) \qquad (3)$$

Note that the above relationship between slew rate and power bandwidth applies only to the 'natural slew rate or naturally-enhanced slew rate' of amplifiers. This applies for frequencies where loop gain is sufficiently high and linear. 'Natural' in this instance implies use of linear operation.

Equation 3 is not valid for amplifiers where unnaturally high slew rates are achieved by forcing mechanisms based on non-linear operation. One example is shown in **Fig. 2**.

Transistors $Tr_{1\text{-}4}$ are connected to form a voltage follower. The natural slew rate is given by $NSR=I_A/C_A$. If I_A is 0.5mA and C_A is 10pF then NSR is 50V/μs. Capacitance C_A is the total equivalent node capacitance seen by sources I_A.

Transistors $Tr_{5,6}$ are incorporated to form a fast parallel path which bypasses $Tr_{1,2}$ when the follower is overdriven. Activated when $|V_{in}-V_{out}|\ge 2V_{be(on)}\approx 1.4$V, this parallel path produces forced large-signal slew rates, FSRs, up to 1000V/μs. Due to its high non-linear operation and associated poor high-frequency performance, it does not contribute as effectively as expected to extend linear power bandwidth in accordance with equation (3).

Response of the circuit to a square wave, assuming zero signal source resistance, is also qualitatively shown in Fig. 2. From point a to b and d to e, where $|V_{in}-V_{out}|\ge 1.4$V, the circuit responds with its forced slew rate. In all other parts, circuit response is controlled by its natural slew rate.

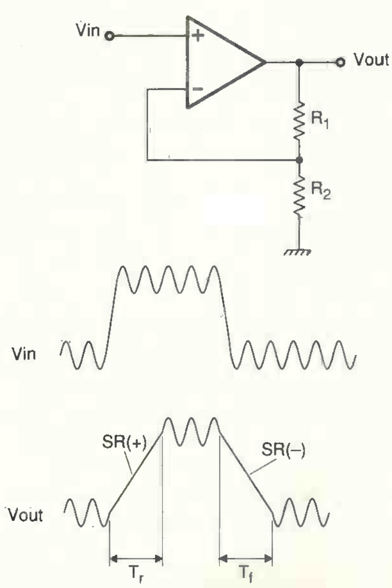
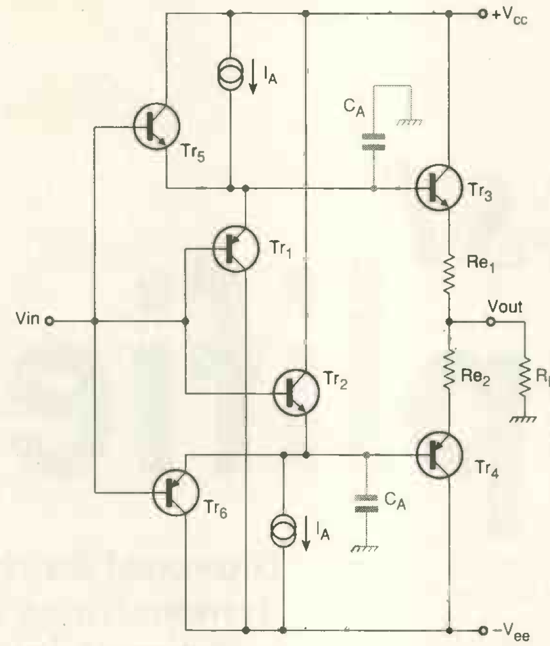


Fig. 1. The phenomenon of slew rate and transient intermodulation in a feedback amplifier.



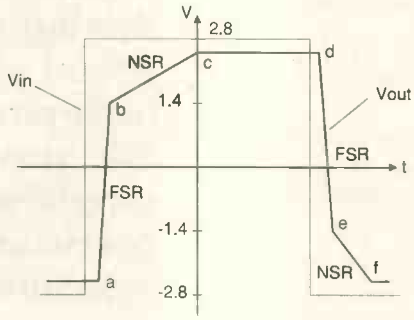


Fig. 2. Slew rate can be enhanced with non-linear mechanisms. Linear power bandwidth, however, is governed by natural slew rate.

Non-slewing amplifier performance results

With an ambient temperature of 28°C, a 50Ω load and $Tr_{14,16}$ connected to the 40V supply rails, the final fast power amplifier, Fig. 9, performed as follows.

- Supply current approximately ±45mA
- Input offset voltage* approximately 3.5mV
- Small signal –3dB bandwidth (G_o=15.7)≈5MHz.
- Overload recovery time ≤20ns for V_{in}≤12V_{pk}
- Harmonic distortion, bandwidth 80kHz:
  Thd ≤0.004%, f=2kHz, V_{out}≤50 $V_{(pk\text{-}pk)}$, G_o=15.7
  Thd ≤0.010%, f=20kHz, V_{out}≤50$V_{(pk\text{-}pk)}$, G_o=15.7
- Maximum achievable output rate of change†,
  a) ±400V/μs for G_o=15.7
  b) ±600V/μs for G_o=7
  c) ±1000V/μs with 1μF or more across R.

* With un-matched transistors and resistors.
† Slew rate is mainly limited by available voltage level of the signal source, about 12V_{pk}. The technique used in case c), useful to 'unnaturally' enhance slew rate, is recommended for pulse amplifier applications only and with low impedance signal sources.

Detailed distortion+noise figures versus output level for the full circuit of Fig. 9 are as follows. Measurement bandwidth is 80kHz.

$V_{out}(V_{pp})$ R_L=50Ω	Thd+n a) f=2kHz	Thd+n b) f=20kHz
3	0.0061%	0.0068%
6	0.0023%	0.0031%
12	0.0024%	0.0042%
24	0.0031%	0.0065%
34	0.0033%	0.0072%
50	0.0041%	0.0110%

Slew rate in conventional amplifiers

Slew rate performance of a generic amplifier configuration can be generally worked out by simply inspecting its circuit. The problem of slew rate in conventional integrated op-amps has been treated comprehensively by J.E. Solomon[1]. Since structure of audio and instrumentation amplifiers is similar to that of IC op-amps, most of Solomon's considerations are still valid.

Therefore we will assume, as a good example of a typical conventional amplifier architecture, the configuration of Fig. 3. This is very similar to those used by Solomon[1] for his generic op-amp and by Self[2] for his audio power amplifier. It includes the following three elements,

- A transconductance input stage. This stage provides an output current I_a proportional, to some degree, to the voltage difference V_1–V_2.
- A transimpedance intermediate gain stage, where output voltage V_b is proportional to input current I_a.
- A voltage follower output stage – providing power gain needed to drive the load.

Main base-collector transistor capacitances, which contribute to define the node capacitances, are indicated. Capacitance C_A is from the current generator I_A. Capacitance C_B is the sum of the output capacitances of I_B, the equivalent collector capacitance of Tr_4 (>C_4 depending on the value of R_3) and base-collector capacitance of Tr_5 and Tr_6.

In Fig. 3, Z_b=R_b//C_b models the input impedance of the output stage. Analogously, $C_{5,6}$ result from of output capacitance of I_C sources and the base-collector capacitance of $Tr_{7,8}$, respectively. External capacitor C_{dom} sets the dominant pole and provides a suitable degree of dynamic stability or phase margin when feedback is applied to the overall amplifier through R_{F1} and R_{F2}.

So, open loop gain of the overall feedback amplifier, assuming k is unity, is given by,

$$A_{OL}(f)=g_m/\{[2\pi f C_{dom}]G_o\},$$

where g_m=I_a/(V_1–V_2) is the transconductance of the input stage, and G_o=[R_{F1}+R_{F2}]/R_{F1} is the low-frequency closed-loop gain.

The amplifier's stable unity-gain frequency f_T, with its suitable phase margin, depends on the device technology and circuit architecture used. This can be written as,

$$f_T=g_m/[2\pi C_{dom}G_o] \qquad (4)$$

In the lower part of Fig. 3, dynamic range of each stage is represented. This should help comprehension of major slew rate limiting mechanisms operating within the amplifier.

Consider, for example, that values for the parameters in Fig. 3 are as follows:

I_A=1mA	I_B=2mA	I_C=10mA
C_A=5pF	C_B=40pF	C_{dom}=60pF
$C_{5,6}$=20pF	$C_{1\text{-}4}$=5pF	R_e=100Ω
V_{cc}=V_{ee}=20V.		

It is easy to evaluate the SR at each node via equation 2. At node n_1, $SR(n_1)$=I_A/C_A, which is 200V/μs, due to the limited current available to charge C_A during the positive input pulse edge. No slew limitation occurs during the negative pulse edge.

At node n_3, where ΔV_3≈0, current in C_3 is virtually null, maximum available current is still limited to I_A for both positive and negative values. Current needed to charge or discharge C_A should be subtracted from or added to I_A.

When slew rate of the amplifier is much lower than $SR(n_1)$, this fact can be neglected. You can assume current available for charging and discharging C_{dom}, at node n_3 is I_A. At node n_4 which C_{dom} is connected across, current available to drive C_{dom}+C_B is limited solely during the positive transition by biasing current I_B. No limitation practically exists for discharging since $\beta_3\beta_4 I_A$ is nominally as high as several amperes.

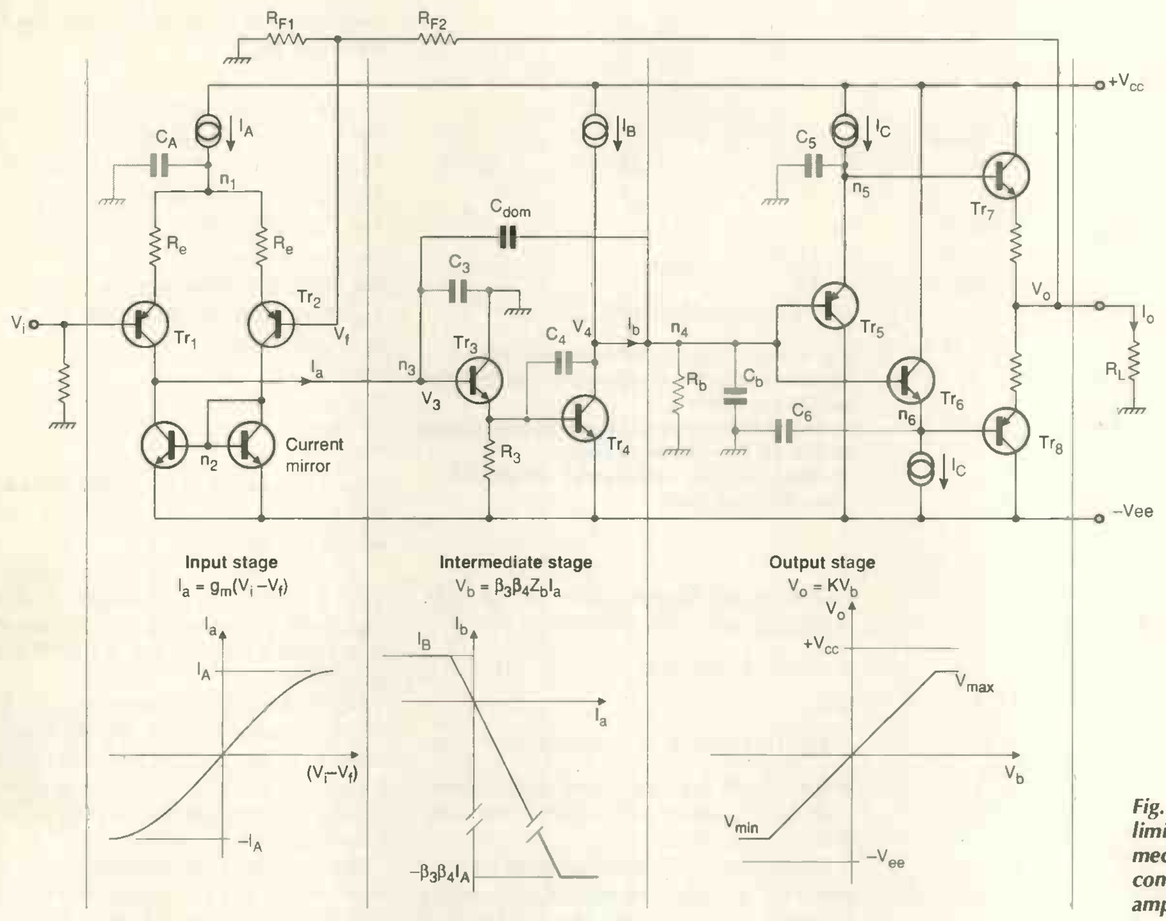


Fig. 3. Slew rate limiting mechanisms in a conventional amplifier.

There are two different slew rate limitation causes at the nodes across which C_{dom} is connected, namely,

$$SR(n_4)'=I_A/C_{dom} \quad (5)$$

$$SR(n_4)''=I_B/(C_{dom}+C_B) \quad (6).$$

The lowest of the above values is the actual *SR* at node n_4. Considering again the circuit values seen in the above example, equations 5 and 6 yield 16V/µs and 20V/µs, respectively – the actual slew rate value at node n_4 is 16V/µs. Similarly, you can calculate slew rate at nodes n_5 and n_6 as $SR(n_5)=SR(n_6)$, which is 500V/µs, assuming base currents of Tr_7 and Tr_8 are much lower than I_C.

This example shows that in conventional amplifier architectures, the most critical nodes, from a slew rate point of view, are the input and output of the intermediate transimpedance gain stage. This is due to limited currents from the bias sources available at both nodes. Signal voltage appearing at node n_4 is the highest within the amplifier. As a result, full power bandwidth expected will be $f_{max}=SR(n_4)/(2\pi V_p)$. Assuming, for simplicity, V_p equals V_{cc}, this provides a maximum frequency of 127kHz.

Slew rate limiting sources associated with the problem of driving the frequency compensation capacitance, C_{dom} are normally defined as 'first order' slew rate limitations. In this context all others are defined 'second order'.

Improving slew rate

Slew rate can be improved in the amplifier configuration shown in Fig. 3 by increasing bias current of the input stage and the intermediate stage if required. However, if the overall amplifier stability degree or phase margin has to be preserved, such current changes must be made without affecting unity gain frequency f_T.

Equation 4 requires that the g_m of the input stage is kept constant by increasing the R_e degeneration resistors.[2] Unfortunately, this approach leads to increased power consumption and the deterioration of amplifier input parameters – noise, offset voltage, current, and relevant drifts.

In some applications these side effects can be tolerated, but in others they are intolerable. As a result, the technique of increasing the bias currents for proportionally improving slew rate is only of limited use.

If higher slew rate figures are necessary in specific applications – instrumentation, electtrostatic transducer and deflection, test equipment, pulse amplifiers, etc – other solutions which do not compromise stability, noise and offset performance of the amplifier, have to be found.

In conventional amplifier configurations, the primary cause of slew limiting is, as mentioned earlier, the limited current available to drive the frequency compensation capacitance C_{dom}. An effective way to overcome this limitation is to make use of a class-AB differential amplifier in the input stage. This amplifier should have a low bias current in order to assure good offset and noise performance as well as phase margin. When driven by large and fast input signals, it should also provide high output currents required for the rapid charging/discharging of C_{dom}.

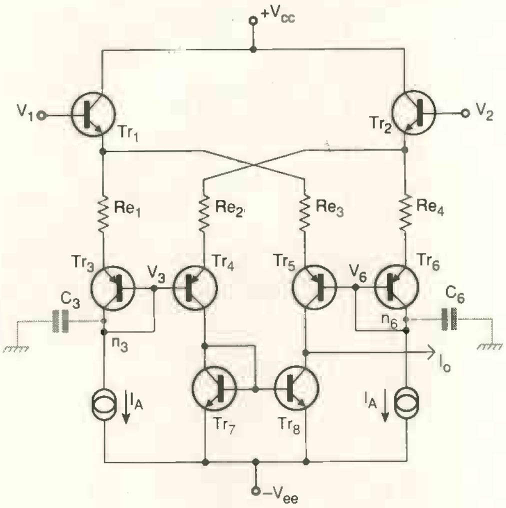
An input stage with such characteristics was first designed by W. E. Hearn[3] for Signetics and used in the monolithic op amps *SE/NE530* and *531*. These provided slew rate improvement of more than an order of magnitude compared to conventional counterparts – even with worse input parameters. Its basic scheme is shown in **Fig. 4a)**. Figure. **4b)** illustrates a different implementation of the same principle. Assuming all transistors are well matched and $R_{e1\text{-}4}$ and R_e are equal then bias current is the same for all transistors $Tr_{3\text{-}6}$ and equal to I_A, in virtue of circuit symmetry. However, output current I_o is no longer limited by bias current. In fact dynamic range of I_o is largely increased and is always controlled by differential input V_1-V_2, as indicated in Fig. **4d)**.

Operating area can divides into two regions. In region 1, the input stage operates in class-A and the input-output relationship, assuming $R_eI_A>V_T=kT/q\approx 25mV$, can be written as,

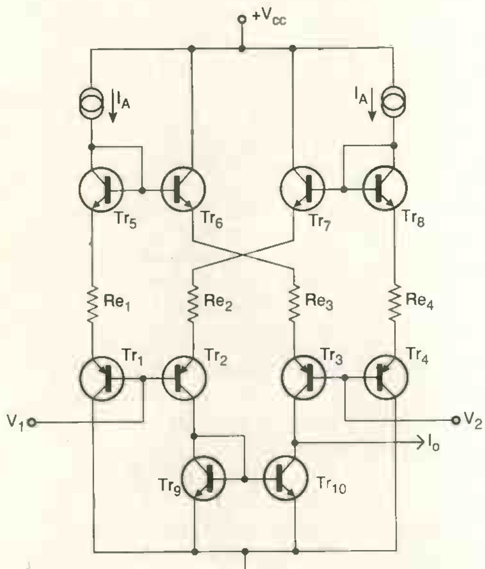
$$I_o\approx 2(V_1-V_2)/R_e. \quad (7)$$

A factor of 2 is present, due to the fact that both left and right halves contribute to the output current.

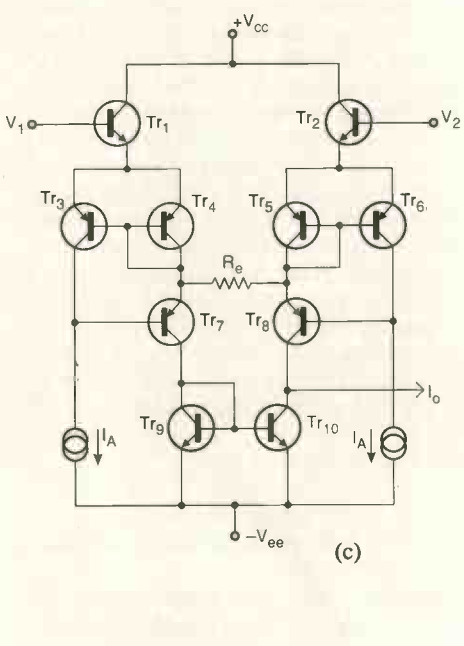
In region 2, the input stage operates in Class-B. Only half of the circuit contributes



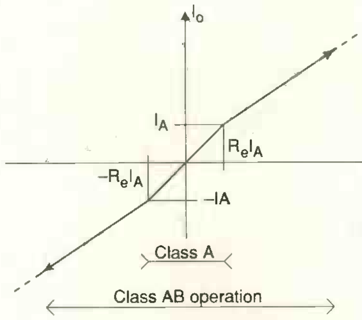
(a)



(b)



(c)



(d)

Fig. 4. Input stages capable of class-AB operation, effectively enhance the natural slew rate of amplifiers:
a) and b) Hearn's input stage implementations.
c) Van De Plassche input stage
d) Output current versus input voltage of a class-AB input stage.

Component list for the non-slewing amplifier prototype, Fig. 9.

Tr_1, Tr_2, Tr_{10}, Tr_{24} =2N 5551
Tr_3, Tr_4, Tr_7, Tr_{22} =2N 5401
Tr_5, Tr_6, Tr_{12}, Tr_{17}, Tr_{21}, Tr_{23} =2N 2907A
Tr_8, Tr_9, Tr_{11}, Tr_{15}, Tr_{25}, Tr_{26} =2N 2222A
Tr_{13}, Tr_{16} =2N 3019
Tr_{14}, Tr_{18} =2N 4033
Tr_{19} =MJE 15030 (on heat sink)
Tr_{20} =MJE 15031 (on heat sink)
All diodes *IN 4448*
R_e=51.1
R=330
C=10pF
R_{F1}=100
R_{F2}=1k47 (function of the closed loop gain G_o)
All resistors 1%

current to the output, either left or right, depending on the sign of difference $V_1–V_2$, so,

$$|I_o|\approx(V_1-V_2)/R_e\leq\beta_pI_A \quad \text{for Fig. 4a)} \qquad (8)$$

and,

$$|I_o|\approx(V_1-V_2)/R_e\leq\beta_nI_A \quad \text{for Fig. 4b)} \qquad (9)$$

Figures 5a,b) show the corresponding current path for a positive and negative step input voltage, respectively.

Implementation depicted in Fig. 4b) is often preferred in integrated technologies, where usually $\beta_n>>\beta_p$. A notable increase in output current and consequently in slew rate can be achieved with the same bias current.

If, for example, R_e is 100Ω, I_A is 0.5mA, β_n is 100 and β_p is 50, then output currents as high as 50 and 25mA can be expected for input voltage $(V_1–V_2)\leq5$V. This translates into potential slew rates of about 800 and 400V/µs, respectively, for a C_{dom} of 60pF.

It is evident that other sources of slew rate limitation can prove dominant and need to be taken into account. In the input stage, the only remaining factor which can limit slew rate and power bandwidth is associated with capacitances C_3 and C_6 at nodes n_3 and n_6 respectively, Fig. 4a). Assuming $C_3=C_6=C$, the maximum speed at which V_3 and V_6 can follow V_1 and V_2 respectively is fixed at $SR=I_A/C$, which is approximately 100V/µs for an I_A of 0.5mA and C of 5pF.

Other *SR* limitation sources can be identified in the rest of the amplifier by inspecting Fig. 3 and considering first-order slew rate limitations expressed by equations 5 and 6. It should be apparent now that the lowest of the two is equation 6. For an I_B of 4mA and other values as those of the above example, equation 6 yields 100V/µs and 40V/µs for a C_{dom} of 0pF and C_{dom} of 60pF, respectively.

When compared with the maximum slew rate achievable at all other nodes, the above results show that slew rate performance of amplifiers using a Hearn input stage are dominated by limited current available at the output node of the transimpedance intermediate stage. This is the case even when there is no need for external frequency compensation, i.e. when C_{dom} is 0pF. It is also the case when C_{dom} is placed between node n_3 and the output as in Hearn's op-amp[3] and in Cherry's audio amplifiers.

Figure. **4c)** shows a voltage-to-current converter designed by Van De Plassche[4]. By virtue of its capability of class-AB operation, I have successfully used it as a slew rate enhancing input stage in amplifiers. To my knowledge, this is a first.

Operation of the converter is similar to the Hearn stage. However, it features better input characteristics and greatly improved full range linearity – its g_m, at $2/R_e$, is virtually constant throughout the class-A region of Fig. 4d). These improvements are due to the fact that transistors $Tr_{1\text{-}6}$ are forced through local feedback to operate at a virtual constant-emitter current equal to $2I_A$ for $Tr_{1,2}$, and to I_A for the remainder.

In my opinion, both Hearn and Van De Plassche input stages can be profitably used in audio power amplifiers using Self's blameless basic architecture. I have used them successfully in 50-80W power amplifiers for instrumentation and test equipment. These feature slew rates up to ±150V/μs and power bandwidth in good agreement with equation (3).

Designing for high slew rate

Intrinsically high slew rate amplifier architectures – whether current or voltage-feedback – are based on the extension of the concept of class-AB operation to all stages of the amplifier. To the best of my knowledge, the first practical application of this concept, aimed at achieving unusually high slew rates in voltage-feedback amplifiers, was reported for the first time in 1980[5]. Related patent applications appeared in 1977.

In the above publication, a discrete true operational amplifier with a slew rate in excess of ±400V/µs, a unity-gain frequency of only 3MHz and a consumption of 4.5mA was presented and discussed. It was stable even in voltage follower configurations. Its basic architecture, with minor differences in the input and output stage, is shown in **Fig. 6**.

An outstanding feature of this amplifier configuration is that, for the first time *all* first-order slew rate limitations have been completely removed. At the time of its publication, this feature was a brand new idea, yet the same basic principles are used nowadays in some commercial high slew rate voltage-feedback op-amps[6,7].

In part, this result has been achieved by developing a complementary-symmetry intermediate gain stage with very high performance. This push-pull class-AB gain stage comprises transistors $Tr_{9\text{-}14}$. In addition, I have redesigned the input stage, improving its ability to drive the new intermediate stage. It is fully symmetrical and is push-pull class-AB in operation.

This approach greatly enhances the slew-rate capability of the amplifier – even with low standby supply current. The output stage is of the same standard as the diamond voltage-follower used in Fig. 3. An evolution of Hearn's input stage consists of two mirrored diamond voltage followers. They feature a higher degree of flexibility and extended symmetrical input common-mode voltage range.

Transistors $Tr_{1,2}$ and $Tr_{7,8}$ perform the level shifting function needed to bias the other transistors. Bias current of transistors $Tr_{3\text{-}6}$ is also controlled mainly by current source I_A.

Emitter resistors $R_{2\text{-}5}$, with values in the range 5-20Ω, make no significant contribution to bias current. As a result, $I_{Q1\text{-}8}$ approximately equals I_A. Instead these resistors are used in discrete implementations for bias stabilisation. Here, input transistors are required to provide high currents during transients and they often suffer from self heating.

Input stage transconductance is controlled via cross coupling resistor R_1, so that $g_m \approx 1/R_1$. Due to its full symmetry, it features better precision and common mode rejection than Hearn's stage. Large-signal performance is similar to that depicted in Fig. 4d), and relationships 8 and 9 are still valid.

In practical implementations, product R_1G_o – the closed-loop gain/input-stage-transconductance ratio – should be kept constant and such that a stable f_T is achieved This results in best performance in terms of closed-loop bandwidth, slew rate and precision, i.e. low offset and noise.

Figure 7 shows basic details of the new intermediate stage. It can be considered a complementary symmetry implementation of the Wilson current mirror. However, the driving approach is substantially different.

Both upper and lower current pairs I_L and I_R, coming from the input stage and suitably directed by current mirrors CM_1 and CM_2, are employed to drive the upper and lower halves of the intermediate stage respectively. As a result, the base of Tr_{11}, node A, is driven by $I_L–I_R$, while the base of Tr_{14}, node B, is driven by the antiphase current $-(I_L–I_R)$. Due to the balanced driving scheme, quiescent current I_Q is not influenced by the input stage. It is set by sources I_{B1} and/or I_{B2}, and is equal to $I_{B1}+I_{B2}$.

Due to the feedback loop inside the Wilson circuit structure, quiescent current is stable under all operating conditions – even in the case of severe overload conditions. For the same reason, current gain $I_b/(I_L–I_R)$ is low but steady over the full dynamic range. As a result, this renders frequency response of the overall amplifier flat and stable.

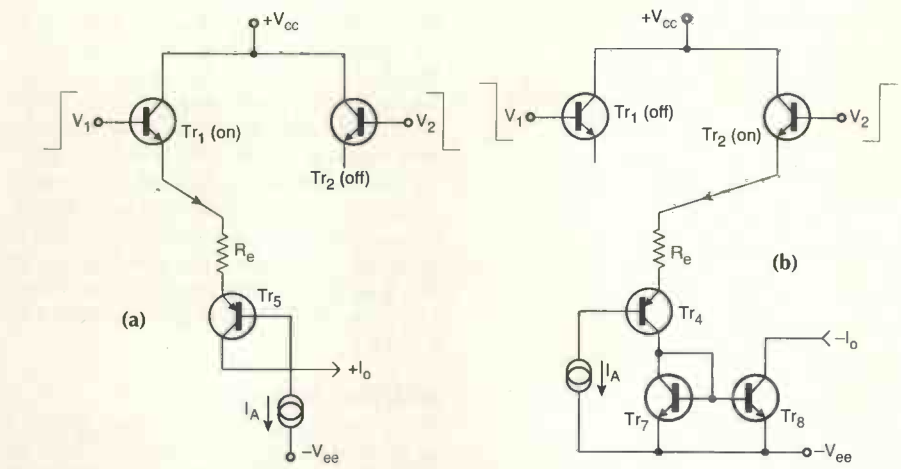


Fig. 5. Current paths in a class-AB input stage under large signal operation.

The simultaneous availability of both wide range currents I_L and I_R at nodes A and B is essential for a fast commutation of transistors Tr_{11} and Tr_{14}. This helps reduce overload recovery time as well as the dangerous simultaneous conduction of these transistors. Capacitances C_{11}, C_{14}, C_b and C_{dom} can be charged and discharged rapidly without exposing any intermediate gain stage transistors to risk of overdrive phenomenon.

The remaining still active slew rate limiting mechanisms are second order,

$$SR(n_1)=SR(n_2)=SR(n_3)=SR(n_4)=SR1=I_A/C_A,$$

assuming $C_{1\text{-}4}$ and C_A are all equal and,

$$SR(n_5)=SR(n_6)=SR2=I_C/C_C,$$

assuming $C_{5,6}$ and C_C are equal. Considering the example used earlier, i.e. I_A=0.5mA, I_C=10mA, C_A=5pF and C_C=20pF, results are

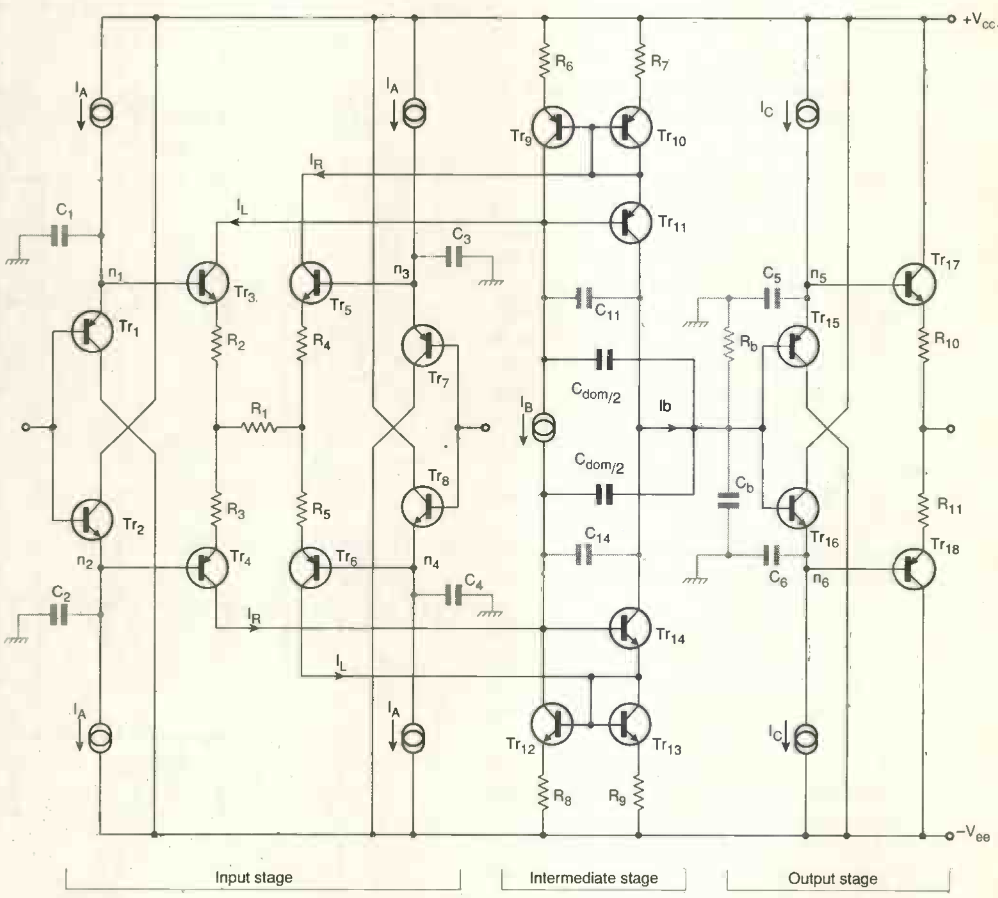


Fig. 6. High slew rate voltage feedback amplifier architecture.

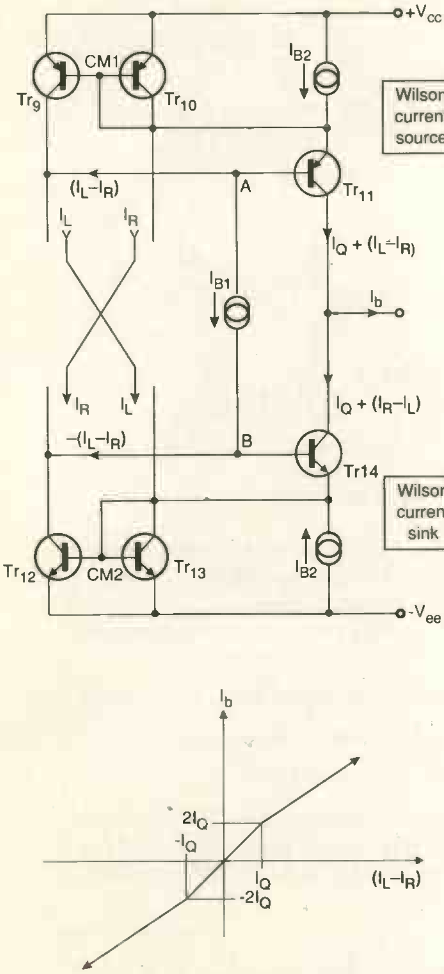


Fig. 7. Details of the class-AB intermediate gain stage and its transfer curve.

100V/µs for *SR*1 and 500V/µs for *SR*2.

For closed loop inverting gains of 1 or greater and non-inverting gains 5 or greater, *SR*2 is the dominant slew rate factor for the overall amplifier. Second-order slew rate limiting factors dominant in high slew rate architectures, are counteracted to a large extent in the high slew rate circuit structure of **Fig. 8**.

Instead of being returned to the supply rails, as in Fig. 6, collector currents of $Tr_{1\text{-}2}$, and $Tr_{7\text{-}8}$ are channelled with the appropriate phase to the inputs of the intermediate stage.

When the input stage is driven by a fast positive step voltage, as in Fig. 8, nodes n_1 and n_4 experience slew rate limitation *SR*1. An analogous reasoning applies for a fast negative step voltage.

Transistors Tr_1 and Tr_8 are momentarily off, whereas Tr_2 and Tr_7 are forced to conduct the peak currents needed to drive node capacitances C_2 and C_3, respectively – and they are capable of doing so.

These extra currents, help to drive Tr_{11} and Tr_{14} considerably during the transients. In this way, exceptionally high positive and negative slew rates can be obtained at node n_5. Slew rate of the output stage is enhanced by driving the current sources I_C by the intermediate stage, Fig. 8.

Improved performance of the intermediate stage is due to diodes $D_{1\text{-}4}$. Under all operating conditions they keep all current mirror transistors away from the saturation region, where gain is lower and speed impaired. Forcing the stage to provide peak slew currents results in considerable benefits in recovery time and distortion. Slew rates in excess of 1500V/µs have been achieved in some discrete op-amp prototypes with total supply current of 20-30mA. These use circuit architecture of Fig. 8, and common bipolar transistors, namely an npn *2N2222A* and pnp *2N2907A* with V_{cc} and V_{ee} at 20V.

Adapting for audio

When suitably adapted, principles embodied in the configurations of Fig. 6 and 8 can be successfully incorporated into the design of very high slew rate audio power amplifiers. Slew rates up to 500V/µs can be achieved with the use of modern power devices – bjts or mosfets. However, useful power bandwidth will not be the theoretical one expressed by equation 3. This is mainly due to limited high-frequency gain and power handling ability of most audio power devices.

In the past ten years I have assembled several prototype power amplifiers designed in accordance with these principles, mainly for test and instrumentation purposes. Although distortion was no better than 0.01% within the audio frequency range, slew rates were exceptional, at ±200 to ±400V/µs.

A non-slewing amplifier?

High slew-rate voltage-feedback amplifier architectures discussed so far are not without their disadvantages. When compared with conventional configuration, Fig. 3, high slew-rate architectures have worse offset and noise input characteristics. This is often due to the complexity of the input stage.

Low current gain of the intermediate stage reduces low-frequency open-loop gain. This sets a limit on the maximum feedback factor that can be applied to the amplifier and, hence, on the precision and distortion performance when used in instrumentation and audio applications.

Some of these drawbacks can be overcome via the amplifier of **Fig. 9**. It features the noise and offset performance of conventional amplifiers, yet retains the speed capabilities of high slew-rate architectures. In this design, second as well as first-order slew rate limitations are virtually eliminated. This makes the definition 'non-slewing amplifier' applicable.

In non-slewing architecture, none of the stages of the amplifier experience strong overdrive non-linearities due to too fast and/or too large an input signal. When charging or discharging node capacitance, as well as for driving active devices, current available at all nodes of the circuit is more or less linearly controlled by the differential input voltage – even during the sharpest and highest of transients. This is true, provided that the input sig-

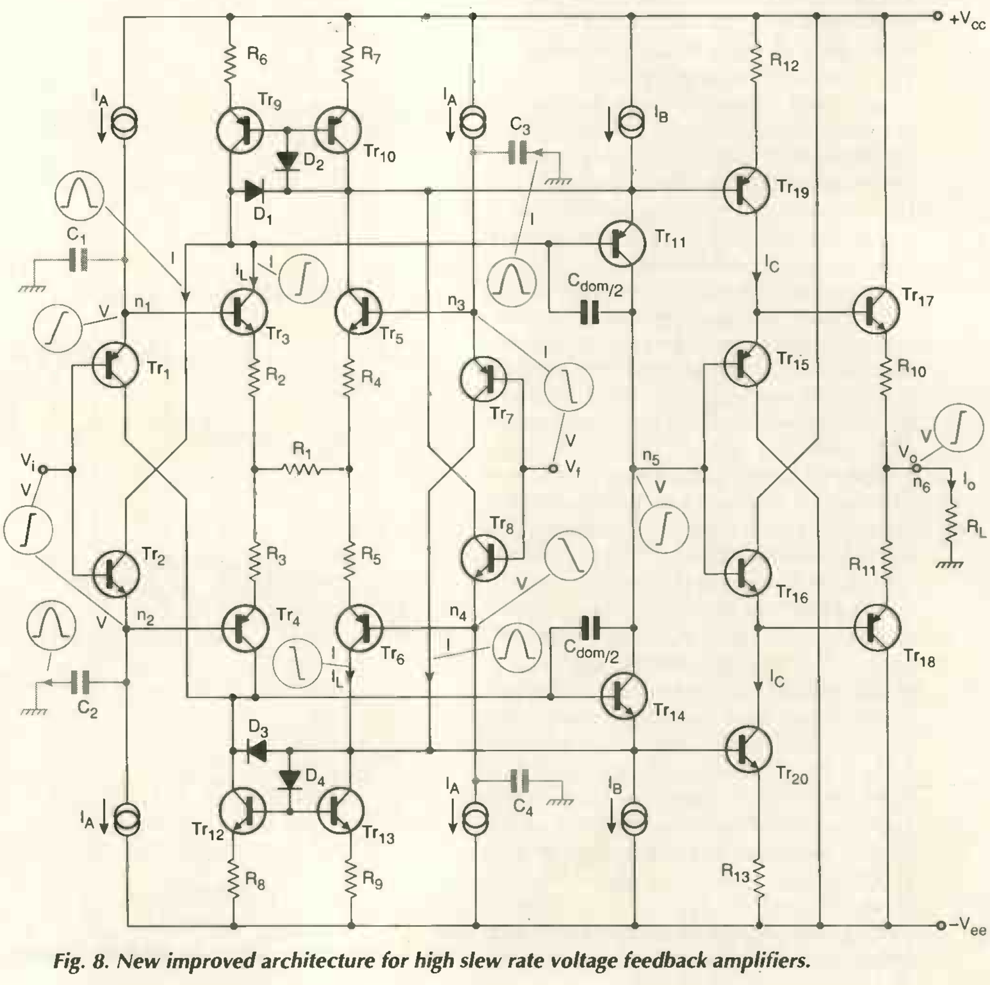


Fig. 8. New improved architecture for high slew rate voltage feedback amplifiers.

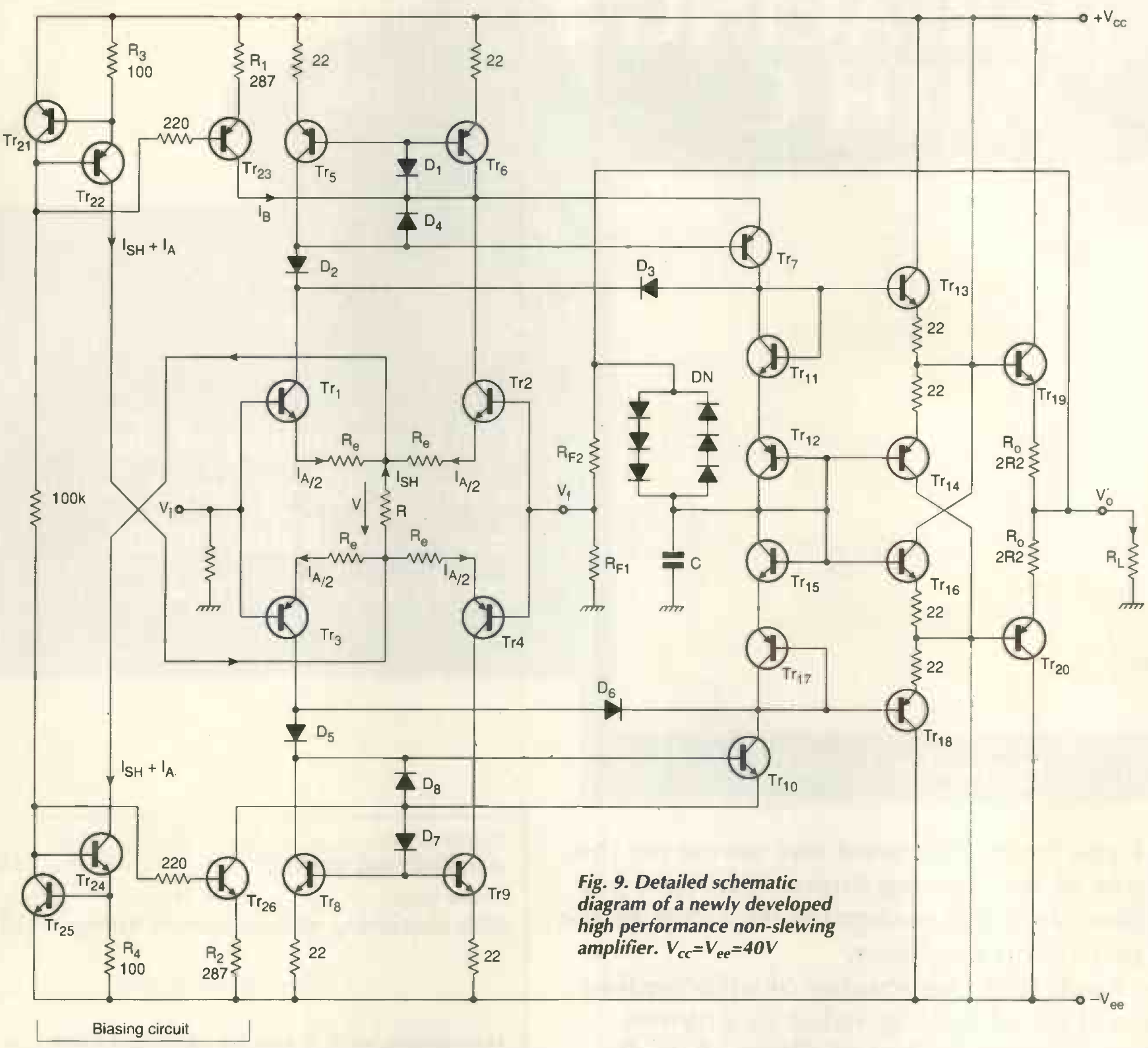


Fig. 9. Detailed schematic diagram of a newly developed high performance non-slewing amplifier. $V_{cc}=V_{ee}=40V$

nal is within the common-mode input voltage range.

The intermediate gain stage is substantially unchanged. To reduce the recovery time of the whole amplifier further and increase reliability, diodes $D_{2,3}$ and $D_{5,6}$ have been added to prevent transistors $Tr_{7,10}$ from deep saturation.

Input circuitry has been simplified in order to improve noise and offset performance and to avoid the second order slewing mechanisms present in Fig. 6 and 8.

Biasing problems associated with high slew-rate configurations, have been solved by moving and simplifying level shifting circuitry into the emitter loops. Only two current sources, I_{SH}+I_A, and resistor R are now needed for this. Current I_{SH} is used to produce the level shifting voltage [$V=RI_{SH}=2V_{be(on)}$] across R. Excess current I_A is forced to flow through the emitters of pairs $Tr_{1,2}$ and $Tr_{3,4}$, fixing the operating point of the input stage.

A great advantage of this solution is that all disturbances associated with biasing current sources, such as noise, imbalances and drift, are seen by the input stage as common mode disturbances. As a result, the disturbances are greatly reduced by the amplifier.

Small-signal transconductance is governed by emitter resistor R_e as well as I_A. It can be set as low as needed without interacting significantly with the biasing scheme. This results in increased gain and improved dc precision. Large-signal transconductance is equal to $1/(R+2R_e)$.

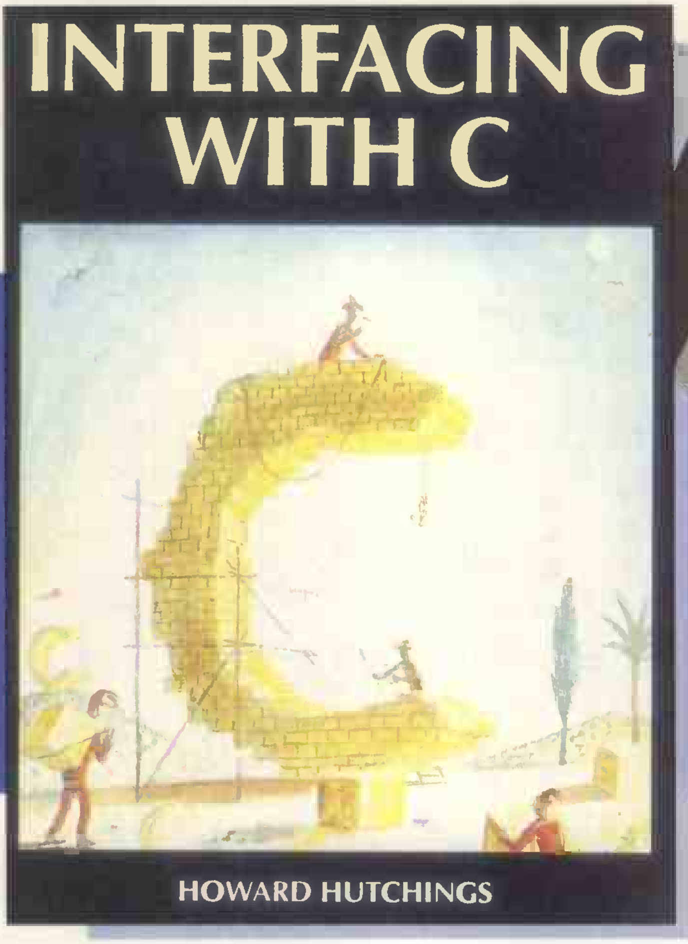
In order to avoid inherent speed limitations of the diamond voltage follower, a self-biasing complementary symmetry darlington configuration is preferred for the output stage. Moreover, output transistors Tr_{19} and Tr_{20} are properly driven, which assures the low push and pull driving resistance necessary for rapid commutation and safe high-frequency operation of the output devices.

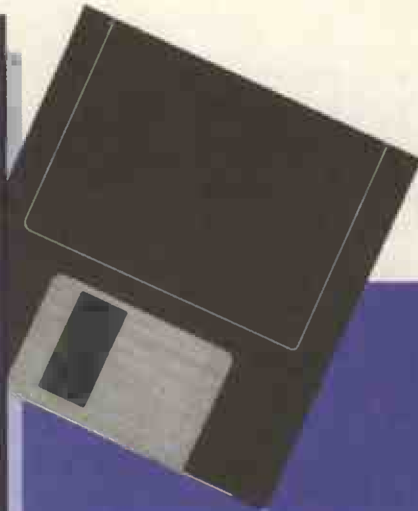
Circuitry around Tr_{11-14} serves as a voltage follower to drive Tr_{19}, while Tr_{15-18} do the same job for Tr_{20}. Transistors Tr_{14} and Tr_{16} have their collectors connected as shown in **Fig. 9** to increase – when necessary – the input impedance of the output stage. This may be needed for instance in high closed loop gain configurations. In power applications however, it is usually safer to connect them to their respective supply rails.

Quiescent current of the output stage devices is set, by the I_B sources and by R_o, to 30mA for Tr_{19} and Tr_{20}, and to a value close to I_B for all other transistors. Diode network *DN* limits output current to approximately 800mA – enough to drive 50Ω at full swing. ■

References

1. Solomon, JE, 'The Monolithic Op Amp: a Tutorial Study', IEEE J. Solid State Circuits, Vol. SC.9, N° 6, Dec. 1974, pp. 314-332.
2. Self, D, 'High Speed Audio Power', *EW+WW*, Sep. 1994, pp. 760-764.
3. Hearn, WE, 'Fast Slewing Monolithic Operational Amplifier', *IEEE J. Solid State Circuits*, Vol. SC.6, Feb. 1971, pp.20-24.
4. Van De Plassche, RJ, 'A Wide-Band Monolithic Instrumentation Amplifier', *IEEE J. Solid State Circuits*, Vol. SC.10, Dec. 1975, pp. 424-431.
5. Stochino, G and D'Amico, A, 'A High Slew Rate Discrete Operational Amplifier with Comparatively Low Unity Gain Frequency', Alta Frequenza, Vol. XLIX, N.1, Jan. Feb. 1980, pp. 18-23.
6. Opa 622, Burr-Brown, data sheets, Dec.1993
7. Smith, D, Koen, M and Witulski, AF 'Evolution of High Speed Operational Amplifier Architectures', *IEEE J. Solid State Circuits*, Vol. 29, No. 10, Oct. 1994, pp. 1166-1179.





A disk containing all the example listings used in this book is available, Please specify size required

If you have followed our series on the use of the C programming language, then you will recognise its value to the practising engineer.

The book is a storehouse of information that will be of lasting value to anyone involved in the design of filters, A-to-D conversion, convolution, fourier and many other applications, with not a soldering iron in sight.

To complement the published series, Howard Hutchings has written additional chapters on D-to-A and A-to-D conversion, waveform synthesis and audio special effects, including echo and reverberation. An apendix provides a 'getting started' introduction to the running of the many programs scattered throughout the book.

This is a practical guide to real-time programming. The programs having been tested and proved. It is a distillation of the teaching of computer-assisted engineering at Humberside Polytechnic, at which Dr Hutchings is a senior lecturer.

842

Credit card orders accepted by phone. Call 0181 652 3614.

Please supply ________ copies of
INTERFACING WITH C **Price £14.95**
Please supply ________ copies of
Disk containing all the example listings **£15.00**

Remittance enclosed £__________

Interfacing with C can be obtained from Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Cheques should be made payable to
Reed Business Publishing Group Ltd

Please debit my credit card as follows:
Access/Master Barclay/Visa Amex Diners

Credit Card No. ____________________

Exp date

NAME (Please print) ____________________

ADDRESS ____________________

____

____

____

POST CODE ____________________

DATE__________ TELE__________

SIGNATURE

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.

GRANDATA LTD

K.P. HOUSE, UNIT 15, POP IN COMMERCIAL CENTRE,
SOUTHWAY, WEMBLEY, MIDDLESEX, ENGLAND HA9 0HB

Telephone: 0181-900 2329 Fax: 0181-903 6126

OPEN Monday to Saturday.

Times: Mon-Fri 9.00-5.30 Sat 9.00-2.00

PLEASE PHONE US FOR TYPE NOT LISTED HERE AS WE ARE HOLDING 30,000 ITEMS AND QUOTATIONS ARE GIVEN FOR LARGE QUANTITIES

Please send £1 P&P and VAT at 17.5%. Govt, Colleges, etc. Orders accepted. Please allow 7 days for delivery. Prices quoted are subject to stock availability and may be changed without notice. TV and video parts sold are replacement parts.

Access & Visa Card accepted

WE STOCK TV AND VIDEO SPARES, JAPANESE TRANSISTORS AND TDA SERIES. PLEASE RING US FOR FURTHER INFORMATION.

TRANSISTORS

Part	Price
AAY32	9p
AC107	40p
AC125	30p
AC126	30p
AC127	30p
AC128K	40p
AC141K	45p
AC176	22p
ACY18	48p
ACY19	48p
AD149	60p
AF125	50p
AF139	30p
AF239	30p
BB105B	18p
BB205B	24p
BC107	8p
BC108	8p
BC109	8p
BC109C	10p
BC140	20p
BC142	20p
BC143	20p
BC147	8p
BC149	8p
BC159	8p
BC160	30p
BC171	10p
BC172	10p
BC177	14p
BC178	14p
BC179	14p
BC182	7p
BC182L	7p
BC183	7p
BC183L	7p
BC184	7p
BC184L	7p
BC212	7p
BC212L	7p
BC213	7p
BC213L	7p
BC214	7p
BC214L	7p
BC237	7p
BC238	7p
BC239	7p
BC300	20p
BC301	20p
BC302	20p
BC303	20p
BC304	25p
BC327	7p
BC328	7p
BC337	7p
BC338	7p
BC441	28p
BC446	8p
BC477	18p
BC516	22p
BC537	25p
BC546	8p
BC547	8p
BC548	8p
BC549	8p
BC550	8p
BC556	8p
BC557	7p
BC558	8p
BC559	8p
BC560	8p
BC637	20p
BC639	20p
BC640	20p
BCY33	200p
BCY34	200p
BCY70	16p
BCY71	16p
BCY72	16p
BD115	30p
BD124P	50p
BD131	25p
BD132	25p
BD133	50p
BD135	20p
BD136	20p
BD137	20p
BD138	20p
BD139	20p
BD140	20p
BD144	90p
BD157	38p
BD166	30p
BD175	30p
BD177	30p
BD179	32p
BD181	45p
BD182	60p
BD184	60p
BD187	30p
BD201	33p
BD202	38p
BD203	42p
BD204	42p
BD222	31p
BD225	31p
BD232	31p
BD233	30p
BD234	32p
BD235	28p
BD236	30p
BD237	21p
BD238	24p
BD239	30p
BD240	40p
BD241A	40p
BD243A	50p
BD244	50p
BD245	50p
BD246A	50p

Part	Price
BD265	45p
BD267	45p
BD269	45p
BD278	50p
BD311	100p
BD314	100p
BD315	150p
BD317	150p
BD331	40p
BD332	40p
BD361	60p
BD362	60p
BD370	30p
BD371	30p
BD410	50p
BD433	28p
BD434	30p
BD435	31p
BD436	30p
BD437	28p
BD438	36p
BD439	40p
BD440	40p
BD441	40p
BD533	50p
BD534	38p
BD535	38p
BD536	38p
BD537	40p
BD538	40p
BD643	50p
BD645	50p
BD647	50p
BD649	50p
BD675	40p
BD676	40p
BD677	38p
BD678	40p
BD679	40p
BD680	40p
BD681	45p
BD682	45p
BD705	50p
BD707	50p
BD709	50p
BD711	50p
BD736	50p
BD826	50p
BD828	50p
BD839	55p
BD897	50p
BD899	50p
BD977	50p
BDX33	60p
BDX65	80p
BDW24	55p
BDW93	50p
BDW94	50p
BDY92	100p
BF137	35p
BF167	30p
BF181	18p
BF183	20p
BF195	7p
BF199	8p
BF200	16p
BF225	30p
BF240	16p
BF245	25p
BF254	15p
BF255	12p
BF256	18p
BF257	18p
BF259	18p
BF262	25p
BF270	18p
BF273	15p
BF311	21p
BF336	20p
BF337	20p
BF338	20p
BF362	30p
BF367	13p
BF371	17p
BF421	18p
BF422	21p
BF423	25p
BF455	12p
BF458	19p
BF462	50p
BF471	28p
BF472	28p
BF479	30p
BF494	16p
BF495	16p
BF595	16p
BF596	16p
BF615	30p
BF617	30p
BF760	40p
BF763	40p
BF870	22p
BF871	22p
BF960	38p
BF961	35p
BF964	38p
BFR90	85p
BFR91	99p
BFT43	30p
BFX29	20p
BFX84	20p
BFX85	20p
BFX87	15p
BFX88	15p
BFX89	60p
BFY50	14p
BFY51	14p
BFY52	14p
BFY56	25p
BFY64	25p

Part	Price
BFY90	45p
BLY48	85p
BR100	14p
BR103	37p
BR303	85p
BSS74	33p
BSX20	15p
BT100A	70p
BT106	180p
BT109	90p
BT119	100p
BT146	99p
BTY79	140p
BU105	80p
BU108	100p
BU109	80p
BU110	90p
BU111	100p
BU124	60p
BU126	65p
BU180	100p
BU184	100p
BU204	65p
BU205	70p
BU206	100p
BU208	70p
BU208A	75p
BU208AT	200p
BU208D	130p
BU209	90p
BU225	120p
BU226	120p
BU312	90p
BU325	55p
BU326A	75p
BU406	60p
BU406D	85p
BU407	55p
BU407D	75p
BU408	60p
BU408D	75p
BU409	85p
BU426A	70p
BU500	100p
BU505	90p
BU505D	90p
BU505DF	90p
BU506	100p
BU506D	70p
BU506DF	120p
BU508A	70p
BU508AF	95p
BU508D	75p
BU508DF	115p
BU508V	110p
BU508VF	100p
BU526	75p
BU536	100p
BU546	125p
BU608	120p
BU626	120p
BU705	130p
BU706DF	175p
BU706F	150p
BU801	70p
BU806	70p
BU807	60p
BU902	110p
BU903	110p
BU920	100p
BU922	110p
BU930	130p
BU2508A	130p
BU2508AF	130p
BU2508D	130p
BU2508DF	150p
BU2520AF	225p
BU2520DF	225p
BU2525AF	325p
BUH515	200p
BUT11AF	55p
BUT12	80p
BUT56A	75p
BU18	80p
BU18AF	80p
BUX10	150p
BUX11	200p
BUX12	150p
BUX20	350p
BUX21	450p
BUX22	450p
BUX37	220p
BUX40	210p
BUX41	200p
BUX42	200p
BUX47A	220p
BUX48A	150p
BUX80	180p
BUX84	50p
BUX85	50p
BUX86	30p
BUX87	50p
BUX98A	350p
BUY69A	200p
BUY71	250p
BUZ11	200p
BUZ71	75p
BUZ80	200p
BY448	20p
BYT11	25p
C106D	28p
IRF630	150p
J174	38p
J300	50p
MJ900	200p
MJ1000	200p
MJ1001	200p
MJ10012	300p
MJ15003	250p
MJ15004	300p

Part	Price
MJ2501	100p
MJ2955	55p
MJ3000	100p
MJ3001	100p
MJE29A	30p
MJE30A	30p
MJE340	25p
MJE350	80p
MJE520	30p
MP8112	45p
MPSA05	15p
MPSA06	15p
MPSA13	15p
MPSA20	15p
MPSA42	15p
MPSA43	15p
MPSA70	15p
MPSA92	20p
MPSA93	20p
MR510	35p
MR856	36p
OC28	350p
OC29	250p
OC35	350p
OC36	250p
OC45	50p
OC200	180p
R2008B	100p
R2010B	100p
S2000A3	175p
S2000AF	175p
S2055A	175p
S2055AF	200p
S2530A	100p
S2800M	72p
TIP29	15p
TIP29A	22p
TIP29C	25p
TIP29E	40p
TIP30	25p
TIP30C	25p
TIP31A	22p
TIP31C	27p
TIP32	24p
TIP32A	21p
TIP32C	28p
TIP33	50p
TIP33C	60p
TIP34	50p
TIP34C	60p
TIP35C	65p
TIP36C	65p
TIP41A	20p
TIP41C	22p
TIP42A	20p
TIP42C	22p
TIP47	40p
TIP48	40p
TIP50	60p
TIP51	80p
TIP52	80p
TIP54	85p
TIP105	65p
TIP106	65p
TIP107	65p
TIP110	40p
TIP111	40p
TIP112	35p
TIP112H	50p
TIP115	30p
TIP116	30p
TIP117	30p
TIP120	37p
TIP121	35p
TIP122	30p
TIP125	30p
TIP126	40p
TIP127	35p
TIP130	30p
TIP131	30p
TIP132	30p
TIP141	65p
TIP142	75p
TIP145	50p
TIP146	70p
TIP147	80p
TIP150	90p
TIP151	60p
TIP2955	42p
TIP3055	42p
TIPL760	100p
TIPL763A	200p
TIPL791A	80p
TIS61	15p
TIS90	15p
TIS93	20p
ZTX107	11p
ZTX108	11p
ZTX109	12p
ZTX212	20p
ZTX300	10p
ZTX301	16p
ZTX302	10p
ZTX303	20p
ZTX304	10p
ZTX320	20p
ZTX501	13p
ZTX502	10p
ZTX503	18p
ZTX504	25p
2N696	26p
2N697	22p
2N698	40p
2N78	22p
2N914	28p
2N930	18p
2N1131	28p
2N1132	28p
2N1613	24p
2N1711	24p
2N1893	30p

Part	Price
2N2102	50p
2N2218A	24p
2N2219	24p
2N2221	23p
2N2222	23p
2N2369	15p
2N2484	15p
2N2646	40p
2N2904	20p
2N2905	20p
2N2906	18p
2N2907	18p
2N3019	28p
2N3053	18p
2N3054	40p
2N3055	38p
2N3055H	50p
2N3442	85p
2N3702	9p
2N3703	9p
2N3704	9p
2N3705	9p
2N3706	9p
2N3707	9p
2N3710	12p
2N3711	12p
2N3771	85p
2N3772	90p
2N3773	100p
2N3799	18p
2N3819	29p
2N3903	11p
2N3906	11p
2N4031	25p
2N4401	12p
2N4403	12p
2N5061	20p
2N5088	20p
2N5192	50p
2N5241	500p
2N5245	45p
2N5294	30p
2N5296	30p
2N5448	12p
2N6107	40p
2N6292	40p
2N6385	120p
2N6403	160p

RECTIFIER DIODES

Part	Price
BY127	8p
BY133	8p
BY164	40p
BY179	35p
BY184	32p
BY206	11p
BY207	9p
BY227	19p
BY228	28p
BY298	15p
BY299	18p
BY448	20p
BYX10	15p
BYX55/600	25p
BYX70/500	
OA47	10p
OA91	10p
OA202	10p
IN4001	3p
IN4002	3p
IN4003	3p
IN4004	3p
IN4005	3p
IN4006	3p
IN4007	4p
IN4148	2p
IN5400	9p
IN5401	8p
IN5402	8p
IN5403	8p
IN5404	8p
IN5405	11p
IN5406	12p
IN5407	12p
IN5408	12p
RGP15	25p
RGP30	16p
SKE4F2/06	60p
SKE4F2/08	80p
SKE4F2/10	100p
SR2M	60p

I.C. SOCKETS

Part	Price
8 PIN	5p
14PIN	6p
16PIN	7p
18PIN	10p
20PIN	12p
22PIN	13p
24PIN	14p
28PIN	16p
40PIN	18p

ZENERS

Part	Price
400 mWatts	
2V7 to 39V	5p
1.3 Watts	
2V7 to 39V	9p

VOLTAGE REGULATORS

Part	Price
7805	25p
7806	25p
7808	25p
7812	25p
7815	25p
7818	25p
7824	25p
7905	25p
7906	30p
7908	30p
7912	30p
7915	30p
7918	30p
7924	30p
78L05	24p
78L08	24p
78L12	24p
78L15	24p
78L18	24p
78L24	24p
79L05	35p
79L08	35p
79L12	35p
79L15	35p
LM309K	100p
LM317T	100p
LM323K	350p
78H08KC	800p
79H12KC	700p
79HGKC	800p

LEDs

Part	Price
3mm	
RED	5p
YELLOW	8p
GREEN	8p
5mm	
RED	5p
YELLOW	8p
GREEN	8p

RECTANGULAR LEDs

Part	Price
5mm x 2.5mm	
RED	5p
YELLOW	8p
GREEN	8p

OPTO COUPLERS

Part	Price
4N37	58p
4N38	68p

BRIDGE RECTIFIERS

Part	Price
W005 1A/50V	16p
W01 1A/100V	18p
W02 1A/200V	19p
W04 1A/400V	21p
W06 1A/600V	23p
W08 1A/800V	28p
BR81D 2A/100V	33p
BR82D 2A/200V	33p
BR84D 2A/400V	37p
BR86D 2A/600V	43p
BR88D 2A/800V	43p
BR32 2A/200V	43p
BR34 2A/400V	43p
BR36 2A/600V	44p
BR62 6A/200V	80p
BR64 6A/400V	72p
BR251 25A/100V	150p
BR252 25A/200V	165p
BR254 25A/400V	185p
BR256 25A/600V	200p
BR258 25A/800V	240p
BR351 35V/100V	185p
BR352 35V/200V	200p
BR354 35V/400V	220p
BR356 35V/600V	230p
BR358 35V/800V	260p
BY164 1.5A/100V	40p
BY176 1.5A/800V	40p

TRIACS

Part	Price
TIC206D 4A/400V	60p
TIC225D 6A/400V	69p
TIC226D 8A/400V	68p
TIC236D 12A/400V	85p
TIC246D 16A/400V	105p
TIC253D 20A/400V	190p
TIC263D 25A/400V	205p

THYRISTORS

Part	Price
2N5061 0.8A/60V	20p
TIC116C 8A/300V	59p
TIC116D 8A/400V	70p
TIC126D 12A/400V	75p
TIC126M 12A/600V	90p
C106D 4A/400V	28p
BR103	37p
BR303	85p
BT106	180p
BT119	100p
17088	200p
17089	200p
17127	200p
15/80H	230p
15/85R	230p
SG264	800p
SG613	1500p

COMPUTER ICs

Part	Price
Z80ACPU	100p
Z80ADMA	200p
Z80ACTC	140p
Z80ASIO-1	210p
Z80ASIO-2	210p
75107	65p
75110	75p
75113	100p
75122	110p
75154	100p
75162	700p
75182	95p
75183	95p
75195	185p
2114	150p
2532	200p
2716	100p
2732	200p
2732A	220p
2764	150p
27C64	200p
27128	150p
27256-25	150p
27512	300p
4116	40p
4164-15	80p
4164-12	90p
41256-15	80p
41256-12	100p
41256-10	110p
41464-12	150p
6116	80p
6264-10	210p
62256-12	300p
6502A	360p
65C02	930p
6522	280p
6800	210p
6802	220p
680	500p
36808	500p
6809	500p
6810	150p
6818	380p
6821	130p
6840	290p
6845	200p
6850	90p
8085A	300p
8086	500p
8088	480p
8156	300p
8224	240p
8226	240p
8250	750p
8251	200p
8253	160p
8257	220p
8271	3400p
8279	270p
8283	400p
8284	440p
8287	260p
8288	650p
8748	700p
8755	800p
8T26	95p
8T28	110p

LINEAR ICs

Part	Price
AN203	210p
AN210	165p
AN214Q	170p
AN228	280p
AN252	150p
AN259	250p
AN262	140p
AN271	230p
AN274	250p
AN301	330p
AN303	250p
AN304	360p

Part	Price
AN315	210p
AN316	350p
AN360	100p
AN362	140p
AN366	150p
AN610	160p
AN3312	350p
AN3821K	600p
AN3822K	600p
AN3990K	300p
AN3991K	400p
AN5025	250p
AN5033	400p
AN5132	250p
AN5150	400p
AN5151	600p
AN5215	100p
AN5256	150p
AN5262	175p
AN5265	80p
AN5352	600p
AN5411	450p
AN5421	150p
AN5429	420p
AN5512	100p
AN5515	160p
AN5520	550p
AN5521	100p
AN5612	200p
AN5613	200p
AN5615	300p
AN5620	250p
AN5622	275p
AN5625	400p
AN5712	180p
AN5722	140p
AN5730	160p
AN5732	120p
AN5753	130p
AN5763	450p
AN5790	240p
AN5791	225p
AN5836	450p
AN5900	130p
AN6135	120p
AN6247	200p
AN6270	400p
AN6300	600p
AN6306	380p
AN6320	180p
AN6332	320p
AN6341	200p
AN6344	440p
AN6350	610p
AN6359	500p
AN6360	320p
AN6362	400p
AN6371	350p
AN6387	480p
AN6884	200p
AN7105	170p
AN7110	75p
AN7114	120p
AN7115	110p
AN7116	90p
AN7120	100p
AN7130	75p
AN7140	170p
AN7145	195p
AN7146	210p
AN7154	180p
AN7156	240p
AN7168	200p
AN7178	180p
AN7222	75p
AN7254	150p
AN7256	250p
AN7310	60p
AN7311	90p
AN7410	150p
AY3-1015	290p
AY3-1270	800p
AY3-1350	450p
AY3-8910	360p
AY3-8912	400p
BA301	55p
BA311	80p
BA313	60p
BA333	80p
BA401	60p
BA402	50p
BA511	145p
BA514	160p
BA516	150p
BA521	100p
BA524	240p
BA526	180p
BA527	95p
BA532	100p
BA534	220p
BA536	150p
BA546	160p
BA612	120p
BA656	110p
BA658	350p
BA684	400p
BA685	400p
BA1310	160p
BA1320	75p
BA1330	120p
BA1360	160p
BA4403	220p
BA5101	350p
BA5102	140p
BA5204	200p
BA5402	180p
BA5406	180p
BA5408	180p
BA6104	250p
BA6208	175p

Part	Price
BA6209	85p
BA6304	120p
BA6305	140p
BA6410	220p
BA6411	250p
BA6993	150p
BA7001	150p
BA7004	200p
BA7007	200p
BA7021	180p
BA7022	350p
BA7751LS	150p
BA7752	250p
BA7755	150p
BA7767AS	155p
CA3011	110p
CA3048	190p
CA3052	190p
CA3054	95p
CA3085	135p
CA3088E	200p
CA3089E	150p
CA3090Q	250p
CA3130S	100p
CA3134E	280p
CA3140E	38p
CA3160	85p
CA3189E	230p
CA3193E	230p
CA3260E	170p
CA3290E	150p
CX108	950p
CX136	600p
CX139A	750p
CX141	750p
CX145	725p
CX150B	325p
CX175	325p
CX187	825p
CX804A	775p
CX867	575p
CX868	525p
CX877	300p
HA1125	120p
HA1197	130p
HA1199	130p
HA1319	200p
HA1338	300p
HA1339A	350p
HA1377	120p
HA1388	320p
HA1389	210p
HA1392	120p
HA1394	170p
HA1397	200p
HA1398	240p
HA11219	280p
HA11221	180p
HA11225	130p
HA11235	120p
HA11251	190p
HA11423	140p
HA11724	650p
HA12002	220p
HA12003	250p
HA12005	180p
HA12017	100p
HA13001	110p
HA13002	200p
HA13006	400p
HA13007	400p
HA13108	350p
HA13412	600p
HA13432	400p
HA17524	250p
ICL7106	650p
ICL7660	240p
KA2102	150p
KA2130	150p
KA2206	150p
KA2209	125p
KA2210	230p
KA2212	80p
KA2213	130p
KA2214	150p
KA2261	100p
KA2263	100p
KA2264	100p
KA2284	100p
KA2401	150p
KA2412	350p
KA2912	125p
KA2914A	300p
LA1130	240p
LA1150	150p
LA1185	150p
LA1201	75p
LA1210	140p
LA1222	80p
LA1230	130p
LA1364	200p
LA1365	120p
LA1368	220p
LA1385	170p
LA2000	150p
LA2101	270p
LA2200	190p
LA3160	120p
LA3210	65p
LA3300	140p
LA3301	110p
LA3361	100p
LA3375	300p
LA4030	180p
LA4031	140p
LA4032	140p
LA4051	160p
LA4100	85p
LA4101	80p
LA4102	100p

Part	Price
LA4110	120p
LA4120	270p
LA4140	60p
LA4160	100p
LA4182	180p
LA4190	300p
LA4192	140p
LA4200	130p
LA4201	120p
LA4260	230p
LA4261	300p
LA4270	300p
LA4420	140p
LA4422	130p
LA4430	130p
LA4440	150p
LA4445	150p
LA4460	120p
LA4461	120p
LA4500	200p
LA4505	220p
LA4508	200p
LA4510	100p
LA4520	170p
LA4550	200p
LA4555	120p
LA4570	130p
LA5112	200p
LA5523	150p
LA5527	150p
LA5700	300p
LA7011	220p
LA7033	400p
LA7042	280p
LA7046	300p
LA7224	150p
LA7505	250p
LA7507	250p
LA7520	200p
LA7620	500p
LA7800	90p
LA7801	100p
LA7802	300p
LA7806	260p
LA7808	250p
LA7820	100p
LA7823	200p
LA7910	150p
LA7940	200p
LC7131	260p
LC7132	400p
LC7137	450p
LF347	110p
LF353	48p
LF355	60p
LF357	70p
LF398	300p
LM301	26p
LM311	35p
LM319	165p
LM324	30p
LM335Z	120p
LM339	35p
LM348	50p
LM358	45p
LM380	80p
LM381	150p
LM382	130p
LM386	60p
LM387	100p
LM393	45p
LM431	50p
LM710	45p
LM723	40p
LM741DIL	18p
LM741MET	45p
LM747	55p
LM1889	300p
LM1894N	200p
LM3900	40p
LM3909	100p
LM3914	160p
LM3915	160p
LM3916	270p
L200	200p
M491BB1	500p
M494B1	700p
M50115P	320p
M50117P	500p
M50119P	525p
M50784	300p
M50786	500p
M50790	600p
M51161	300p
M51381P	200p
M51387P	800p
M51544	150p
M51848	150p
M54523P	200p
M54563P	200p
M58484	500p
M51516	260p
M51518	200p
MB3712	140p
MB3713	130p
MB3714	270p
MB3715	250p
MB3722	280p
MB3730	160p
MB3731	220p
MB3756	160p
MB3759	200p
MB8719	360p
MC1455	45p
MC1496	65p
MC3401	45p
NE555	20p
NE556	40p
NE558	80p
NE565	110p

CIRCLE NO. 116 ON REPLY CARD

GPIB testing made simple

This simple, low cost, GPIB tester is useful both as a diagnostic tool for interface troubleshooting and as a learning aid. Designed by Giorgio Delfitto and Andrea Sambo*.

IEEE-488 – also known as GPIB and HPIB – is the best known and most widespread parallel instrumentation interface. Many instruments now include an IEEE-488 interface as standard.

Despite its versatility, IEEE-488 can be problematical because way the hardware and software interact. When failures occur, this interaction can make troubleshooting difficult.

Controller boards for IEEE-488 are provided with driver software comprising a routine library including diagnostic tools. When the diagnostic tools fail, the tester described here allows the physical evolution of the interface state to be displayed. The tester is useful as a diagnostic aid, for setting up a new instrument and as a learning tool.

Connecting the tester to the computer controlling the interface system allows the routines sending data or messages from the computer to other devices to be tested. This is useful for verifying the transmission protocol. By placing an instrument capable of sending information to the computer on the bus, it is also possible to analyse the reception protocol.

*The authors are with the Physics Department of the University of Padua in Italy.

Communication protocols

Every interface operation occurs in two distinct steps. During the first, where ATN is 1

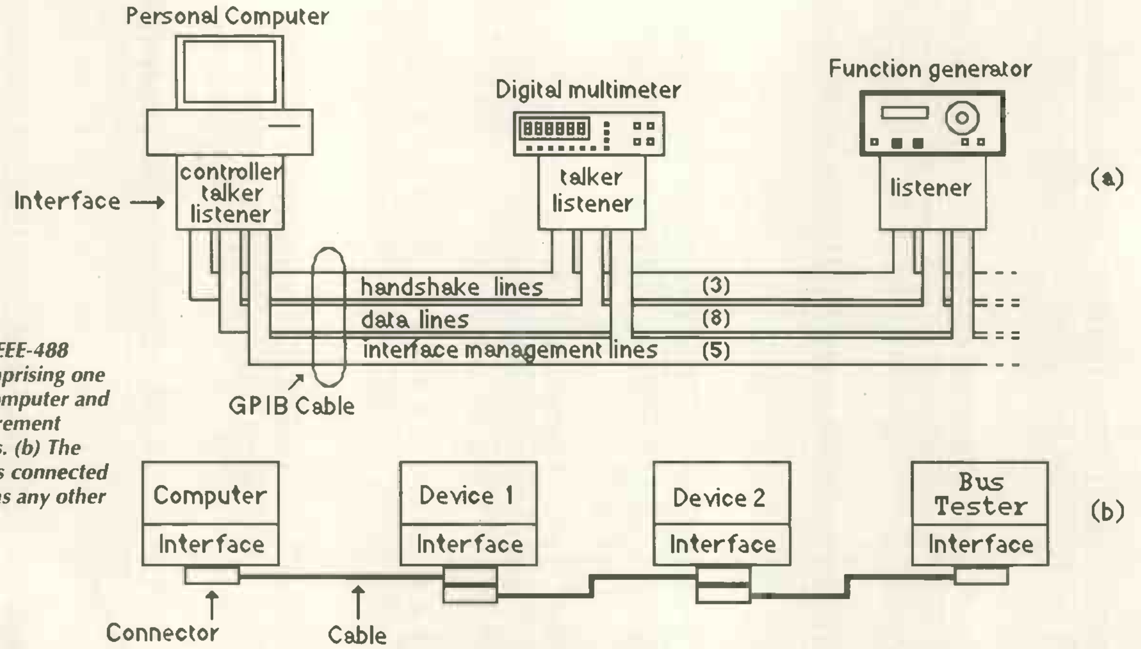


Fig. 1. (a) IEEE-488 system comprising one personal computer and two measurement instruments. (b) The bus-tester is connected to the bus as any other instrument.

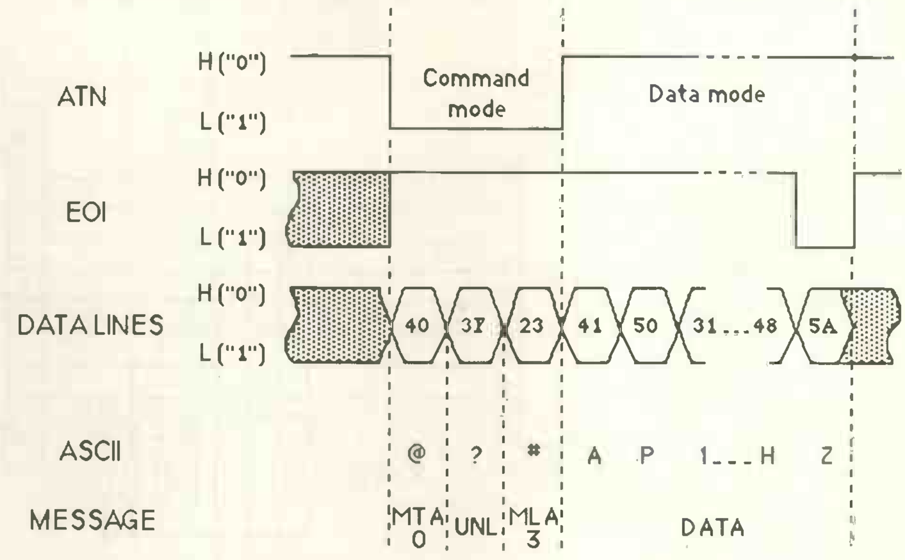


Fig. 2. IEEE-488.2 transmission protocol. Single bytes values are in hexadecimal form. A possible command string is shown.

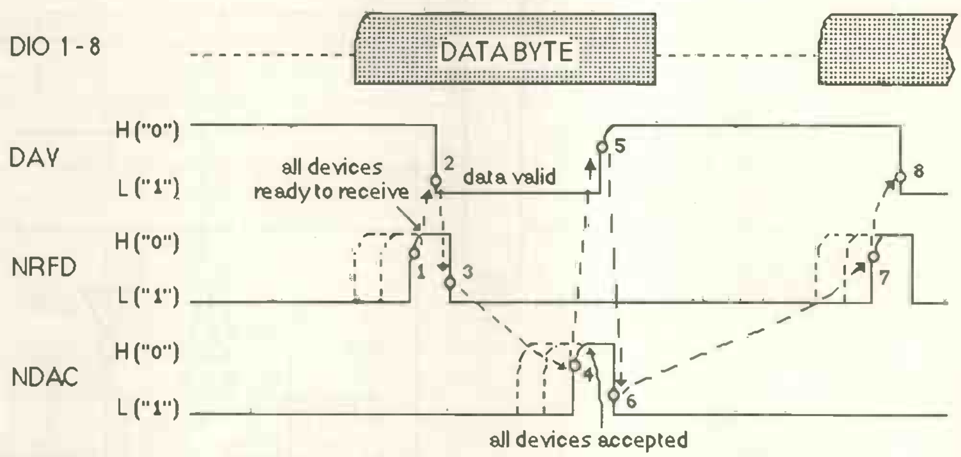


Fig. 3. IEEE488 uses handshaking so that devices of different speeds can communicate.

representing command mode, all the devices involved in the communication are addressed, or are sent interface commands. During the second, i.e. data mode, ATN is zero and data transfer takes place.

Note that programming messages, sent to the devices to set the operating condition – device dependent commands – are considered as data and transmitted during the data mode. Library routine **Send** can be used to transmit the programming message to a device. For example, a call to the Basic routine sending a programming string to a function generator is as follows,

Structure of a Basic command for sending a programming string to a function generator with IEEE-488 interface.

CALL Send (Board, Gen, Data$, Len, TermMod)

Board is an integer variable identifying the controller interface board.
Gen is an integer variable storing the generator address.
Data$ is a string variable containing the programming message.
Len is an integer variable storing the number of characters of **Data$**.
TermMod is an integer variable indicates to the talker – in this case the computer – how to signal end of transmission. Either the EOI line 'End Or Identify' can be asserted, or a particular 'End of Transmission' character can be added to the programming string.

Execution of the Send routine lets the bus state evolve following the *IEEE-488.2* transmission protocol, **Fig. 2**. The controller sets ATN true, i.e. logic low, then sends the computer talker address. For address zero for example, set MTA 0 to 40_{16} or 01000000_2. Next, the interface message UNL, i.e. $3F_{16}$, disables all the listeners previously active. Finally, the generator listener address is set. To set MLA 3 to 3 for example, apply 23_{16} or 00100011_{16}.

Now the controller removes ATN. The talker sends the programming string followed by the termination character, if set, and/or asserting EOI on the last byte of the string. Abbreviations MTA 0, MLA 3, UNL represent interface messages detailed in the standard. 'My talk address' is MTA, 'my listening address' is MLA and UNL tells the device to 'unlisten'

The Receive routine can be used to poll an instrument, in the format.

CALL Receive (Board, Mult, Meas$, Len, TermMod)

Here too the variable Board identifies the controller interface board. Variable Mult contains the multimeter address while TermMod stores, in this case, the termination mode used by the talker – multimeter – when sending data. The Len variable specifies the maximum number of characters the multimeter has to read if the termination condition is not detected, for example because of a circuit failure.

After the call of the routine Receive, the variable Meas$ contains a string representing the result of the measurement. Execution of Receive produces the following activity on the bus as established by the following IEEE-488.2 reception protocol.

The controller sets ATN true and sends UNL. This disables all the previous listeners.

Next MLA 0 is set to 20_{16}, which is the computer listener address. The multimeter talker address is sent, and finally, ATN is removed.

The computer receives data bytes until the end of message condition is verified;

The IEEE-488 bus tester

To understand how the tester works, consider handshake diagram **Fig. 3**.

Every byte is transferred under control of the handshake lines, named DAV (Data Valid), NRFD (Not Ready For Data), NDAC (Not Data Accepted). Use of these signals is asynchronous, allowing for devices having different response speeds.

An active talker with a byte to send must sample the NRFD line. A low level on this line means that one or more listener is not ready to receive data. In this case, the talker must wait until NRFD becomes false as shown by point 1 in **Fig. 3**. In the meantime the listeners keep NDAC true to indicate they are not accepting data.

When NFRD becomes false, the talker asserts DAV to validate the byte it has already put on the data lines, as in point 2 of Fig. 3.

After detecting the falling edge of DAV, the listeners immediately assert NRFD (point 3), and acquire the data byte (point 4). Obviously,

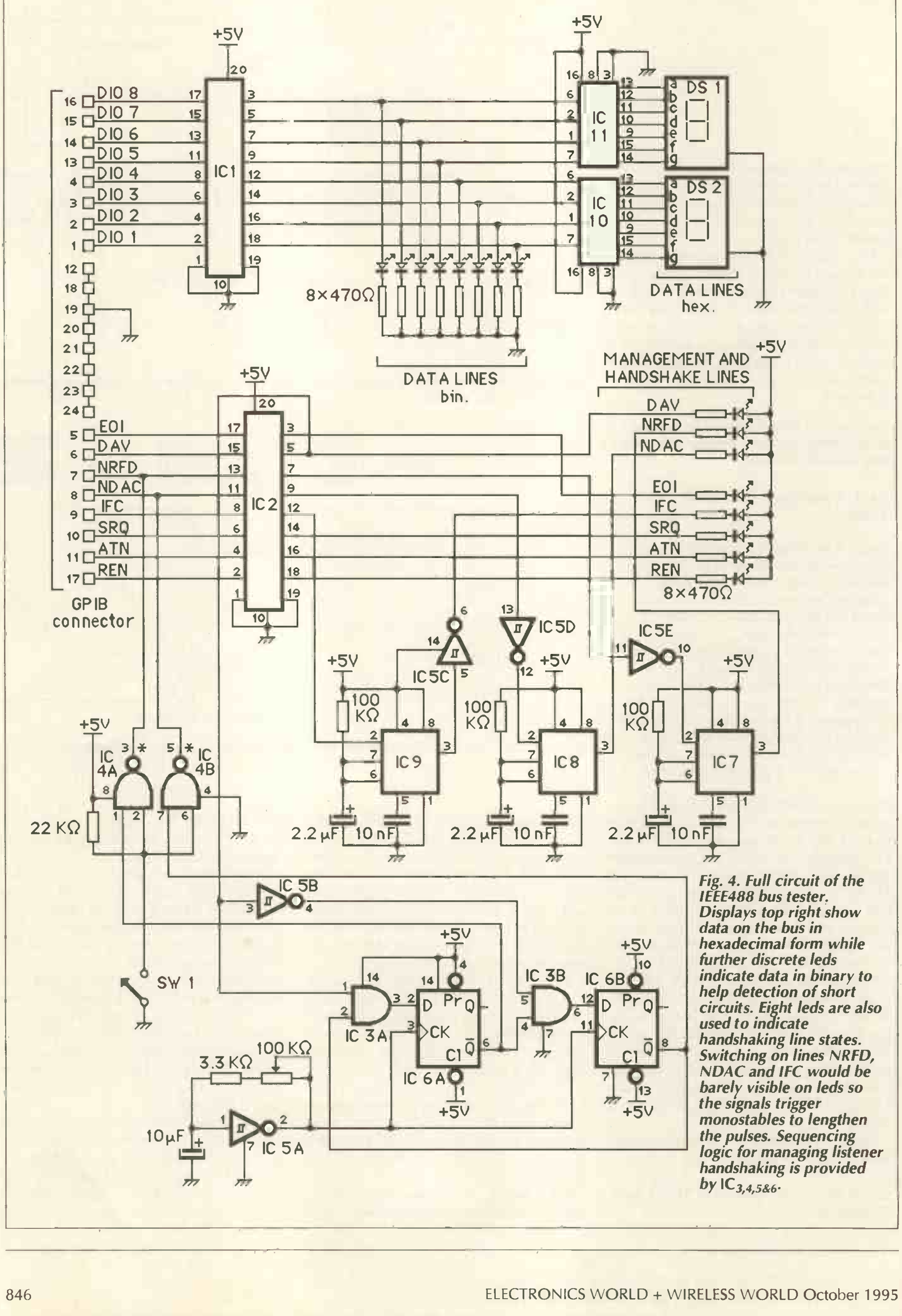


Fig. 4. Full circuit of the IEEE488 bus tester. Displays top right show data on the bus in hexadecimal form while further discrete leds indicate data in binary to help detection of short circuits. Eight leds are also used to indicate handshaking line states. Switching on lines NRFD, NDAC and IFC would be barely visible on leds so the signals trigger monostables to lengthen the pulses. Sequencing logic for managing listener handshaking is provided by $IC_{3,4,5\&6}$.

IEEE-488 overview

The most important features of the IEEE-488 interface are the bus structure and the ttl negative-logic convention. Open-collector outputs are used to drive the bus, so it is possible to wire-or signals without additional gating.

Figure 1 shows that the bus comprises 24 lines. Eight of the lines are devoted to data transfer, eight are ground connections, detailed in the panel. The remaining eight are control lines grouped as five interface management lines and three handshake lines.

Activity on the bus is supervised by a device called the controller, which is usually a personal computer. This device – one of a maximum of 15 – co-ordinates the operation of the whole system via the interface management lines. Communication over the data lines is controlled by handshake lines.

When a data transfer takes place, only one device – called the talker – can transmit data whereas one or more devices, known as listeners, can receive them simultaneously.

Each device has its own address, used by the controller to designate the active talker and listeners. There are 31 possible addresses, but each device can have more than one address. Each address is represented by the five least significant bits of a byte (00000 to 11110). The all-ones configuration is mentioned later.

Two other bits, weighted 2^5 and 2^6, specify whether a device is a listener or a talker. The possible binary addresses are then x0100000 to x0111110 for the listeners, and x1000000 to x1011110 for the talkers.

Any device can be talker or listener. A digital multimeter, for example, must be able to receive programming data and send the results of the measurement to the computer.

Therefore, in a GPIB communication, active talker and listeners have to be designated before the data can be transferred. To do that the controller sends the addresses over the data lines after asserting the attention line, labelled ATN. Its aim is to inform all the devices that the controller is sending interface messages to the interface circuitry, namely addresses or other commands.

When the attention line is asserted, all the devices must listen to the interface messages. If a device is addressed, it prepares itself for the data transfer that will start when ATN is removed.

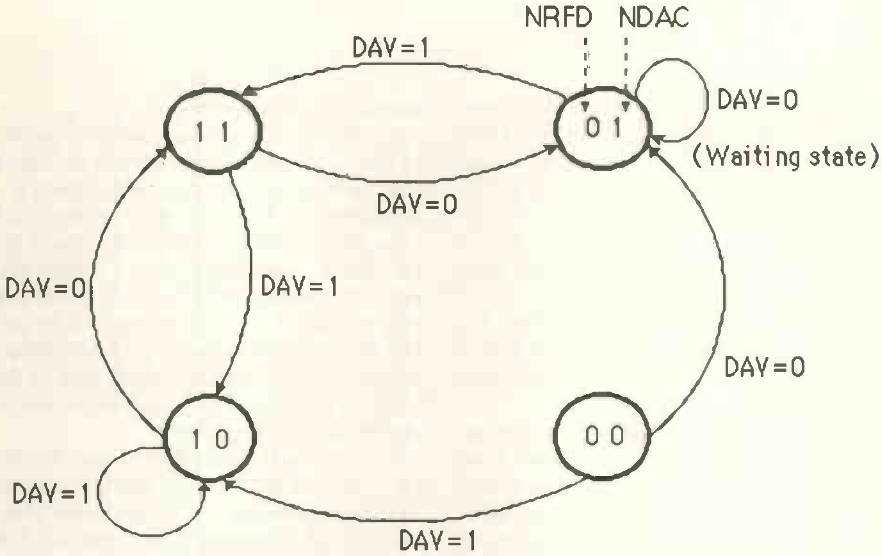


Fig. 5. State diagram of the handshaking logic of Fig. 4. Should the two outputs both be zero on power up, they return to the 'waiting' condition, i.e. NRFD=0 and NDAC=1, within three clock pulses. All these boolean variables are negative logic, i.e. 0V is true.

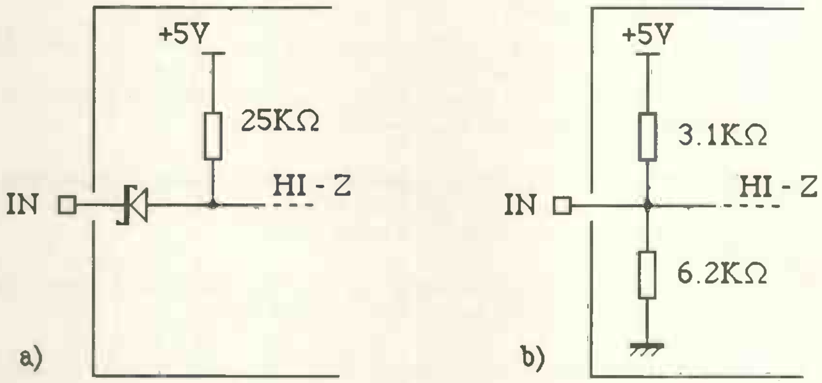


Fig. 6. Comparison between an ls-ttl input circuit, (a) and a typical IEEE-488 input (b).

because of the wired-or connection, the rising edge of this line is set by the slowest device, point 5. Subsequently, the listeners set NDAC to one and NRFD to zero (points 6 and 7), waiting for a new data transfer (point 8).

If one of the devices has a handshaking problem, the system can lock indefinitely. If, for example, a device has NDAC shorted to ground, the talker will wait forever for the rising edge of NDAC shown in point 4 of Fig. 3. To avoid such problems, it is possible to set a timeout by means of the controller board configuration program. When the preset time expires, the controller automatically aborts the i/o operation, activating an error condition.

From the handshake diagram it is clear that the active talker, before modifying the state of DAV, must always wait for NRFD or NDAC going false (see points 1 and 2 or 4 and 5).

As a result, the data transfer rate depends on the speed of the slowest device connected to the bus. This means that, by connecting an always active listener – the tester for example – with adjustable response speed, the system can be made to work very slowly. This allows the bus state to be displayed in real time.

In order to work so slowly, a long timeout must be set to avoid error conditions. Furthermore, it will be necessary to disable the Automatic Serial Polling function, if present. In this mode, the controller board executes some operations autonomously. Since these operations are outside of the program's control, the bus sequences that result can be difficult to interpret.

Circuit details

There are three distinct section of the tester. In the first, comprising $IC_{1,10,11}$, displays $DS_{1,2}$, show the data lines state, in hexadecimal and in binary notation by means of eight leds. These light when the line is true.

Hexadecimal notation allows rapid decoding of the data, whereas the binary indication can be useful in case of short circuit of a data line to ground or the supply rail. In this case, the corresponding led will be permanently on or off indicating the failure to the operator.

The second section, incorporating of $IC_{2,7,8,9}$, displays the state of the handshake and management lines via eight further leds.

Signals NRFD, NDAC and IFC can be so fast – even at low transfer rate – as to become almost invisible. For this reason they are not displayed directly: rather they are used as trigger pulses for three one-shot multivibrators that generate long pulses. These are more readily detectable by the human eye.

The third section includes $IC_{3,4}$ and IC_6. These ICs form a sequential circuit capable of managing the listener handshake, whose state diagram is shown in Fig. 5.

The 3.3kΩ resistor, IC_{5A}, the 100kΩ potentiometer and the 10μF capacitor make a variable frequency oscillator that clocks the circuit. When SW_1 is open, the handshake circuit is always active with no dependence on ATN. This makes it possible to follow the slowed bus activity both in data and in command mode.

By closing SW_1, the open-collector outputs of $IC_{4A,B}$ are disabled. The tester no longer contributes to the handshake so the bus activity proceeds as if the tester were disconnected.

An *75452* interface driver was chosen for the NDAC and NRFD output buffer IC_4. According to the standard, the maximum sink current is 48mA, which is too high for the normal ttl or hc-mos outputs. We have deliberately avoided GPIB transceivers such as the *SN75161* or *MC3446* since they are expensive and not so readily available.

Inputs of the buffers *74LS240* and *74LS244* ($IC_{1,2}$) present to the bus the equivalent circuit shown in **Fig. 6a** that can be considered a negligible load compared to the typical GPIB input circuit, Fig. **6b**. ■

Further reading

Official documents:

ANSI/IEEE (New York) Std 488.1 – 1987, *IEEE Standard Digital Interface for Programmable Instrumentation.*

ANSI/IEEE (New York) Std 488.2 – 1987, *IEEE Standard Codes, Formats, Protocols and Common Commands for use with IEEE-488.*

Handbooks and application notes:

Hewlett-Packard, *Tutorial description of the Hewlett-Packard Interface Bus* (1983).

National Instruments (Austin TX), *In-depth course on IEEE-488.2 (GPIB)* – (June 1991).

Takeda Riken (Tokyo), *Application note No. 2-1, GP-IB INTERFACE: General Description.*

Texas Instruments (Dallas TX). *Linear and Interface Circuits Applications* (1986).

IEEE488 bus details

Front and side views of the GPIB connector are shown here. This type of connector is male on one side, female on the other, allowing cascade connections as shown in Fig. 1b.

Data and handshake lines are detailed in the main text. Management lines are ATN, IFC, REN, EOI, SRQ. Their meaning and principal functions are listed below.

ATN *(Attention). This signal is managed by the controller. Its active state indicates that the controller is sending commands or addresses (interface messages). When not asserted, it says to talker and listeners that the bus is ready to the data transfer.*

IFC *(Interface Clear). By asserting this line for a short period of about 100μs the controller can reset the interfaces of all the devices connected to the bus.*

REN *(Remote Enable). The controller keeps this line permanently asserted while the interface is working.*

SRQ *(Service Request). All devices can use this line to request service from the controller. For example, at the end of the measurement, an instrument can signal that it is ready to be read.*

EOI *(End Or Identify). This line is asserted by the active talker while the last byte is sent, to signal the 'end of string' condition. It is used by the controller in a particular service request response mode.*

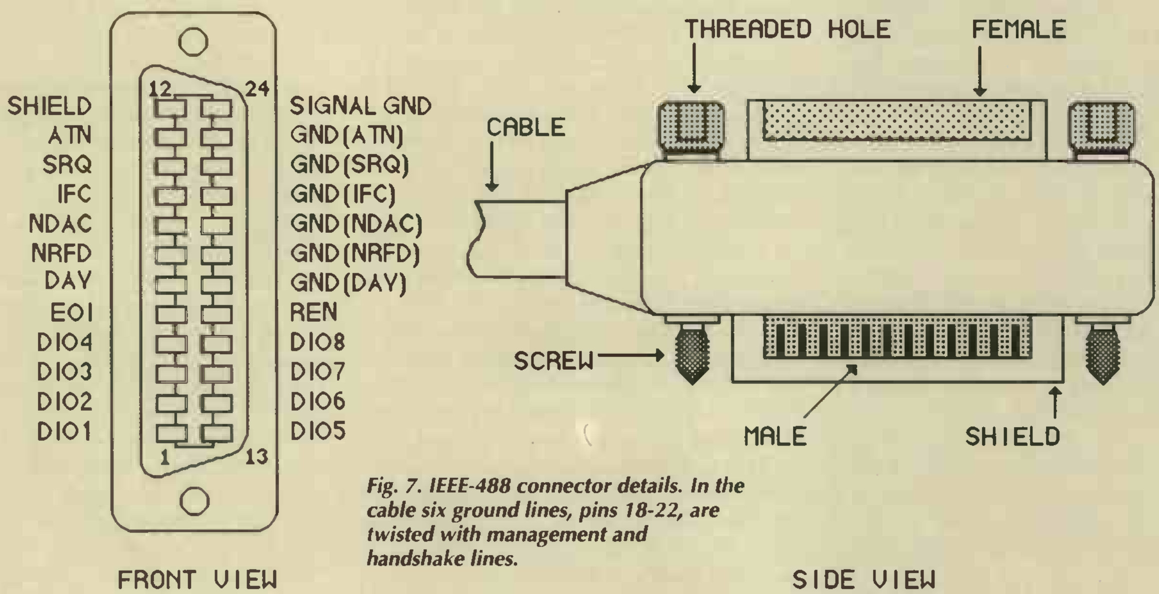


Fig. 7. IEEE-488 connector details. In the cable six ground lines, pins 18-22, are twisted with management and handshake lines.

Analysing dc via SPICE

Owen Bishop describes how to get the best from your circuit emulator when performing dc analysis.

At present there are numerous Spice-based circuit simulation packages, most of them based on Spice2 and some on the more recent member of the Spice family, Spice3. In this article I will be working with Spice3, referring where necessary to Spice2 on the few points of difference. References to Spice without a qualifying digit apply equally to Spice2 and Spice3.

IsSpice4 is a popular implementation of Spice3, and is used here to illustrate this discussion. Another Spice2-based simulator is *Micro-Cap IV*, which also has some Spice3 capabilities. Naturally, each implementation has its own distinctive enhancements, but the essentials are common to both. Most routines described are also applicable to a wide range of other packages.

The following analysis of a simple *RLC* circuit, **Fig. 1,** illustrates the syntax and input /output routines of Spice, using *IsSpice4*. This program is distributed as part of the ICAP/4 package, together with two linked programs, as outlined below. Begin running the ICAP package with a double click on the ICAPS icon. In the Select Project dialogue box, click on Cancel, as this is a new circuit and there is no existing file to select. In the Name New Project box, key in the file name. The next box to appear gives the option of selecting which part of ICAP/4 to use:

* Edit Text Files – the *IsEd program* for entering and editing netlists.
* Launch IsSpice – for simulations.
* Launch Scope – for *Intuscope*, an oscilloscope simulator.
* Launch SpiceNet – for entering schematic diagrams.

Figure 1 was produced with SpiceNet, but it can be entered as a netlist, using *IsEd*. To enter the netlist, select Edit Text Files and key

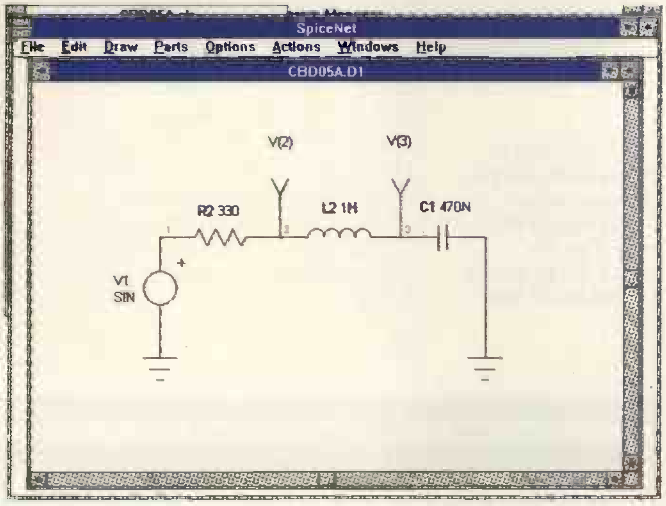


Fig. 1. This simple RLC circuit was drawn using SpiceNet. The Y-shaped symbols represent output or test points. Note the ground symbol on node 0. When the schematic is complete, the program automatically generates the netlist, ready for analysis.

Spice and beyond

Spice-based simulation packages differ in the degree to which they retain the features of the Spice prototype. Windows-based *IsSpice* uses netlists in the syntax common to Spice2 and Spice3.

Results of analyses are printed out or displayed in the 'teletype' format of the original Spice, but may be displayed more effectively using the linked program, ruscope. *Micro-CapIV* and *TopSpice* are similar to *IsSpice*, but dos based. All three are enhancements of Spice in that they allow for subsequent analyses of the same circuit to be called from dialogue boxes. All allow the circuit to be entered as a netlist. The circuit may also be entered as a schematic. All have facilities for displaying output as graphs-on the monitor screen. SpiceAge, though drawing on the principles of Spice in the sense that it uses a netlist with syntax close to that of Spice, has adopted an entirely new approach to initiating analyses and displaying the results.

Although SpiceAge does not include routines for drawing schematics and converting them to netlists, these facilities are available in an linked program known as *GESECA*.

Table 1. This is the Spice netlist for the *RLC* circuit of Fig. 1. The .PRINT and .PLOT commands of Spice2 are not available in Spice3, but *IsSpice* has retained these commands for convenience.

CBD05 – series RLC circuit

```
V1    1    0      SIN    0    1V 500HZ1M
R1    1    2      330
L1    2    3      1
C1    3    0      470N
.TRAN       100U 25M
.PRINT TRAN       V(2)   V(3)
.PLOT TRAN V(2) V(3)
.END
```

in **Table 1** on the editing screen. The first line is the title, and is ignored by Spice. The second line defines the voltage source, with its positive connection to node 1 and its negative connection to node 0. It is a sine-wave generator with zero offset and an amplitude of 1V. Its frequency is 500Hz and there is a delay of 1ms before it begins. All resistors must have a name beginning with R to identify them as resistors. Following the name are their node numbers and values.

Capacitors are similarly listed. The netlist next has a set of command statements. The .TRAN command instructs Spice to calculate values every 100μs, for a total period of 25ms. The .PRINT command asks for the voltages at nodes 2 and 3 to be listed in the output file. The .PLOT command asks for these voltages to be plotted as a graph. It is obligatory to conclude the netlist with an .END statement.

After saving the netlist file, with a .cir

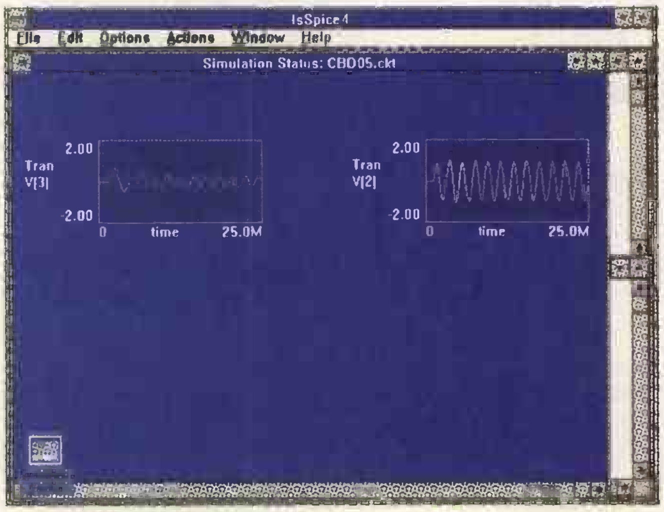


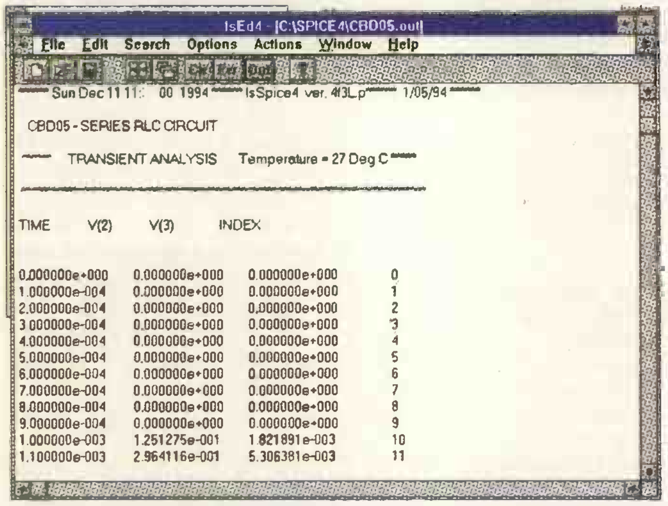
Fig. 2. IsSpice produces this display at the end of the transient analysis of the RLC circuit.

Schematic entry – an advantage or not?

With most of the newer Spice-based simulators, it is possible to prepare the netlist by drawing the schematic on the screen. If the drawing is correct, you can be sure that the netlist generated from it is correct too.

Error messages may point out deficiencies of the schematic such as unconnected component terminals. This advantage is offset by the need to learn, usually, complicated routines for drawing the schematic. There would be some compensation for this if the printed schematic could be used as art-work but, in all the packages I have seen, the graphics quality is inadequate for this. Also, a number of symbols provided by the package may be non-standard, such as the zig-zag resistor, though there may be a facility for drawing your own symbols.

In some programs it is necessary to use the 'ground' symbol to indicate the line that is to be Node 0, but the ground symbol is inappropriate in many contexts. When working on a circuit, it is invariably necessary to revise the circuit, but editing a schematic can be horrendous. Recipe for success? Scribble the design on paper, number or name the nodes, key in the netlist.



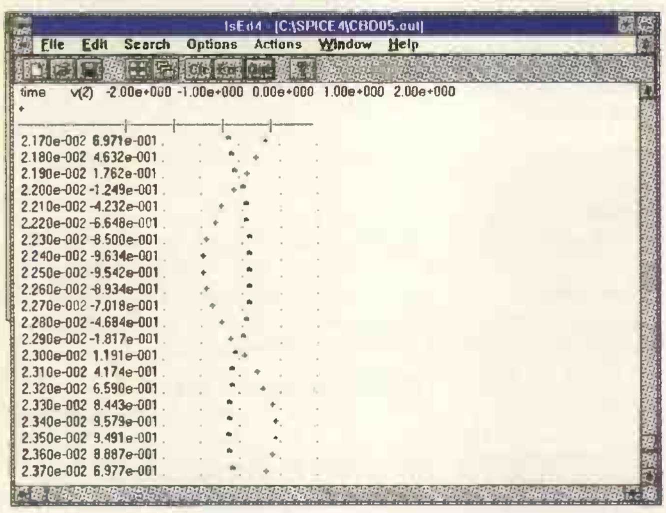
***** Sun Dec 11 11: 00 1994 ****** IsSpice4 ver. 4f3L.p****** 1/05/94 ******

CBD05 - SERIES RLC CIRCUIT

***** TRANSIENT ANALYSIS Temperature = 27 Deg C *****

TIME	V(2)	V(3)	INDEX
0.000000e+000	0.000000e+000	0.000000e+000	0
1.000000e-004	0.000000e+000	0.000000e+000	1
2.000000e-004	0.000000e+000	0.000000e+000	2
3.000000e-004	0.000000e+000	0.000000e+000	3
4.000000e-004	0.000000e+000	0.000000e+000	4
5.000000e-004	0.000000e+000	0.000000e+000	5
6.000000e-004	0.000000e+000	0.000000e+000	6
7.000000e-004	0.000000e+000	0.000000e+000	7
8.000000e-004	0.000000e+000	0.000000e+000	8
9.000000e-004	0.000000e+000	0.000000e+000	9
1.000000e-003	1.251275e-001	1.821891e-003	10
1.100000e-003	2.964116e-001	5.306381e-003	11

Fig. 3. First part of the transient analysis 'printout' of the IsSpice output file, as viewed on the screen. It can also be printed out as hard copy.



time v(2) -2.00e+000 -1.00e+000 0.00e+000 1.00e+000 2.00e+000

time	v(2)
2.170e-002	6.971e-001
2.180e-002	4.632e-001
2.190e-002	1.762e-001
2.200e-002	-1.249e-001
2.210e-002	-4.232e-001
2.220e-002	-6.648e-001
2.230e-002	-8.500e-001
2.240e-002	-9.634e-001
2.250e-002	-9.542e-001
2.260e-002	-8.934e-001
2.270e-002	-7.018e-001
2.280e-002	-4.684e-001
2.290e-002	-1.817e-001
2.300e-002	1.191e-001
2.310e-002	4.174e-001
2.320e-002	6.590e-001
2.330e-002	8.443e-001
2.340e-002	9.579e-001
2.350e-002	9.491e-001
2.360e-002	8.887e-001
2.370e-002	6.977e-001

Fig. 4. Part of the teletype-style graphical plot showing the variations in V(2) as pluses, and V(3) as asterisks.

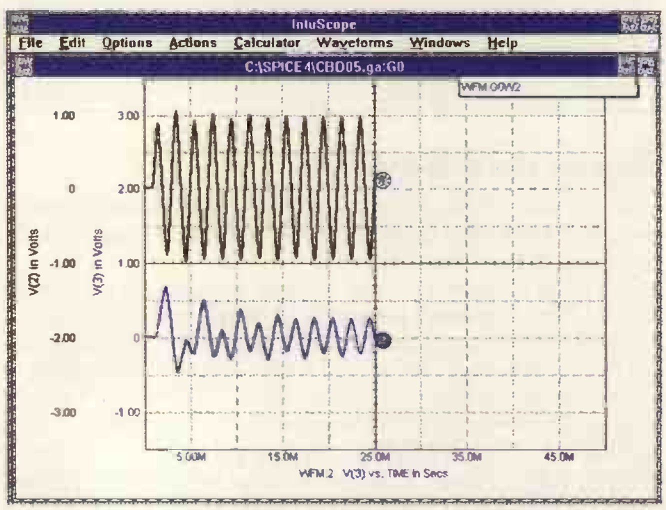
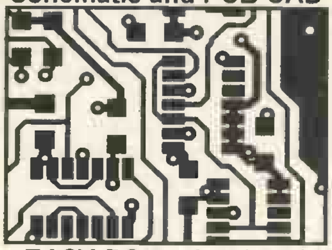


Fig. 5. Another way of looking at the results of the IsSpice analysis is by using Intuscope. This oscilloscope-like display shows the two output waveforms tiled, with V(2) above and V(3) below. Alternatively, they can be shown superimposed on the same set of coordinates.

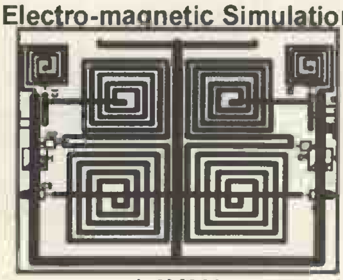
RAPID, ACCURATE ELECTRONICS CAD

Schematic and PCB CAD



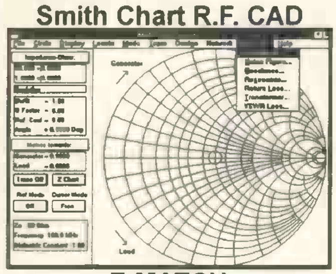
EASY-PC Professional

Electro-magnetic Simulation



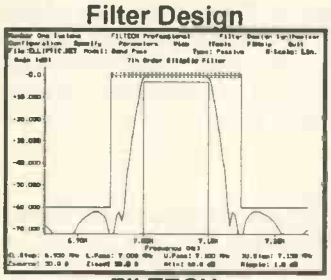
LAYAN

Smith Chart R.F. CAD



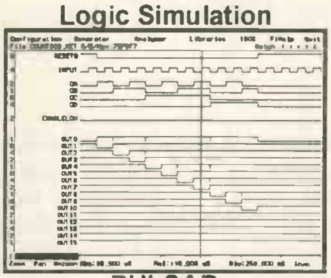
Z-MATCH

Filter Design



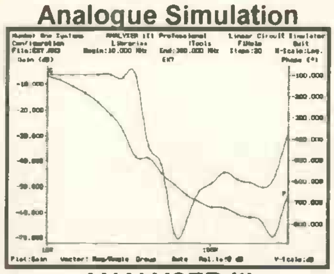
FILTECH

Logic Simulation



PULSAR

Analogue Simulation



ANALYSER III

Number One Systems

Europe: Ref: WW, Harding Way, St.Ives, Cambs, PE17 4WR, UK
Tel: +44 (0) 1480 461778
Fax: +44 (0) 1480 494042

USA: REF: WW, 126 Smith Creek Drive, Los Gatos, CA 95030, USA
Tel/Fax: (408) 395-0249

From £98.00

CIRCLE NO. 117 ON REPLY CARD

SYNTHESISED SIGNAL SOURCE

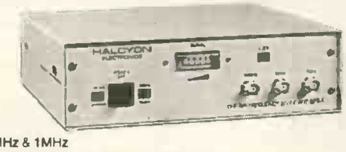
NEW from Halcyon

an innovative design from an established 'Off-Air' Company

- dc to 16 MHz in 0.01 Hz steps
- Sinewave output 0dBm into 50Ω
- Can be run independently or genlocked to external source
- Custom designed chip set
- Freestanding rack mounting, or OEM options available
- Increased resolution and increased stability options available

Models available October, contact us for prices

'OFF-AIR' FREQUENCY STANDARD



Variants from **£195**+VAT

- ★ Provides 10MHz, 5MHz & 1MHz
- ★ Use it for calibrating equipment that relies on quartz crystals, TCXOs, 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 1×10^{-8} (1 sec)
Typical – 4×10^{-9} (1 sec)
Long term – tends to 2×10^{-12} (1000 sec)
Call for 'Off-Air' Standard list

TEST EQUIPMENT

We are well known for our quality, new and used Test Equipment. Our list is extensive, ranging through most disciplines. Call for details and a complete list

HALCYON ELECTRONICS VISA

423, KINGSTON ROAD, WIMBLEDON CHASE, LONDON SW20 8JR
SHOP HOURS 9-5.30 MON-SAT. TEL 0181-542 6383. FAX 0181-542 0340

CIRCLE NO. 118 ON REPLY CARD

STOCK CLEARANCE SALE
QUALITY USED TEST & MEASURMENT EQUIPMENT

SIGNAL SOURCES

Arbitrary Waveform Synthesiser dc-50 MHz HP 8770	£4000
Programmable Function Generator 20 MHz Schlumberger 4431	£1200
Pulse Generator Lyons Instruments PG-28	£200

ANALYSERS

Logic Analyser HP16300	[illegible]400
Logic Analyser Dolch Palas 40C50	£3[illegible]
Logic Analyser Philips PM 551A/30	£800
Logic Analyser Philips PM3500	[illegible]
RF Network Analyser [illegible] to 1.3GHz HP 8754A	£2800

SPECTRUM ANALYSERS

Spectrum Analyser 1.8 GHz TR4122	£POA
Spectrum Analyser HP 8557A	£1200
Spectrum Analyser LF HP 3580A	£1000

SIGNAL

S-Parameter Test Set 25GHz HP 8515A	£POA
Impedance Analyser LF 13MHz HP 4192A	£7000

FREQUENCY/COUNTER TIMERS

Microwave Frequency CounterEIP 548A	£1800
Counter Timer dc-1.3GHz Racal-Dana 1992	£600

OSCILLOSCOPES

Oscilloscope 20MHz CompactTelequipment 034	£120
Oscilloscope 50 MHz Philips PM3055	£400
Oscilloscope 60MHz Tektronix 2215	£350
Oscilloscope Digital 100M sample/sTektronix 2230	£1300
Oscilloscope Digital Sampling Tektronix 11802	£12000
Oscilloscope Digitising 1 GHz HP 54100D, (inc. 4 x 54100A 1GHz Probes)	£6000
Oscilloscope Gould OS3000	£200
Oscilloscope 1GHz Mainframe 7854	£1000
Oscilloscope 100MHz Philips [illegible]	£700

TELECOMMS/DATACOMMS TEST

Cellular Radio Interface HP 8956A	[illegible]
Parallel & Serial Word Generator HP8018A	[illegible]
[illegible] Tester, HP3762A/HP3763A	£400
Digital [illegible] Analyser HP3764A/001	£1200
Protocol Analyser [illegible]	£1600

PLOTTERS

Graphics Plotter 2 Pen A4 HP7470A/002	£150
Graphics Plotter 6 Pen A3 HP7475A/001	£300
Graphics Plotter 8 Pen A3 HP7550A	£500
Graphics Plotter "ColorPro" HP7440A	£200

DIGITISERS

Graphics Tablet HP 9111A	£50

MISCELLANEOUS

Probe HP1120A	£50
Probe HP1121A	£50
Resistive Divider Probe Kit HP10020A	£50
Solder Iron, Sucker, and Pump Lab Set	£50

Intec Systems

CALL NOW FOR FURTHER DETAILS
01702-258700
OR FAX US ON 01702-258461

VISA

INTEC SYSTEMS INT'L LTD, ASHTREE HOUSE, GT STAMBRIDGE, ROCHFORD, ESSEX SS4 2AX

CIRCLE NO. 119 ON REPLY CARD

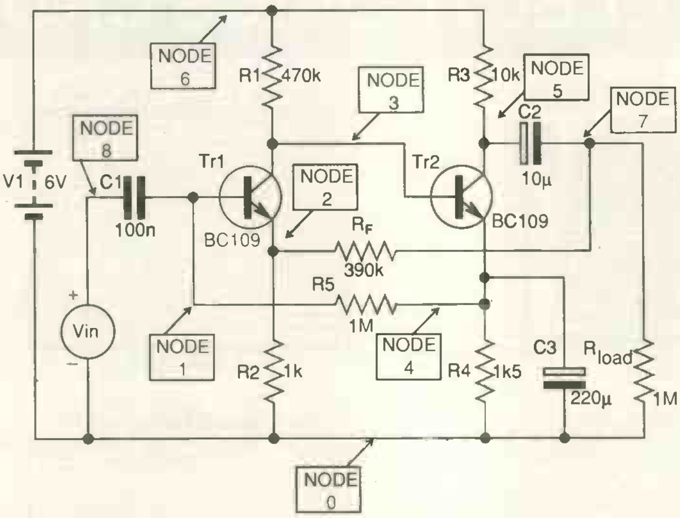


Fig. 6. This low-noise amplifier is used to demonstrate some of the data obtainable from a Spice dc analysis.

extension, select the Actions menu and click on Simulate. **Figure** 2 shows the screen after the Simulation Control box – not needed here – has been Minimised and the Error File and Output File windows reduced in width.

The small-scale graphs summarise transient analysis of the voltages at nodes 2 and 3, showing how voltages at various nodes vary during the period of analysis. If there are errors in the netlist or analysis, they are reported in an Error File – same name but with .err extension – visible in the Error File Window.

Generating output files

To generate the 'output file', select the File menu, then click on Exit/Quit. This causes the results of the analysis to be saved simultaneously in an 'output file' with the same name but with an .out extension. The program then takes you back to the ICAPs menu. Select Edit Text File, which displays the netlist again, then click on the OUT button on the toolbar to see the 'Output file'.

Production of a separate output file harks back to the early days of Spice, when output was produced on a teletype machine. The routine begins by repeating the netlist, but with models expanded. It then tabulates the initial transient solution of the circuit – the nodal voltages when t=0.

All nodes are at 0V in this example. The first part of this is shown in **Fig. 3**. It lists the voltages, which are all zero to start with, owing to the specified delay of 1ms. Later sections of the list could be used as the basis of further analyses with a calculator.

As there is a .PLOT statement in the netlist, the output file is completed by a graphical plot, as might be made on a line printer, part of which is shown in **Fig. 4**. This is useful for finding the exact location of points such as maxima and minima.

Using the oscilloscope

Selecting the Scope option from the Actions menu runs the *IntuScope* program. The Waveform menu lists the waveforms available for display. In this example, select V(2) and then V(3) to obtain **Fig. 5**. This has the appearance of an oscilloscope screen, the bold lines of the plot helping to enhance the effect. The two traces are identified by a circled number and are plotted in different colours.

DC analysis

After that brief summary of the program, I will discuss more systematically what Spice can do and how it does it. The analyses in Spice comprise the dc analysis of steady states, ac analysis dealing mainly with the effects of frequency and transient analysis which shows how voltages vary in time.

Initially in a dc analysis, Spice converts all capacitances to open-circuits and all inductances to short-circuits. It then computes the stable operating point of the circuit with only dc sources applied. Finally, it sweeps the dc source voltages over given ranges and calculates the corresponding node voltages and branch currents. As an example of this, take **Fig. 6** – a low-noise amplifier circuit. **Figure 7** shows what this looks like to Spice as it performs the dc analysis.

Assuming that this circuit is to be entered as a netlist, not a schematic, first draw the schematic on paper, numbering the nodes, with the 0V (ground line) as node 0. Using *IsEd*, key in the netlist, **Table 2**. Note the use of MEG for MΩ. The letter Q is always used for a bipolar transistor, followed by its connections (collector, base, emitter) and its model name – in this instance, *BC109*.

A definition of the model must appear somewhere in the netlist, after the word .MODEL. This states whether the transistor is npn or pnp, then lists the more important parameters. Any parameters not listed are assigned default values. In this example the model statement defines IS (saturation current), NF (forward emission coefficient), BF (forward current gain), ISE (BE junction leakage current), IKF (b_F high current rollover corner, and NE (BE junction leakage emission coefficient). Default values are automatically

Spice netlist format

- The first line is a *title* statement. Any netlist details referred to in this line are ignored.
- Lines if any beginning with * are comment statements and are ignored. *Element statements* list each device on a separate line.
- Lines beginning with a full-stop and a command, for example .TRAN and .PRINT are control statements. These instruct the computer to perform given types of analysis, and to produce given types of output.
- Lines beginning with .MODEL are statements which set the values of the parameters of a named model.
- The last line is the *end statement,* which is always .END.

Table 2. Spice netlist for the low-noise amplifier of Fig. 7.

```
CBDO5 – low-noise amplifier
R1      6  3  470k
R2      2  0  1k
R3      6  5  10k
R4      4  0  1.5K
R5      4  1  MEG
RF      7  2  390k
RLOAD   7  0  1MEG
C1      1  8  100N
C2      5  7  10U
C3      4  0  220U
Q1      3  1  2   BC109
Q2      5  3  4   BC109
.MODEL BC109 NPN(IS=18F, NF=1,
BF=400, ISE=0, IKF=0.01, NE=1.5)
V1    6  0  DC  6
VIN   8  0  AC  SIN   0   0.005   1K
.DC   V1 0  6   0.2
.OP
.PRINT DC V(7)
.END
```

Table 3. Part of the output file from a dc analysis consists of the Small Signal Bias Solution, and currents through the sources.

```
Circuit: CBD05 – low-noise amplifier
***** Small signal bias solution – op

       Node          Voltage
***
       V(8)          0.000000e+000
       V(7)          6.726277e-003
       V(1)          5.283758e-001
       V(4)          5.517291e-001
       V(5)          2.331081e-003
       V(2)          9.349525e-003
       V(3)          1.166624e+000
       V(6)          6.000000e+000

       Source        Current

       v1#branch     -3.77176e-004
       vin#branch    0.0000000e+000
```

Spice command statements for dc analysis

.DC initiates a dc analysis with all capacitances open-circuited, all inductances short-circuited, and all ac sources inactivated. Dc inputs (one or two voltage or current sources) are swept over prescribed ranges. Node voltages and branch currents are calculated.

.OP Operating point (or bias point). Prints the voltages at all nodes, the current through each source, and the total power consumption. Also prints the currents, terminal voltages and sundry parameters of all non-linear devices. These values are always calculated when a dc analysis is called for, but not printed unless the .OP command is given.

.TF Calculate the small-signal transfer function (the gain) as a voltage gain, a current gain, a transconductance or a transresistance, depending on the quantities specified after the command. Also calculates input and output resistances.

.SENS Calculates the effect of the values of circuit elements and of model parameters on selected output variables. For example, the effect of variations in the base resistance of a modelled transistor on the output current of the circuit, expressed as amps percent. This identifies the quantities which are most critical in determining the performance of a circuit. Sensitivity analysis is usually a available only in the more expensive simulation software.

.TEMP Specifies the ambient temperature at which the circuit is operating. The default value is 27°C. If several temperatures follow this command, the analysis is repeated at each temperature.

.NODESET Sets the initial voltage at one or more nodes to a prescribed value. Used when the Spice algorithms can not find a sensible initial solution.

.PRINT DC Calls for the results of the analysis to be printed as a set of tables (not in Spice).

.PLOT DC Calls for the results of the analysis to be plotted as a graph (not in Spice3).

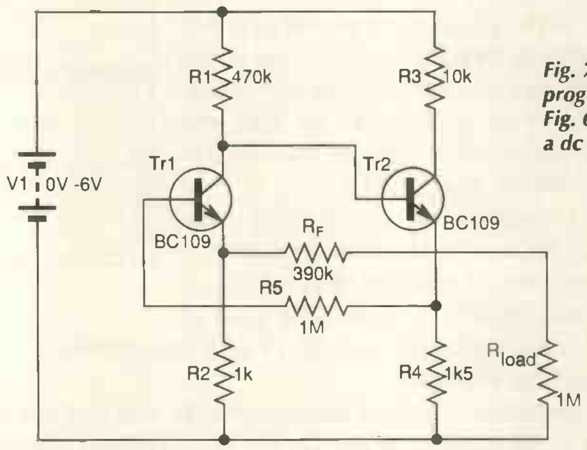


Fig. 7. This is how a Spice program sees the circuit of Fig. 6 when asked to perform a dc analysis.

given to the other 37 parameters – it is up to the user to decide which ones are important enough to warrant specifying.

The two sources are named as V1, the battery, and VIN which is a sine-wave signal source. The battery is shown connected to nodes 6 and 0 with a value 6V dc. The 'DC' is optional in the statement but helps to make the net list more intelligible. Voltage VIN is inactive during the dc analysis but is defined as connected between nodes 8 and 0, with ac output in the form of a sine wave, 0V offset, 0.005V amplitude and a frequency of 1kHz. It is not essential to define its output for a dc analysis. Only the node connections are required. Spice assumes that the voltage is zero.

The .DC command instructs Spice to sweep V1 from 0V to 6V in 0.2V steps. The .OP command calls for a printout of the operating point voltages (see box) The .PRINT command asks for a table of the voltages at node 7 as V1 is swept from 0 to 6V.

Running the dc analysis

Select the Actions menus and click on Simulate. The preliminary output graph shows no appreciable slope in the curve of Y(7) against VIN because the voltages are too small and the graph is not automatically scaled.

However, the results can be seen later by using *Intuscope* and by examining the output file. To generate the output file, select the File menu, then click on Exit/Quit, select Edit Text File, then click on the OUT button. A window then displays the Output file. This first lists the netlist, then the operating point analysis, or small signal bias solution (Table 3).

Voltage at each node is tabulated and shows zero voltage at node 8 because the ac source is inactive, 6Y at node 6, the power supply line.

The output also contains information about current through the two sources. Current through V1 is small. Note that the current through V1 is negative. In Spice, a positive current through the source flows from the positive terminal of a voltage source to its negative terminal. Thus a negative current flows from positive to negative through the external circuit. Spice uses zero-voltage sources as current-measuring devices, as will be demonstrated in a later circuit.

The output file concludes with a print out of the voltage at node 7 as VIN is swept from 0V to 6V. This shows that V(7) does not increase significantly until Vin reaches about 2.4V. The results are given to 7 significant figures (assuming that all seven figures are really significant). The result shows the early near-zero value of V(7) as VIN ramps up from 0V to 3V. This is followed by an exponential increase to 4mV as VIN increases from 3 to 4.2V. Finally there is a linear increase with V(7) reaching 6.73mV as VIN gets to 6V.

The list of command statements shows there are several other aspects to dc analysis. ■

SI multipliers

Because Spice originated in the days of teletype, when only upper-case letters could be printed, its unit multiples and submultiples may be typed in upper or lower case and it does not distinguish between them. The most frequently used are:

SI mult.	F point	Spice*
p, pico	E–12	P or p
n, nano	E–9	N or n
μ, micro	E–6	U or u
m, milli	E–3	M or m
k, kilo	E+3	K or k
M, mega	E+6	MEG or meg
G, giga	E+9	G or g
T, tera	E+12	T or t

*Spice ICAP/4

Note the confusion between milli and mega in the two systems. Letters following the multiplier are ignored by *IsSpice*, so that 220UF or 220UFARAD are both read as 220U.

Having designed a 32W power amplifier with a full power bandwidth of 5Hz to 55kHz and 0.07% distortion at 20W, Jeff Macaulay has found that combining valves and semiconductors can produce unexpectedly good performance.

Hot audio power

Despite rapid advances in semiconductor technology that have occurred over the past few decades, there are many audiophiles who believe that valves are best. Although at first sight this idea may seem ludicrous, it may not be quite as fanciful as some of the dubious products that the high fidelity industry has come up with of late.

Despite disadvantages of separate heater supplies and the need for high voltage supply lines, valves do have some advantages over their semiconductor rivals.

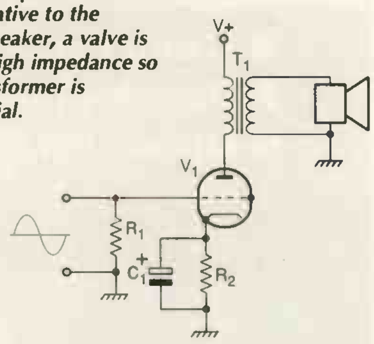
Why use valves?

Firstly, valves are easy to drive. At low frequencies the grid of a valve has an impedance approaching 100MΩ, but without the large parallel capacitance of a v-fet. Similarly, being mechanical devices, the characteristics are far better matched between samples than, say, transistors from the same batch. Consequently, a class-AB amplifier output stage built with valves can be far more linear than a solid state equivalent. Most surprisingly of all, for those of us weaned on silicon, is the amazing amount of abuse that valves can take without disappearing in a puff of smoke.

It was in the spirit of curiosity that the design described here was developed. It uses a pair of formerly widely used *EL34*s driven by a solid state circuit.

There are several reasons why the *EL34* is a good choice of output valve. Primarily, it has

Fig. 1a. Simplest form of valve amplifier is Class-A. Relative to the loudspeaker, a valve is very high impedance so a transformer is essential.



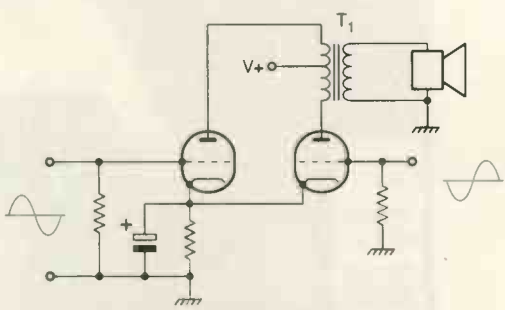


Fig. 1b. In the conventional valve output stage, equal and anti-phase signals are applied to the grids to generate push-pull output.

a high 25W anode dissipation. It also fits into a standard octal relay socket and is relatively cheap. Reasons for the solid state driver will become apparent as the article progresses, but first it will be useful to get to grips with some output stage basics.

The simplest form of valve output stage is the single-ended class-A triode, **Fig. 1a)**. Because valves have limited current handling capacity and rather large internal resistance, anode drive is applied to the loudspeaker through an impedance matching transformer. This system works fine but its maximum theoretical efficiency is only 50%. Usually because of the anode characteristics practical efficiency is more often in the region of 25%. If I had been writing this article a couple of years ago, I could have said that single ended triode output stages were a thing of the past. However audio 'purists' have resurrected them. If you have the money and inclination you can purchase one particular triode amplifier for a cool £30,000.

Valve output stages

The conventional valve output stage is shown in Fig **1b)** where for simplicity the valves are shown as triodes. Output is fed from the valve anodes to the output transformer primary. The centre tap of this winding is connected to the positive supply.

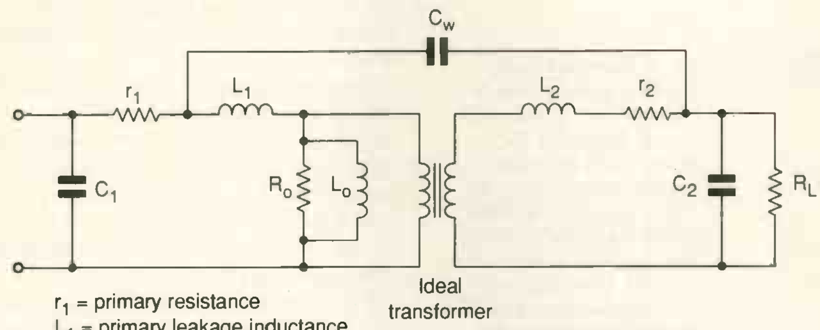
When equal and antiphase input signals are applied to the valve grids, push-pull operation is obtained. As with solid state designs the operating class is decided by bias current.

This push-pull stage has the usual advantages of cancelling even-harmonic distortion and increased power output. In addition hum voltages at the anodes cancel, producing an inherently high power supply ripple rejection.

Using *EL34*s in this type of circuit, it is possible to get outputs in the 20-50W range with reasonable ht voltages. However, the main problem with valve output stages is the output transformer – particularly in terms of frequency response.

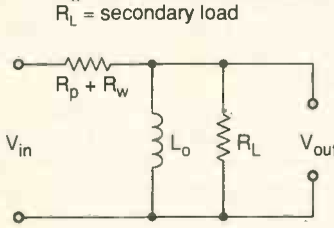
A real transformer, as opposed to a theoretical model, requires considerable primary inductance for good bass. Similarly at the high end, leakage inductance and winding capacitance limit response.

A modelled real transformer is shown in **Fig. 2**. Figure **2a)** shows an equivalent circuit at low frequencies. Here primary inductance forms a high-pass filter with the valve's anode impedance. Clearly, the greater the inductance



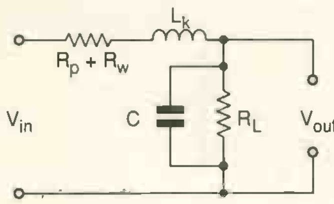
r_1 = primary resistance
L_1 = primary leakage inductance
r_2 = resistance of secondary
L_2 = equivalent secondary leakage
R_o = equivalent core loss resistance
L_o = primary inductance
C_1, C_2 = equivalent lumped capacitance of primary and secondary
C_w = interwinding capacitance
R_L = secondary load

Fig. 2. Model of the output transformer, above. For good bass, the transformer requires significant primary inductance. Low and high-frequency equivalents are shown below in a) and b) respectively.



R_p = anode resistance
R_w = winding resistance
L_o = primary inductance
R_L = secondary load x turns ratio squared

a) low frequency equivalent circuit



L_k = leakage inductance
C = winding capacitance

b) high frequency equivalent circuit

Components

Resistors 1%, 0.5W metal film unless indicated		
R_1	56k	[2]
$R_{2/5}$	10k	[4]
$R_{3/4}$	1k8	[4]
$R_{12/13}$	68k	[4]
$R_{6/9}$	60k	[4]
$R_{7/8}$	220k	[4]
R_{10}	470R, 3W ww	[2]
R_{11}	6k8	[2]
$R_{14/15}$	470R, 1W	[4]
R_{16}	1k, 1W	[2]
Capacitors		
$C_{1,2}$	100nF, 1000V WKG polyprop	[4]
C_3	100µF, 100V	[2]
C_4	220µF, 25V	[2]
$C_{5,6}$	470µF, 400V	[2]
$C_{7,8}$	1000µF, 63V	[4]
Active devices		
A_1/A_2	*TL072*	[2]
V_1/V_2	*EL34*	[4]
$Tr_{1,2}$	*2SC2547E*	[4]
$D_{1,2}$	*1N4001*	[4]
BR_1	W08	[1]
Wound components		
T_1	Output transformer 20:1 ratio, centre tapped. Primary inductance >8H, Leakage inductance <10mH	[2]
T_2	Mains, 240V prim. 280V, 700mA second. 6-0-6V 4A second.	[1]

Transformer availability

Three transformers especially wound for this design have been produced by Antrim Transformers. The set is available to UK readers for £99.99 plus £8 postage – fully inclusive of VAT. Antrim Transformers Ltd is at 25 Randalstown Road, Antrim, Co Antrim BT41 4LD, tel. 018494 28734, fax 018494 68745. Overseas readers should contact Antrim for export details. Readers who already have the mains transformer can obtain the output pair for £79.50 plus £8 postage, again inclusive of VAT.

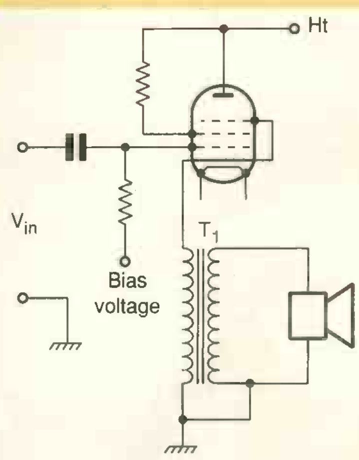


Fig. 3. Valve equivalent of the emitter follower. Putting the transformer in the cathode improves performance but driving the circuit needs a prohibitively large supply rail.

here the better if good bass response is to be secured.

Figure **2b)** shows a corresponding equivalent circuit of the transformer at high frequencies. At these frequencies primary inductance has no influence but leakage inductance in conjunction with the winding capacitance forms a second-order low-pass filter.

Both leakage inductance and winding capacitance are functions of the way the transformer is built. Reducing these factors is usually done by sectioning the transformer windings. Again you can see from the equivalent circuit that leakage inductance needs to be minimised for good ht response.

When calculating values of these inductances for a given anode resistance, calculations show how rapidly required inductance falls when anode resistance is lowered. In fact, if output impedance could be made zero the required primary inductance would also disappear. Similarly, it can be shown that transformer distortion is also highly dependent on anode resistance and similarly drops to zero with zero impedance drive.

One argument which can be put forward in defence of triode output stages is that they have lower anode impedance than pentodes. Hence, primary inductance can be made lower for a given bass extension. Most practical designs use overall negative feedback to lower effective anode resistance.

Normally the loop is taken from the output winding of the transformer – including it within the feedback loop. However, due to reactive elements present in an output transformer the amount of feedback that can be employed in this manner is strictly limited.

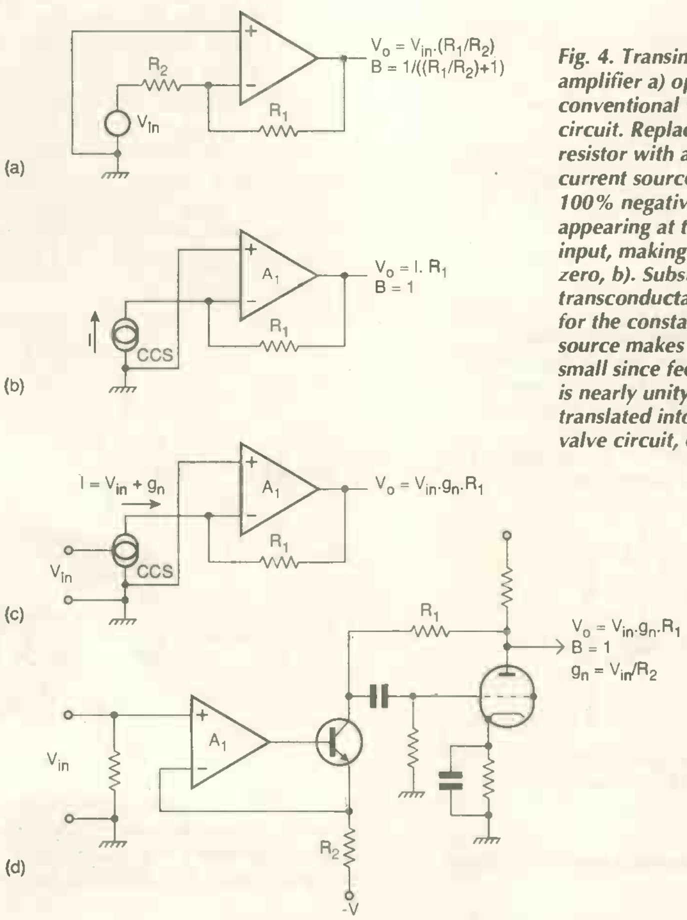


Fig. 4. Transimpedance amplifier a) operating as a conventional virtual-earth circuit. Replacing the resistor with a constant-current source results in 100% negative feedback appearing at the inverting input, making voltage gain zero, b). Substituting a transconductance amplifier for the constant-current source makes distortion very small since feedback factor B is nearly unity c). Circuit c) translated into a hybrid valve circuit, d).

One of the best ways of solving the problem is to use a cathode follower, **Fig. 3**. It is analogous to the more familiar emitter follower with similar features. Voltage gain is always less than unity and output impedance is significantly lower than that obtained from a triode used in a normal grounded cathode stage. Distortion is typically an order of magnitude smaller.

These limitations make the circuit more of a laboratory curiosity, since driving it fully would require almost twice the signal swing allowed by the ht voltage. However, the circuit is tantalising and I played with the idea of a push-pull cathode follower output driven by an inter-stage transformer before developing the present circuit.

There is however another way of producing a cathode follower style output stage which possesses all the virtues and few of the vices of a conventional valve output stage. The circuit is an amalgam of a transconductance and a transresistance amplifier, **Fig. 4**.

I cannot understand why this particular circuit is not used more often since it allows very high performance with a low component count. Figure **4a** shows a transimpedance amplifier operating as a conventional virtual earth amplifier.

If open-loop gain is very high then closed-loop performance is determined by the ratio of R_1 to R_2. If R_1 were to be substituted for a constant current source, Fig. **4b)**, the amplifier would 'see' 100% negative feedback at its inverting input and voltage gain would be zero.

Replace the current source with a transconductance amplifier and the amplifier will give an output of IR_1. Distortion generated by the transimpedance stage will be very small because feedback factor B (the proportion of

Supplying ht

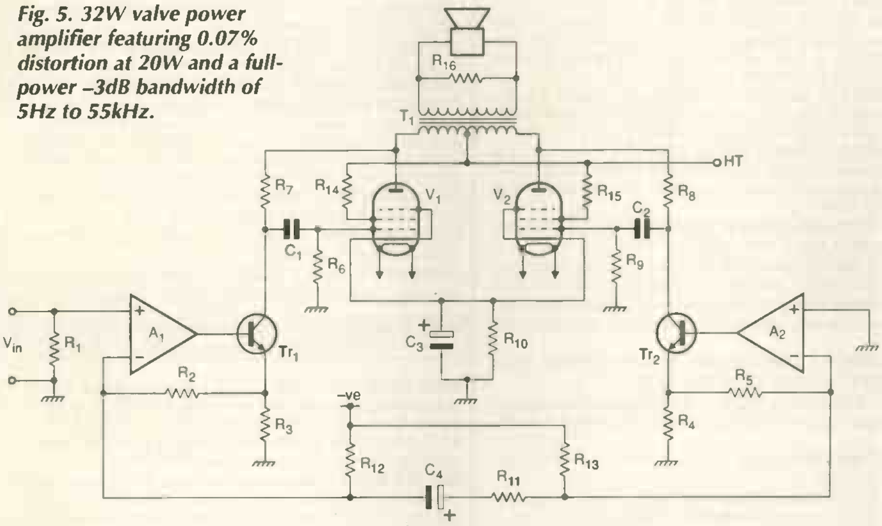
Power supply for the circuit is conventional. Ht is derived from the 280V secondary coil of T_2 – full-wave rectified by BR_1 and smoothed by the parallel combination of C_5 and C_6. Apart from extra ripple rejection this combination of capacitors stores a huge amount of energy – around 68J. This helps maintain supply lines even when feeding awkward loads.

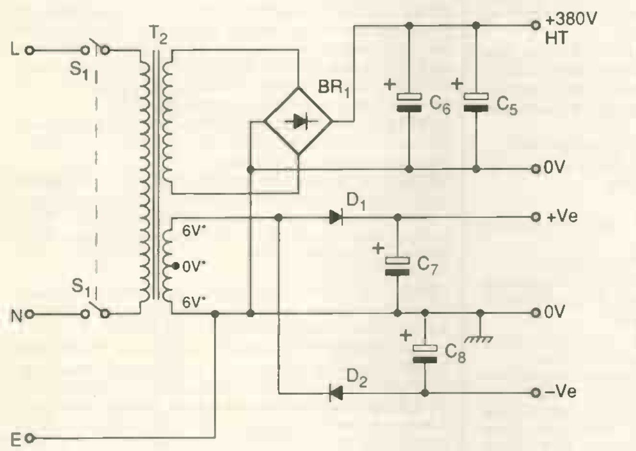
Supply lines for the op-amp circuit are derived from the heater secondaries. For a stereo amplifier, 6V at 3A minimum/channel is required. A 6-0-6V, 50VA transformer is suitable.

Secondaries connect in series and the voltage doubler D_1 and D_2 provides the dual dc supply, smoothed by C_7 and C_8. Heaters connect in series/parallel across the 12V supply as shown in the schematic overleaf.

Because of the totally balanced operating mode of the amplifier, ripple voltages effectively cancel out – simplifying psu design.

Fig. 5. 32W valve power amplifier featuring 0.07% distortion at 20W and a full-power –3dB bandwidth of 5Hz to 55kHz.





Being entirely balanced, the amplifier effectively cancels out ripple, simplifying design of the power supply. Voltage for the op-amps is derived from the transformer heater windings. For stereo, two heaters connect to each 6V winding.

the signal fed back) is almost unity. As the transconductance amplifier can also be made with unity gain a very well-behaved circuit is obtained.

In the present circuit the transimpedance amplifier is replaced by the valve. A transistor in the feedback loop of an *TL072* op-amp is the basis of the transconductance amplifier. Across the audio band the circuit gives an output impedance greater than 10MΩ.

Required voltage gain can be achieved by altering the transconductance ratio R_2 – both transconductance and transimpedance amplifiers have unity voltage gain. A well balanced push-pull output from the driving circuitry is also required to drive the push-pull output stage. This can easily be obtained by linking inverting inputs of the op-amps via a resistor and dc blocking capacitor.

Unfortunately a valve driver – though possible – is very difficult to design. An *EF86* pentode valve is a possibility but the only way of obtaining the requisite high impedance drive is to use low operating current. High current drive is required from this stage since impedance seen at the output valves grid is low due to feedback employed.

Figure 5 shows the amplifier's complete circuit. Input signals are fed across R_1 to the non-inverting input of A_1 which sets input impedance. Op-amp A_1 in conjunction with Tr_1 form a transconductance amplifier as discussed previously. Feedback is taken from emitter resistor R_3 to the inverting input via R_6. Resistors $R_{12,13}$ connect to the supply rail and provides bias for $Tr_{1,2}$ setting the quiescent current of the stage.

Output current from the collector of Tr_1 feeds into R_7 which connects in shunt between the anode and grid circuit of V_1. Capacitor C_1 isolates the valve from the dc level present at Tr_1 collector and R_6 returns the grid to ground. At ac, R_7 and R_6 appear as a parallel load to Tr_1. This impedance is effectively reduced by around 9.2 times by the valve gains.

Biasing of the output stage is effected by R_{10}, shunted at ac by C_3. Screen grids are also biased by R_{14} and R_{15}.

Both circuit halves are identical. Phase splitting is produced by coupling inverting inputs of A_1 and A_2 together via R_{11} and dc blocking capacitor C_4. This results in two antiphase equal amplitude signals at the emitters of Tr_1 and Tr_2 to drive the output stage.

Output voltages from V_1 and V_2 are applied to the primary coil of T_1 while ht is applied to the valves through the centre tap. Audio output signals are taken from the secondary coil of T_1 and applied to the loudspeaker. Resistor R_{16} keeps the output stage under control in the absence of a suitable load.

Because of heavy negative feedback within the circuit, overall feedback around the output transformer was found unnecessary. However, for those who like to experiment, feedback can be taken from the output side of the output transformer to the non-inverting input of A_2. If this is tried, R_{11} should be reduced to increase open-loop gain

Implementation

Building this design is straightforward. I used a readily available chassis and tagstrips. For the heater wiring, 5A loudspeaker cable is ideal. It should be laid close to the chassis but need not be twisted together as in low-level valve circuitry.

Potentially lethal voltages are present on capacitors C_5 and C_6 and all ht lines, and there is of course live mains around the transformer primary circuit. Always power up the amplifier with the *EL34*s *in situ* and make sure that the heaters heat up before turning off again. As long as the valves are in circuit and conducting, they will discharge the decoupling capacitors rapidly after turn off. If they are not installed, high voltage will linger for hours – sometimes days.

The amplifier requires no setting up. Provided it is wired correctly the circuit will operate first time.

Conclusion

Was it the effort? Yes, I certainly think so. The prototype gives out 32W continuous per channel with a full power bandwidth of 5Hz to 55kHz, –3dB. Measured thd at 1kHz and 20W output is 0.07% while output impedance is a mere 0.6Ω – minuscule by valve amplifier standards.

Mainly though, the amplifier excels at driving awkward loads and can suffer short circuits on the output without complaint. Last, but by no means least, it was fun to design. ■

PORTABLE X RAY MACHINE PLANS Easy to construct plans on a simple and cheap way to build a home X-ray machine! Effective device, X-ray sealed assemblies, can be used for experimental purposes. Not a toy or for minors! £6/set. Ref F/XP1.
TELEKINETIC ENHANCER PLANS Mystify and amaze your friends by creating motion with no known apparent means or cause. Uses no electrical or mechanical connections, no special gimmicks yet produces positive motion and effect. Excellent for science projects, magic shows, party demonstrations or serious research & development of this strange and amazing phychic phenomenon. £4/set Ref F/TKE1.
ELECTRONIC HYPNOSIS PLANS & DATA This data shows several ways to put subjects under your control. Included is a full volume reference text and several construction plans that when assembled can produce highly effective stimuli. This material must be used cautiously. It is for use as entertainment at parties etc only, by those experienced in its use. £15/set. Ref F/EH2.
GRAVITY GENERATOR PLANS This unique plan demonstrates a simple electrical phenomena that produces an anti-gravity effect. You can actually build a small mock spaceship out of simple materials and without any visible means- cause it to levitate. £10/set Ref F/GRA1.
WORLDS SMALLEST TESLA COIL/LIGHTENING DISPLAY GLOBE PLANS Produces up to 750,000 volts of discharge, experiment with extraordinary HV effects, 'Plasma in a jar', St Elmo's fire, Corona, excellent science project or conversation piece. £5/set Ref F/BTC1/LG5.
COPPER VAPOUR LASER PLANS Produces 100mw of visible green light. High coherency and spectral quality similar to Argon laser but easier and less costly to build yet far more efficient. This particular design was developed at the Atomic Energy Commision of NEGEV in Israel. £10/set Ref F/CVL1.
VOICE SCRAMBLER PLANS Minature solid state system turns speech sound into indecipherable noise that cannot be understood without a second matching unit. Use on telephone to prevent third party listening and bugging. £6/set Ref F/VS9.
PULSED TV JOKER PLANS Little hand held device utilises pulse techniques that will completely disrupt TV picture and sound! works on FM too! DISCRETION ADVISED. £8/set Ref F/TJ5.
BODYHEAT TELESCOPE PLANS Highly directional long range device uses recent technology to detect the presence of living bodies, warm and hot spots, heat leaks etc. Intended for security, law enforcement, research and development, etc. Excellent security device or very interesting science project. £8/set Ref F/BHT1.
BURNING, CUTTING CO2 LASER PLANS Projects an invisible beam of heat capable of burning and melting materials over a considerable distance. This laser is one of the most efficient, converting 10% input power into useful output. Not only is this device a workhorse in welding, cutting and heat processing materials but it is also a likely candidate as an effective directed energy beam weapon against missiles, aircraft, ground-to-ground, etc. Particle beams may very well utilize a laser of this type to blast a channel in the atmosphere for a high energy stream of neutrons or other particles. The device is easily applicable to burning and etching wood, cutting, plastics, textiles etc £12/set Ref F/LC7.
MYSTERY ANTI GRAVITY DEVICE PLANS Uses simple concept. Objects float in air and move to the touch. Defies gravity, amazing gift, conversation piece, magic trick or science project. £6/set Ref F/ANT1K.
ULTRASONIC BLASTER PLANS Laboratory source of sonic shock waves. Blow holes in metal, produce 'cold' steam, atomize liquides. Many cleaning uses for PC boards, jewllery, coins, small parts etc. £6/set Ref F/ULB1.
ULTRAHIGH GAIN AMP/STETHOSCOPIC MIKE/SOUND AND VIBRATION DETECTOR PLANS Ultrasensitive device enables one to hear a whole new world of sounds. Listen through walls, windows, floors etc. Many applications shown, from law enforcement, nature listening, medical heartbeat, to mechanical devices. £6/set Ref F/HGA7
ANTI DOG FORCE FIELD PLANS Highly effective circuit produces time variable pulses of accoustical energy that dogs cannot tolerate £6/set Ref F/DOG2
LASER BOUNCE LISTENER SYSTEM PLANS Allows you to hear sounds from a premises without gaining access. £12/set Ref F/LLIST1
CRAWLING INSECT ROASTER PLANS Harmless high frequency energy pulses destroy pests as they crawl into the energy field! £4/set Ref F/RCR1
LASER LIGHT SHOW PLANS Do it yourself plans show three methods. £6 Ref F/LLS1
PHASOR BLAST WAVE PISTOL SERIES PLANS Handheld, has large transducer and battery capacity with external controls. £6/set Ref F/PSP4
INFINITY TRANSMITTER PLANS Telephone line grabber/ room monitor. The ultimate in home/office security and safety! simple to use! Call your home or office phone, push a secret tone on your telephone to access either: A) On premises sound and voices or B) Existing conversation with break-in capability for emergency messages. £7 Ref F/TELEGRAB.
BUG DETECTOR PLANS Is that someone getting the goods on you? Easy to construct device locates any hidden source of radio energy! Sniffs out and finds bugs and other sources of bothersome interference. Detects low, high and UHF frequencies. £5/set Ref F/BD1.
ELECTROMAGNETIC COIL GUN PLANS Projects a metal object a considerable distance-requires adult
ELECTRIC MAN PLANS, SHOCK PEOPLE WITH THE TOUCH OF YOUR HAND! £5/set Ref F/EMA1
PARABOLIC DISH MICROPHONE PLANS Listen to distant sounds and voices, open windows, sound sources in 'hard to get' or hostile premises. Uses satellite technology to gather distant sounds and focus them to our ultra sensitive electronics. Plans also show an optional wireless link system. £8/set ref F/PM5
2 FOR 1 MULTIFUNCTIONAL HIGH FREQUENCY AND HIGH DC VOLTAGE, SOLID STATE TESLA COIL AND VARIABLE 100,000 VDC OUTPUT GENERATOR PLANS Operates on 9-12vdc, many possible experiments. £10 Ref F/HVM7/ TCL4.

WOLVERHAMPTON BRANCH NOW OPEN AT WORCESTER ST W'HAMPTON TEL 01902 22039

MINI FM TRANSMITTER KIT Very high gain preamp, supplied complete with FET electret microphone. Designed to cover 88-108 Mhz but easily changed to cover 63-130 Mhz. Works with a common 9v (PP3) battery. 0.2W RF. £7 Ref 1001.
ELECTRONIC SIREN KIT Impressive 5 watt power output. Ideal for car/bike alarm etc. 6-12v dc max current 1A. 1.2khz £6 Ref 1003.
3-30V POWER SUPPLY KIT Variable, stabilized power supply for lab use. Short circuit protected, suitable for profesional or amateur use 24v 3A transformer is needed to complete the kit. £14 Ref 1007.
1 WATT FM TRANSMITTER KIT Supplied with piezo electric microphone 8-30vdc. At 25-30v you will get nearly 2 watts! £12 ref 1009.
FM/AM SCANNER KIT Well not quite, you have to turn the knob your self but you will hear things on this radio that you would not hear on an ordinary radio (even TV). Covers 50-160mhz on both AM and FM. Built in 5 watt amplifier, inc speaker. £15 ref 1013.
MOSQUITO REPELLER KIT Modern way to keep midges at bay! Runs for about a month on one 1.5v battery. £7 Ref 1015.
3 CHANNEL SOUND TO LIGHT KIT Wireless system, mains operated, separate sensitivity adjustment for each channel, 1,200 w power handling, microphone included. £14 Ref 1014.
MOTORBIKE/CYCLE TREMBLER ALARM KIT Adjustable sensitivity, preset alarm time, auto reset. Could be connected to horn etc. £12 Ref 1011.
0-5 MINUTE TIMER KIT adjustable, will switch up to 2A mains. Perfect for alarms, photography, etc. £7 Ref 1020.
4 WATT FM TRANSMITTER KIT Small but powerful FM transmitter, 3 RF stages, microphone and audio preamp included. £20 Ref 1028.
STROBE LIGHT KIT Adjustable from 1-60 hz (a lot faster than conventional strobes). Mains operated. £16 Ref 1037.
ULTRASONIC RADAR KIT Ideal as a movement detector with a range of about 10 metres, automate your cat flap! 12v dc. £15 Ref 1049.
LIQUID LEVEL DETECTOR KIT Useful for tanks, ponds, baths, rain alarm, leak detector etc. Will switch 2A mains. £5 Ref 1081.
COMBINATION LOCK KIT 9 key, programmable, complete with keypad, will switch 2A mains. 9v dc operation. £10 ref 1114.
PHONE BUG DETECTOR KIT This device will warn you if somebody is eavesdropping on your line. £6 ref 1130.
ROBOT VOICE KIT Interesting circuit that distorts your voice! adjustable, answer the phone with a different voice! 12vdc £9 ref 1131
TELEPHONE BUG KIT Small bug powered by the 'phone line, starts transmitting as soon as the phone is picked up! £8 Ref 1135.
FUNCTION GENERATOR KIT Produces sinusoidal, saw tooth and square waves from 20-20khz, separate level controls for each shape. Will produce all 3 together. 24vac. £16 ref 1008.
3 CHANNEL LIGHT CHASER KIT 800 watts per channel, speed and direction controls supplied with 12 LEDS (you can fit triacs instead to make kit mains, not supplied) 9-12vdc £17 ref 1026.
12V FLOURESCENT LAMP DRIVER KIT Light up 4 foot tubes from your car battery! 9v 2a transformer also required. £8 ref 1069.
VOX SWITCH KIT Sound activated switch ideal for making bugging tape recorders etc, adjustable sensitivity. £8 ref 1073.
INCAR SOUND TO LIGHT KIT Put some atmosphere in your car with this mini 3 channel sound to light. Each channel has 6 led's. £10 ref 1086.
7W HI FI AMPLIFIER KIT Useful, powerful, ideal for audio systems, intercoms etc. 12-18vdc £7 ref 1025.
PHONE CALL RELAY KIT Useful device that operates a relay whenever the 'phone rings. Switches mains at 2A. £10 ref 1122.
LEAD ACID CHARGER KIT Two automatic charging rates, visual indication of battery state, ideal for alarm systems etc, 100mA 12vdc £12 ref 1095.
CAR ALARM KIT Works on voltage drop and vibration, entry/exit delays, adjustable alarm duration. Ideal caravans etc £12 ref 1019.
PORTABLE ALARM KIT Based on mercury switch, alrm continues to sound until reset by owner. Buzzer inc. £11 ref 1150.
PREAMP MIXER KIT 3 input mono mixer, sep bass and treble controls plus individual level controls, 18vdc, input sens 100mA. £15 ref 1052.
METAL DETECTOR KIT Range 15-20cm, complete with case, 9vdc. £8 ref 1022.
SINGLE CHANNEL SOUND TO LIGHT KIT Mains operated, add rythum to your party for only £8 ref 1006.
SOUND EFFECTS GENERATOR KIT Produces sounds ranging from bird chips to sirens. Complete with speaker, add sound effects to your projects for just £9 ref 1045.
GUITAR PREAMP KIT Complete with tone controls, small enough to fit in any guitar, based on TL082 IC, 9-12vdc £8 Ref 1091.
15 WATT FM TRANSMITTER (BUILT) 4 stage high power, preamp required 12-18vdc, can use ground plane, yagi or open dipole. £69 ref 1021.
TELEPHONE AMPLIFIER KIT Very sensitive amplifier which uses a pickup coil (supplied) will let you follow a conversation with out holding the 'phone. £11 ref 1059.

*SOME OF OUR PRODUCTS MAY BE UNLICENSABLE IN THE UK

BULL ELECTRICAL

250 PORTLAND ROAD, HOVE, SUSSEX. BN3 5QT. (ESTABLISHED 50 YEARS).
MAIL ORDER TERMS: CASH, PO OR CHEQUE WITH ORDER PLUS £3 POST PLUS VAT.
PLEASE ALLOW 7-10 DAYS FOR DELIVERY PHONE ORDERS WELCOME (ACCESS, VISA, SWITCH, AMERICAN EXPRESS)
TEL: 01273 203500
FAX 01273 323077

HUMIDITY METER KIT Builds into a precision LCD humidity meter, 9 ic design, pcb, lcd display and all components included. £49
PC TIMER KIT Four channel output controlled by your PC, will switch high current mains with relays (supplied). Software supplied so you can program the channels to do what you want whenever you want. Minimum system configeration is 286, VGA, 4.1,640k, serial port, hard drive with min 100k free. £24.99
DIVINING RODS Expensive technology cannot challenge the fool proof art of water divining, passed down from generation to generation. Seeing is believing. Use in the home, garden, countryside or desert, it's divinely simple! £4.99 a pair ref E/3.
HUGE BUBBLE MAKING KIT You'll be amazed at the the size of the bubbles you can acheive with this bubble making kit. Once you have got the knack it is possible to make bubbles of up to 40 feet long. £11.99 ref E/9.
FM CORDLESS MICROPHONE This unit is an FM broadcasting station in minature, 3 transistor transmitter with electret condenser mic+fet amp design result in maximum sensitivity and broad frequency response. 90-105mhz, 50-1500hz, 500 foot range in open country! PP3 battery required. £15.00 ref 15P42A.
MAGNETIC MARBLES They have been around for a number of years but still give rise to curiosity and amazement. A pack of 12 is just £3.99 ref GI/R20
STETHOSCOPES A fully functioning stethoscope for all those intricate projects. Enables you to listen to motors, pipes, heartbeats, walls, insects etc. £6 ref MAR6P6.
NICKEL PLATING KIT Proffesional electroplating kit that will transform rusting parts into showpieces in 3 hours! Will plate onto steel, iron, bronze, gunmetal, copper, welded, silver soldered or brazed joints. Kit includes enough to plate 1,000 sq inches. You will also need a 12v supply, a container and 2 12v light bulbs. £39.99 ref NIK39.
SHOP WOBBLERS! Small assemblies designed to take D size batteries and 'wobble' signs about in shops! £3.99 Ref SEP4P2.
OMRON ELECTRONIC INTERVAL TIMERS.
*****NEW LOW PRICES TO CLEAR!!!******
Minature adjustable timers, 4 pole c/o output 3A 240v,
HY1230S, 12vDC adjustable from 0-30 secs. £4.99
HY1210M, 12vDC adjustable from 0-10 mins. £4.99
HY1260M, 12vDC adjustable from 0-60 mins. £4.99
HY2460M, 24vAC adjustable from 0-60 mins. £2.99
HY243H, 24vAC adjustable from 0-3 hours. £2.99
HY2401S, 240v adjustable from 0-1 secs. £4.99
HY2405S, 240v adjustable from 0-5 secs. £4.99
HY24060m, 240v adjustable from 0-60 mins. £6.99
DRINKING BIRD Remember these? hook onto wine glass (supplied) and they drink, standup, drink, standup ETC! £4 each Ref EF1
SOLAR POWER LAB SPECIAL You get TWO 6"x6" 6v 130mA solar cells, 4 LED's, wire, buzzer, switch plus 1 relay or motor. Superb value kit just £5.99 REF: MAG6P8
BUGGING TAPE RECORDER Small voice activated recorder, uses micro cassette complete with headphones. £28.99 ref MAR29P1.
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
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.
13.8V 1.9A psu cased with leads. Just £9.99 REF MAG10P3
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
MAINSCABLE Precut black 2 core 2 metre lengths ideal for repairs, projects etc. 50 metres for £1.99 ref AUG2P7.
COMPOSITE VIDEO KIT. Converts composite video into separate H sync, V sync, and video. 12v DC. £8.00 REF: MAG8P2.
UNIVERSAL PC POWER SUPPLY complete with flyleads, switch, fan etc. 200w at £20 REF: MAG20P3 (265x155x125mm).
GYROSCOPE About 3" high and an excellent educational toy for all ages! Price with instruction booklet £6 Ref EF15.
FUTURE PC POWER SUPPLIES These are 295x135x60mm, 4 drive connectors 1 mother board connector. 150watt, 12v fan, lec inlet and on/off switch. £12 Ref EF6.
VENUS FLYTRAP KIT Grow your own carnivorous plant with this simple kit £3 ref EF34.
TWEETERS 2" diameter good quality tweeter 140R (ok with the above speaker) 2 for £2 REF: MAG2P5 or 4 for £3 REF: MAG3P4
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! 30 m for £12.99 ref MAG13P1
ROCK LIGHTS Unusual things these, two pieces of rock that glow when rubbed together! belived to cause rain! £3 a pair Ref EF29.
3" by 1" AMORPHOUS SOLAR PANELS 14.5v, 700mA 10 watts, aluminium frame, screw terminals, £44.95 ref MAG45.
ELECTRONIC ACCUPUNCTURE KIT Builds into an electronic version instead of needles! good to experiment with. £7 ref 7P30
SHOCKING COIL KIT Build this little battery operated device into all sorts of things, also gets worms out of the ground! £7 ref 7P36.
FLYING PARROTS Easily assembled kit that builds a parrot that actually flaps its wings and flies! 50 m range £6 ref EF2.
HIGH POWER CATAPULTS Hinged arm brace for stability, tempered steel yoke, super strength latex power bands. Departure speed of ammunition is in excess of 200 miles per hour! Range of over 200 metres! £7.99 ref R/9.
BALLON MANUFACTURING KIT British made, small blob blows into a large, longlasting balloon, hours of fun! £3.99 ref GI/E99R

WE BUY SURPLUS STOCK FOR CASH

FREE CATALOGUE

1995 100 PAGE CATALOGUE NOW AVAILABLE, 45P STAMP OR FREE ON REQUEST WITH ORDER.

CIRCLE NO. 124 ON REPLY CARD

Best rf article '95

Following the success of 1994's Writers Award, ***Electronics World*** and **Hewlett-Packard** are launching a new scheme to run from January to December 1995.

Only articles which have an element of rf design will be eligible for consideration by the judging panel. It is hoped that this year's award will focus writer interest on rf engineering in line with the growing importance of radio frequency systems to an increasingly cordless world.

The aim of the award scheme is to locate freelance authors who can bring applied electronics design alive for other people.

Qualifying topics might include direct digital synthesis, microstrip design, application engineering for commercially available rf ICs and modules, receiver design, PLL, frequency generation and rf measurement, wideband circuit design, spread spectrum systems, microstrip and planer aerials... The list will hopefully be endless.

All articles accepted for publication will be paid for – in the region of several hundred pounds for a typical design feature.

The prize for the coming year's award is a £4000 Hewlett-Packard HP8647A 1GHz programmable signal generator. It features HPIB interface, solid state programmable attenuator and built in AM-FM modulation capability.

For further details about our quest for the best, call or write to:
Martin Eccles, Editor, Electronics World, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS
Tel 081-652 3128

Exclusive *EW+WW* reader offer – versatile dmm & tester for £14.95

Featuring 10A dc measurement capability and transistor h_{FE} test facility, the DT830B is a compact, 3.5 digit multimeter with six measurement functions. This attractive meter normally sells at £23.44, excluding postage. As a special introductory offer – exclusive to *EW+WW* readers in the UK* – instrument distributor Vann Draper Electronics is offering this meter for just £14.95, fully inclusive of vat and postage.

In addition to reading dc and ac voltage, dc current and resistance, the DT830B has a diode-test function and a transistor h_{FE} range indicating gains from 0-1000. Supplied with test leads and battery, this compact multimeter weighs just 170g and measures 70 by 126 by 24 – truly a pocket sized instrument. Its liquid crystal display has high-contrast 0.5in high characters.

*Overseas readers, please read the note on the coupon.

Use this coupon to order your meter

Name
Company (if any)

Address

Post code
Phone number fax

Make cheques payable to Vann Draper Electronics Ltd
Or, please debit my Master, Visa or Access card.

Card No Expiry date

Please mail this coupon to Vann Draper Electronics, together with payment. Alternatively fax credit card details with order on 0116 257 0893 or telephone on 0116 281 3091. Address orders and all correspondence relating to this offer to Vann Draper Electronics at Alexander House, Bampton Close, Wigston, Leicester LE18 2RZ.

*Overseas readers can also obtain this discount but details vary according to country. Please ring, fax or write to Vann Draper Electronics.

DT830B key specifications

DC voltage	0.2/2/20/200/1000V
Basic accuracy	±0.5%
Input impedance	1MΩ
Max input	1000V dc
AC voltage	200/750V
Basic accuracy	±1.2%
Input impedance	0.45M
Frequency range	45-400Hz
Max input	750V ac
DC current	200μ/2000μ/20m/200m/10A
Basic accuracy	±1.0%
Overload protection	0.2A fused 10A not fused
Resistance	200/2000/20k/200k/2M
Basic accuracy	±0.8%
Overload protection	250V dc/ac

Next issue – November – on sale 26 October

Free with *EW+WW*

Cover-mounted TO-92 three-terminal voltage regulator

Manufactured by Zetex, this high-performance 5V regulator is similar to the industry standard 78L05, except that it has a quiescent current of around 350μA as opposed to 2-3mA. In addition, it has double the output current, at 200mA, and improved line and load regulation.

Remember... you can reserve your copy of *Electronics World* with your local newsagent. Simply fill in the card in the magazine to guarantee your monthly copy.

CIRCUIT IDEAS

SEND YOUR CIRCUIT IDEAS TO THE EDITOR, ELECTRONICS WORLD, QUADRANT HOUSE, THE QUADRANT, SUTTON, SURREY SM2 5AS

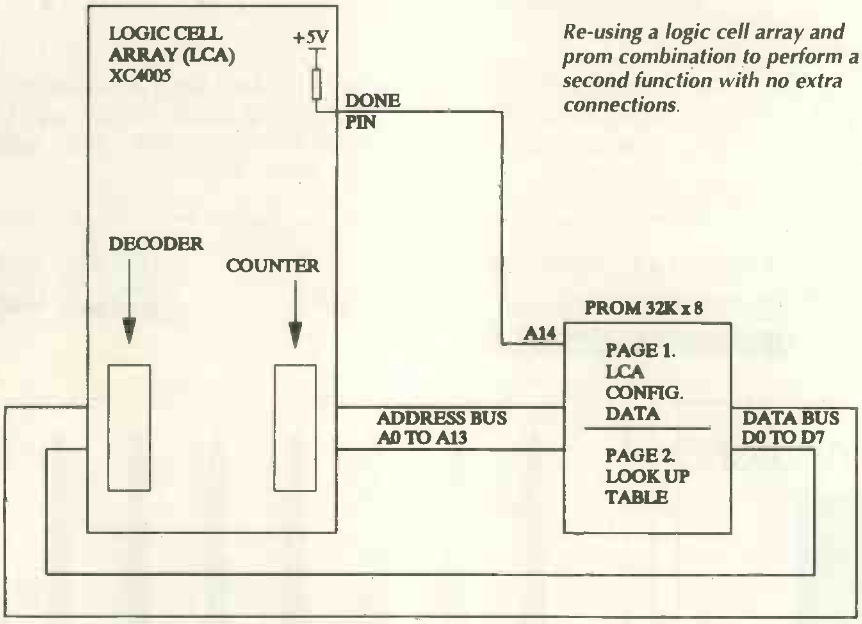
Do you have an original circuit idea for publication? We are giving £100 cash for the month's top design. Additional authors will receive £25 cash for each circuit idea published. We are looking for ingenuity in the use of modern components.

£100 WINNER

Prom and logic array in harmony

Once a prom has configured a logic cell array, some of the circuitry configured into the array enables the prom to perform a second function.

Xilinx XC2000, 3000 and 4000 arrays can be used for this function and the prom is industry-standard, connected to the data and address configuration pins of the array.



Re-using a logic cell array and prom combination to perform a second function with no extra connections.

Configuration data for the array is in the first page of the prom, the second page carrying data for other functions, in this case a look-up table, the circuits for which are in the array. Connections between the two devices are used for both configuration and, after that is finished, as user-programmable i/o pins.

In the diagram, an *XC4005* and a 32K by 8 prom are used together, the first page of the prom taking up 0-16K for the configuration task and 16-32K to form a look-up table to sequence events encoded as data bytes. Counters for prom addressing and a decoder for the table output are in the circuit configured into the array, as is the rest of the circuitry.

A dedicated "Done" pin on the array is low on power up and during configuration, being pulled high by its internal resistor to indicate that the process is complete; it is therefore used to page the second page of the prom at pin 14.

Brian Wood
British Aerospace
Stevenage
Hertfordshire

Measuring low frequencies using a frequency multiplier

Measuring very low frequencies either takes too long (nearly 17 minutes for 0.1% at 1Hz) or gives the reciprocal, which must be worked out. This circuit provides a high, easily measured frequency directly proportional to the low frequency and only needs one cycle of the input to give the output.

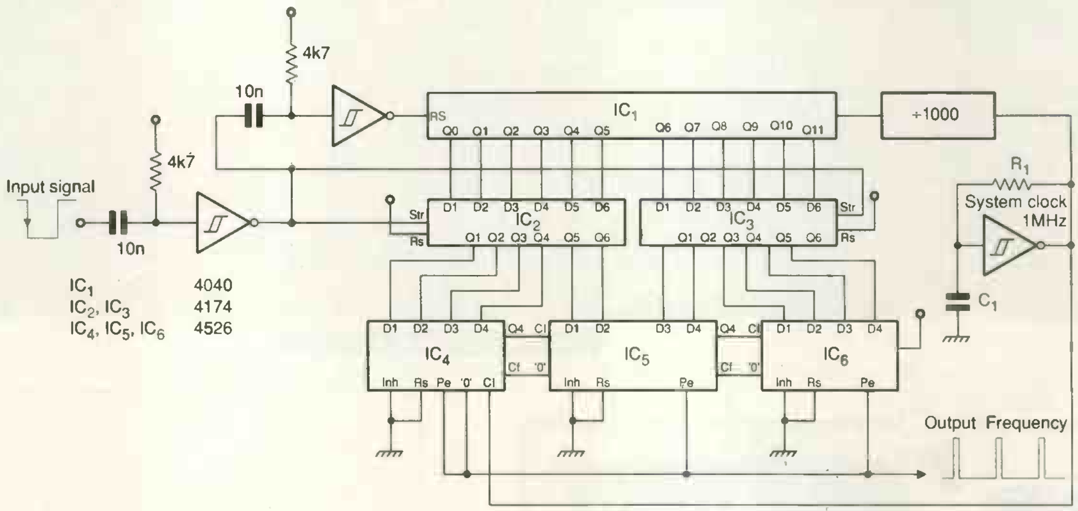
One cycle of the lf input gates a stable clock, divided in frequency by 1000, into a *4040* 12-bit binary counter, which then contains a binary number proportional to the period of the lf. Dividing this by means of the *4526* into the original clock gives an output signal 1000 times higher in frequency then the input.

Negative-going transitions of the input lf are differentiated to give a strobe pulse, which latches the binary result from the counter IC_1 into the *4174*s, $IC_{2,3}$, this binary number being used by the *4526* dividers $IC_{4,5,6}$ as divisor. The strobe also forms the pulse to reset IC_1.

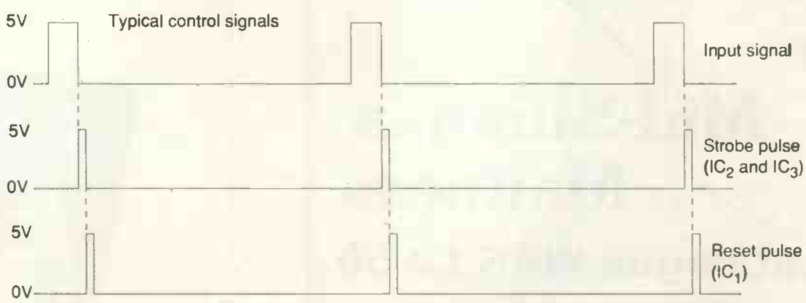
As an example, suppose the input is 2Hz and the clock 1MHz; the binary number in IC_1 will be (1MHz/1000)/2=500 and the output frequency 1MHz/500=2kHz.

If required, overflow circuitry could be arranged on IC_1 to show an out-of-range input.

Des Keppel
Ballon
County Carlow
Republic of Ireland



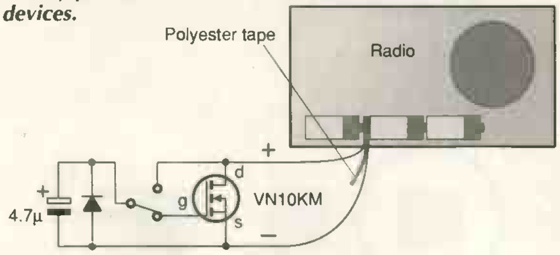
Frequency multiplier for low frequencies surmounts the traditional frequency-measurement difficulties. It needs only one input cycle of low frequency to give a measurable output.



Non-invasive two-terminal timer

Very simple and elegant circuit acts as both on-off switch and 'snooze' timer for battery-powered devices.

This is a 'snooze' switch for battery-powered radios or other appliances that calls for no modification to the equipment.



A polyester tape coated on each side with copper is simply slipped between two of the cells inside the radio and led out through the lid —there is usually enough of a gap to allow this.

Four components form the circuit, the switch being a sub-miniature, spring-biased microswitch, shown in its rest position. In normal operation in use as an on-off switch, operating the switch once charges the capacitor to the battery voltage which, when the button is released, is applied to the *VN10KM* vmos fet, turning it on and completing the battery circuit.

A second switch operation discharges the capacitor through the transistor; when the button is released, the zero voltage on the capacitor turns the fet off.

As a timer, the circuit depends on leakage through the diode. If the radio is left on, leakage slowly discharges the capacitor and, after about 30 minutes, the fet turns off.

Scott Arnesen
Oslo
Norway

Phase-synchronising a crystal oscillator

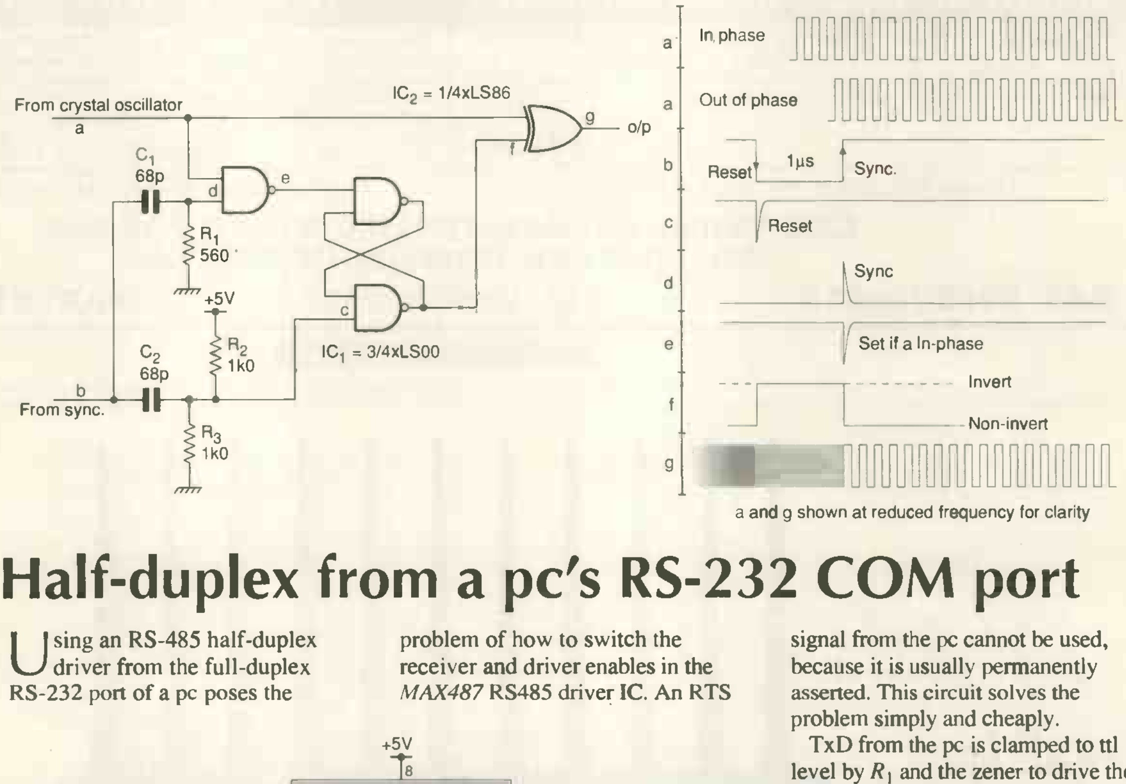
Synchronising the output of a crystal oscillator to an external signal within one cycle is practically impossible, because the Q of the crystal is so high. You can pull the frequency by capacitance, but that takes several cycles; and if the oscillator is switched on and off, it starts in random phase and may well affect its stability. The circuit shown here allows synchronising to a sync. pulse to within 90°, close enough in some applications.

The Ex-Or provides the appropriate polarity after comparison in the Nand gate. If the oscillator is in phase with the sync., signal (e) appears and sets the latch; if it is out of phase, signal (e) is absent and the latch is not set, the Ex-Or inverting the oscillator signal or not accordingly.

Better resolution could be obtained by using an oscillator of a frequency n times higher than the output, dividing it as needed. To select the correct phase, reset the divide-by-n divider counter as the sync. pulse arrives. A presettable counter would allow phase-shifting as well as synchronisation.

C J D Catto
Elsworth
Cambridgeshire

Circuit synchronises a crystal oscillator to an external pulse to within 90° in less than one cycle.



a and g shown at reduced frequency for clarity

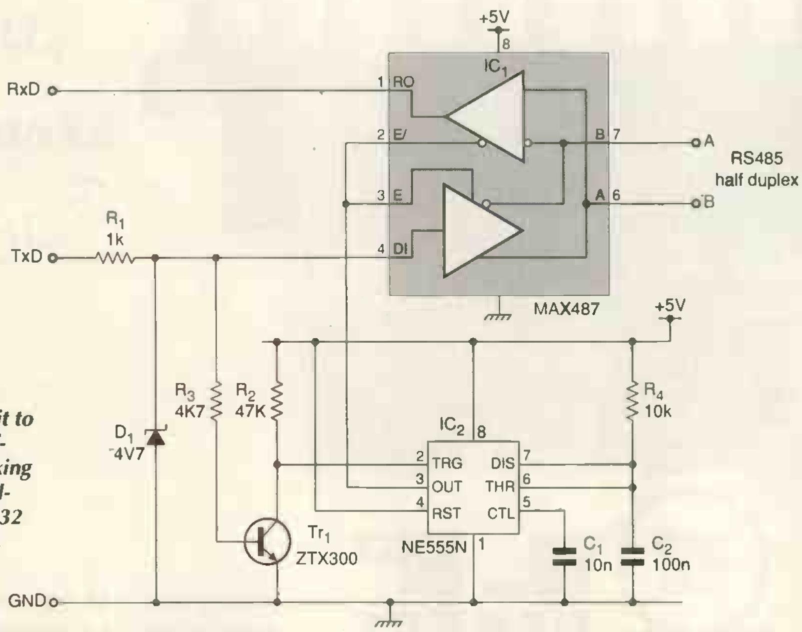
Half-duplex from a pc's RS-232 COM port

Using an RS-485 half-duplex driver from the full-duplex RS-232 port of a pc poses the problem of how to switch the receiver and driver enables in the *MAX487* RS485 driver IC. An RTS signal from the pc cannot be used, because it is usually permanently asserted. This circuit solves the problem simply and cheaply.

TxD from the pc is clamped to ttl level by R_1 and the zener to drive the 487's driver; ttl output from the receiver will drive most pc RxD inputs directly. The 487 receiver is normally enabled and its driver disabled to allow characters to be sent to the pc. When a character is output, the start bit triggers the 555 astable for exactly one transmission period, set by the values of R_4 and C_2 at 1.1ms, to enable the driver and disable the receiver. These values give almost exactly 9600 baud, but clearly others could be used for different speeds.

Since RS-232 output levels invert ttl inputs, A and B differential outputs of the 487 have to be connected the "wrong" way round.

D Burns
dB Electronic Design
Hertfordshire



Simple and cheap circuit to provide half-duplex working from the full-duplex RS-232 port of a pc.

The MICRO MODULE
A NEW LOW COST controller that gives you customisation for as little as £95 one off +VAT

For users of PCs, 8051 & 68000

and that's just the half of it!..

SAVE TIME... REAL TIME!
The Micro Module is a very low cost micro controller which is easily adapted to your exact requirements getting that job done quicker.

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^2C 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
- A full range of other Controllers available

ADDITIONAL FUNCTIONS
Additional functions are supported including: Analogue I/O, Digital I/O Serial ports, LCDs, Keyboards, Video, also a comprehensive range of signal conditioning including relays, AC & DC power switching, contact detectors, opto isolation, 4-20mA, thermocouples etc.

STARTER PACK AT ONLY £295+VAT
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, Down-loader, a single copy of MINOS, extensive example software, and free unlimited technical support all for £295+VAT.

CUSTOM USE
The Micro Module is ideal for those one off jobs where you can add the special hardware interfacing required for your project, keeping costs down and making the final product unique to your company.

MANUFACTURE
CMS offer a full manufacturing facility to manufacture the Micro Module to your exact requirements even in low volumes.

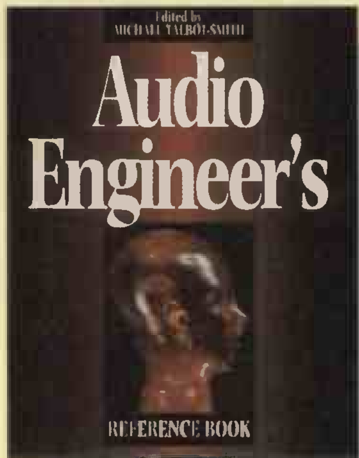
CMS

Cambridge Microprocessor Systems Limited
Unit 17-18 Zone 'D',
Chelmsford Rd. Ind. Est.,
Great Dunmow, Essex, U.K, CM6 1XG
Phone 01371 875644 Fax 01371 876077

CIRCLE NO. 134 ON REPLY CARD

Reference books to buy

For Audio Engineers



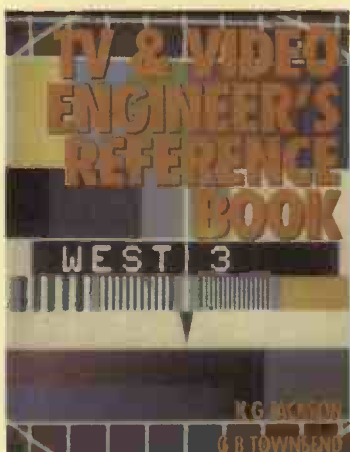
Subjects include

- Recording, microphones and loudspeakers
- Digital audio techniques
- Basic audio principles
- Acoustics and psychoacoustics
- Audio and television studios and their facilities
- Radio and telephony

- **Comprehensive – over 600 pages**
- **Written by leading authorities from the audio world**
- **Easy to read, compiled for maximum accessibility**
- **Concise and authoritative**
- **Covers topics from noise measurement to studio installation**

Invaluable reference work for anyone involved with audio – from broadcast consultant to serious enthusiast. *Audio Engineer's Reference Book* is written by an international team of experts and edited by Michael Talbot-Smith – previously a trainer of audio engineers at BBC Wood Norton and now a freelance audio consultant and technical writer.

For TV & Video Engineers



Subjects include

- Fundamentals of colour TV
- TV studios
- High definition TV
- Satellite broadcasting
- Distribution of broadband signals
- TV receiver servicing
- Video and audio recording and playback
- Teletext

- **Over sixty chapters on the latest techniques in video and television**
- **Up to date reference on EMC requirements, DBS and HDTV**
- **Easy-to-use reference, eminently suitable for students**
- **Topics range from materials and construction to medical and defence applications of television.**

The *TV & Video Engineer's Reference Book* will be of immense value to anyone involved with modern tv & video techniques – in particular broadcast engineers. The new format makes it an excellent reference for students. Edited by KG Jackson and GB Townsend from contributions written by acknowledged international experts.

Please supply me ________ copies of the
Audio Engineer's Reference Book,
(ISBN 0 7506 0386 0)
Fully-inclusive price – UK £62.50, Europe £68, Worldwide £78. Please add vat at local rate where applicable.

Please supply me ________ copies of the
TV & Video Engineer's Reference Book,
(ISBN 0 7506 1953 8)
Fully-inclusive price – UK £42.50, Europe £48.00, Worldwide £58.00, Please add vat at local rate where applicable.

Remittance enclosed £__________
Cheques should be made payable to Reed Business Publishing Group Ltd
Please return to: Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS
Please debit my credit card as follows:
Access/Master   Barclay/Visa   Amex   Diners

Credit Card No. ____________________
Exp date
NAME (Please print) ____________________
ADDRESS ____________________
____
____
____
POST CODE ____________________
DATE__________TEL____________________

SIGNATURE

VAT RATES
6% Belgium, 25% Denmark, 5.5% France, 7% Germany, 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 receive further details about books, journals and information services.

Business purchase: Please send me the book 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 resalable condition for a full refund.

Credit card orders accepted by 'phone. Call 0181 652 3614

M & B RADIO (LEEDS)

THE NORTH'S LEADING USED TEST EQUIPMENT DEALER

OSCILLOSCOPES

TEKTRONIX 475 200 MHz dual trace £495
TEKTRONIX 434 25 MHz dual trace storage £400
TEKTRONIX SC504/TM504/DM501 80 MHz Oscilloscope/multimeter £450
TEKTRONIX 7000 series oscilloscopes in stock please phone for prices & details
TEKTRONIX 5113 dual beam storage mainframe (new) £275
TEKTRONIX T922R 15 MHz rack mount oscilloscope £150
TEKTRONIX 212 500 KHz miniscope £150
TEKTRONIX 326 25 MHZ miniscope £275
BALLANTINE 1022B 25 MHz miniscope £225
HP 1743A 100 MHz delta measurements £500
HP 1715A 200 MHz with dvm £450
HP 1703A storage oscilloscope £295
PHILIPS 3311 60 MHz digital storage 125 MHz clock £700
PHILIPS 3262 100 MHz dual trace £400
PHILIPS 3055 50 MHz dual trace £400
PHILIPS 3217 50 MHz dual trace £375
PHILIPS 3244 50 MHz 4 channel oscilloscope £400
IWATSU SS6122 100 MHz 4 channel with cursors £800
IWATSU SS5710 60 MHz 4 channel £400
LEADER LBO524L 40 MHz dual trace delayed t/b £300
GOULD 4035 20 MHz digital storage IEEE £550
GOULD 1420 20 MHz digital storage £400
GOULD OS4000 10 MHz digital storage £200
GOULD OS250B 15 MHz dual trace £120

SPECTRUM ANALYSERS

TEKTRONIX 492 21 GHz spectrum analyser £5500
TEKTRONIX 7L12 10 KHz-1.8 GHz + mainframe £2000
HP140T/8552B/8553B 1 KHz-110 MHz spectrum analyser £450
HP141T/8552B/8554B 100 KHz-1250 MHz + (8553B) £1000
HP140T/8552A/8555B 10 MHz-18 GHz + (8553B) £1700
HP8410/8414A 12 GHz network analyser £950
MARCONI TF2370 30 Hz-110 MHz spectrum analyser £950
MARCONI TF2370 30 Hz-110 MHz latest version £2000
MARCONI TF2370/2373 30 Hz-1250 MHz with frequency convertor £2000
BRUEL & KJAER 2033 1 Hz-20 KHz audio analyser £2250

SIGNAL GENERATORS

HP8672 2 GHz-18 synthesized signal generator £6000
HP8683D 2.3 Ghz-13 GHz OPT 001/003 solid state generator (as new) £4500
HP8620C/86290B 2 GHz-18 GHz sweeper (IEEE) £2500
HP8620C/86230B 1.8 GHz-4.2 GHz sweeper (IEEE) £1000
HP8620C sweeper mainframes (as new) IEEE £250
HP3586A 50 Hz-32.5 MHz selective level meter £1800
HP3314A 0.001 Hz-19.99 MHz function/waveform generator £2950
HP3336B 10 Hz-21 MHz synthesizer/level meter £650
HP8640A 500 KHz-512 MHz signal generator £500
HP8654A 10 MHz-520 MHz signal generator £350
HP8406A comb generator £275
HP8018A serial data generator £250
HP8007B 10 Hz-100 MHz pulse generator £250
HP8005B 0.3 Hz-20 MHz pulse generator £200
HP8616A 1.8 GHz-4.5 GHz generator £195
ROHDES & SCHWARTZ APN62 0.1 Hz-260 KHz LF generator (new) £2000
FARNELL SSG2000 10 KHz-2000 MHz synthesized generator (as new) £2000
FARNELL DSG2 0.0001 Hz-110 KHz synthesized (new) £350
FARNELL SSG520 10 MHz-520 MHz synthesized generator £400
RACAL 9081 5 MHz-520 MHz synthesized generator £450
ADRET 7100D 300 KHz-600 MHz synthesized generator £500
SYSTRON DONNER 1702 100 KHz-1000 MHz synthesized generator £600
WILTRON 610D/501 1 MHz-1500 MHz sweeper £1000
GIGA GR1101A 12 GHz-18 GHz pulse generator (as new) £650
POLARAD 1106ET 1.8 GHz-4.6 GHz with modulator £300
MARCONI TF2008 10 KHz-510 MHz signal generator/sweep £250
MARCONI TF2016 10 KHz-120 MHz signal generator £195
MARCONI TF2016A 10 KHz-120 MHz with rev power trip £245
MARCONI 6055B 850 GHz-2150 GHz signal source £225
MARCONI 6056B 2 GHz-4 GHz signal source £225
PHILIPS PM51320 0.1 Hz-2 MHz function generator £300
WAVETEK 182A 1 Hz-4 MHz function generator £195
EXACT 502LC 1 Hz-5 MHz function generator £195
ADRET 2230A 200 Hz-1 MHz synthesized source £195
LINSTEAD G100 10 Hz-10 MHz synthesized oscillator £200
SAYROSA MA30 10 Hz-10 KHz oscillator £150
THANDAR TG503 0.005 Hz-5 MHz pulse/function generator £225

TEST EQUIPMENT

ANRITSU MS65A 2 GHz error detector £1500
TEKTRONIX 1141/SPG11/TSG11 pal video generator £1500
TEKTRONIX 145 pal gen lock test signal generator £1500
TEKTRONIX 521A vector scopes £350
TEKTRONIX 318 50 MHz 16 channel logic analyser £350
TEKTRONIX A6902A isolator £450
TEKTRONIX TM501/DM501 bench multimeter £125
TEKTRONIX P6045 FET differential probe £250
TEKTRONIX P6015 high voltage scope probe £95
SYSTEMS VIDEO 2360 component video generator £1500
SYSTEMS VIDEO 1152/1155 compact 19" waveform monitor/vectorscope £600
PHILIPS PM5567 pal vectorscopes £600
PHILIPS PM8252A dual pen recorder £225
SCHUMBERGER 7702 digital transmission analyser (new) £750
SCHUMBERGER 4010 radio test set £400
SCHLUMBERGER 4900 AF/RF measuring unit £400
SCHLUMBERGER AF405 3 tone generator/modulator £150
AMBER 4400A audio test set £500
FERROGRAPH RTS 2 audio test set **+ ATU 1** £350
ROD-L M100BVS5 hipot tester £250
BRANDENBURG 0-30KVolt power supply £200
WANDAL & GOLTERMAN PSS19 level generator £650
MARCONI 6950/6910 10 MHz-20 GHz RF power meter £850
MARCONI 6593A VSWR indicator £495
MARCONI 6440/6421 10 MHz-12.4 GHZ RF power meter £250
MARCONI TF2306 programmable interface unit £400
MARCONI TF2304 modulation meter £350
MARCONI TK2374 zero loss probe £200
MARCONI TF2300B modulation meter £100
MARCONI TF2432A 10 Hz-560 MHz frequency counter £125
MARCONI TF2604 RF millivoltmeters with probes £75
MARCONI TF2913 13 test line generator/insertor £250
MARCONI TF2160 20 Hz-20 KHz monitored AF attenuators £50
MARCONI TF2700 LCR meter battery portable £150
EIP 371 18 GHz source locking microwave counter £950
HP 5342A 500 MHz-18 GHz microwave frequency meter OPT001/003 £1500
HP 435B/8481A/8484A/11708A 10 MHz-18 GHz (new/HP case/manuals) £1100
HP 435B/8481A 10 MHz-18 GHz RF power meter £800
HP 435A/8482AH 100 KHz-4.2 GHz RF power meter £550
HP 436A digital RF power meters £650
HP 3581C 15 Hz-50 KHz selective voltmeter £600
HP 4815A RF vector impedance meter with probes £450
HP 4951A protocol analyser £350
HP3779A primary multiplex analyser £350
HP 3780A pattern generator/error detector £350
HP 333A distortion analyser £295
HP 3762A data generator £295
HP 11667A DC-18 GHz power splitter (new) £450
HP 11710A down converter £250
HP 8405A 1 MHz-1000 MHz vector voltmeter £300
HP 4261A LCR meter £350
HP 8750A storage normaliser £350
HP 3400A true RMS voltmeter (analogue) £145
HP 3403C true RMs voltmeter (digital) £195
HP 3406A 10 KHz-1200 MHz RF sampling voltmeter with probes £200
HP 3465A 4.5 digit multimeter £125
HP 3466A 4.5 digit autoranging multimeter £200
HP 3468A 5.5 digit multimeter/auto cal (LCD) £400
HP 5004A signature analyser £150
HP 5005A signature multimeter £300
HP 355D DC-100 MHz VHF attenuator 50ohm 1-120db £150
HP 1600A/1607A 32 bit logic analyser £100
BIRD 43 RF wattmeters £100
BIRD 81B termaline 80 watt coaxial resistor £150
BIRD 8321 30db attenuator 50w £185
BIRD 8329 30db coaxial attenuator 2000w £500
TELEWAVE TWL-300 RF dummy load 50 ohm £75
EXACT 334 precision current calibrator £195
SYSTRON DONNER M107 precision DC voltage source £450
FLUKE 103A frequency comparator £250
FLUKE 3330B prog constant current/voltage calibrator £450
BALLANTINE 6125C prog time/amplitude test set £400
HALCYON 500B/521A universal test system £150
BRADLEY 192 oscilloscope calibrator £500
ALTECH 533X-11 calibrator (1 HP355c/1 HP355D ATT) £295
KEMO DP1 1 Hz-100 KHz phase meter (new) £150
WAYNE KERR CT496 LCR meter battery portable £75
RADIOMETER TRB11 RLC component comparator £150
AVO 215-L/2 AC/DC breakdown/ionisation tester £400
AVO 8 MK5 testmeters with case/probes £75
FARNELL RB 1030/35 electronic load £495
FARNELL TM8 10 KHz-1000 MHz true RMS sampling voltmeter £350
SIEMENS U2233 psophometer (new) £350
SIEMENS D2108 200 KHz-30 Mhz level meter £350
SIEMENS W2108 200 KHz-30 mhz level oscillator £350
NARDA 3001 450MHz-950 MHz directional coupler 10/20-30db £100
NARDA 3041-20 500 MHz-1000 MHz directional coupler 20db £125
NARDA 3044B-20 3.7 GHz-8.3 GHz 20db directional coupler £150
NARDA 3004-10 4 GHz-10 GHz 10db directional coupler £175
NARDA 60132 solid state amplifier 8 GHz-12 GHz £150
SAYROSA AMM 1.5 MHz-2 GHz automatic modulation meters £195
IWATSU SC7104 10 Hz-1000 MHz frequency counter £275
ROHDE & SCHWARZ NKS RF power meter £600
ROHDE & SCHWARZ ESU2 test receiver 25 MHz-1000 MHz £1200
EDDYSTONE 1837/2 30 MHz receiver + 1529 FSK unit £600
RACAL RA17 30 MHz valve receiver £200
RACAL RA1218 30 MHz receiver £300
RACAL RA1772 30 MHz receiver £750
RACAL RA1779/MA 1107 30 MHz receiver £1500
RACAL TTA1860S HF Transmitter 30 MHz 1.25KW £POA
RACAL 9063 two tone oscillator £200
RACAL 9009 10 MHz-1500 MHz automatic modulation meter £250
RACAL 9008 1.5 MHz-2000 MHz automatic modulation meter £300
RACAL DANA 9904M 50 MHz universal counter timer £95
RACAL DANA 9914 10 Hz-200 MHz frequency counter £115
RACAL DANA 9915 10 Hz-560 MHz frequency counter £120
RACAL DANA 9916 10 Hz frequency counter £195
RACAL DANA 9919 10 Hz-1100 MHz frequency counter £295
RACAL DANA 9908 10 Hz-1100 MHz universal counter timer £400
RACAL DANA 9921 10 Hz-3000 MHz frequency counter £400
RACAL DANA 1991 10 Hz-160 MHz universal counter timer 9 digit £500
RACAL DANA 6000 microprocessing digital voltmeter £250
BRUEL & KJAER 2203 precision sound level meter/WB0812 filter £450
BRUEL & KJAER 2971 phase meter £450
BRUEL & KJAER 1022 beat frequency oscillator £350
BRUEL & KJAER frequency response analyser £250
BRUEL & KJAER 2425 0.5 Hz-500 KHz electronic voltmeter £225

SPECIAL OFFERS

BECKMAN DM110 digital multimeter with case/probes £50
SOLARTRON 7045 4.5 digit bench multimeter battery/mains £60
SMITHS 3" diameter altimeters £65
SIEMENS PDRM82 portable LCD radiation meters (new) £50
FARNELL LFM2 audio oscillators £45
SIMPSON 269-3 test meter with probes/manual (new) £45

ALL PRICES PLUS VAT AND CARRIAGE · ALL EQUIPMENT SUPPLIED WITH 30 DAYS WARRANTY

86 Bishopgate Street, Leeds LS1 4BB
Tel: (0113) 2435649 Fax: (0113) 2426881

CIRCLE NO. 135 ON REPLY CARD

Hewlett Packard 8683D

Solid State Microwave
Signal Generators
2.3-13 GHz Freq' Range
Wideband FM for satellite
AM/FM & pulse modulation
Built in pulse generator
Options 001/003 fitted

£2,950 + Carriage + Vat

Supplied fully tested in as new condition. With 30 days parts & labour warranty.

M&B Radio DEALERS IN SURPLUS ELECTRONIC TEST EQUIPMENT
86 BISHOPGATE STREET LEEDS LS1 4BB
TEL: 01132 435649 FAX: 01132 426881

CIRCLE NO. 136 ON REPLY CARD

Versatile stepper motor controller

Handling three stepper motors together with eight digital inputs and eleven analogue ports, this interface designed by Pei An controls three axis movement while making available a variety of feedback information from sensors.

This versatile triple stepper motor controller board is able to control 3 stepper motors. It also provides an 8-bit input port and an 8-bit output port. Moreover, it incorporates an 11 channel 8-bit a-to-d converter which enables the board to read analogue signals from 11 channels.

The board connects to a pc via a general purpose COM or LPT port i/o card, outlined in the panel.

System overview

Four blocks make up the stepper driver system – a stepper motor unit incorporating three separate drivers, a data i/o unit, an a-to-d converter unit and a buffer selector. **Figure 1**.

Each unit has one or several data buffers associated with it, each sharing the same internal data bus. In order to write data to a particular buffer, the clock signal must be supplied to latch the data as generated by the buffer selector. **Figure 2** gives the complete circuit diagram.

Stepper motor controller specifications

Stepper motor driver

Stepper motors controllable	3
Type of stepper motors	four-phase, unipolar
Modes of stepper motor operation	one-phase, full-phase, half-step
Maximum voltage, with heatsink	35V for stepper motor controls
Maximum current, with heatsink	1.5A

User i/o ports

Numbers of ttl input lines	8
Numbers of ttl output lines	8

A-to-d converter, for serial i/o

Conversion accuracy	8bit
Conversion frequency	45,000/second
Multiplexed analogue inputs	11
Input voltage range	0-2.5V

PC i/o requirements

Centronics 25 line i/o card or RS232 25 line i/o card

Buffer selection

Chip selection for the buffers is based on a *74LS138* 3-to-8-line decoder. Decoded lines Y_{0-7} are normally logic high. Applying an address on pins A_{0-2} causes one of the output lines to go low.

Address lines A_{0-2} connect to C_{0-2} of port C of the *8255*. Output lines Y_{0-4} are used to latch data to the five data buffers. Correspondence between the address applied to the *74LS138* and the data buffers selected is shown in **Table 1.**

Table 1. Addresses on A_{1-3} of the LS138 select the various Y outputs to control the three motors, the output port and the a-to-d converter data buffer.

A_0	A_1	A_2	Output	Data destination
0	0	0	Y_0 low	IC_5, motor driver 1
1	0	0	Y_1 low	IC_6, motor driver 2
0	1	0	Y_2 low	IC_7, motor driver 3
1	1	0	Y_3 low	IC_8, 8-bit o/p port
0	0	1	Y_4 low	IC_{11}, a-to-d buffer

Stepper motor driving

Working principle of a stepper motor, **Fig. 3**, shows an imaginary four phase unipolar stepper motor with a single permanent magnet rotor. Its stator comprises two pairs of electro-magnetic poles.

Although this motor only has four steps per revolution, it operates on the same principle as a real motor, which will have more pole pairs.

During operation, terminals A, B, C and D are connected to the negative rail of the power supply individually or in combination to generate a rotational electro-magnetic field inside the stator. As a result, the rotor turns accordingly.

Three methods of driving a stepper motor are 'wave', 'full-step' and 'half-step' drive. Wave, or single-phase drive is the simplest. Each winding is energised in sequence. The rotor turns to align its magnetic poles with the corresponding magnetised poles of the stator. The rotor moves to each position

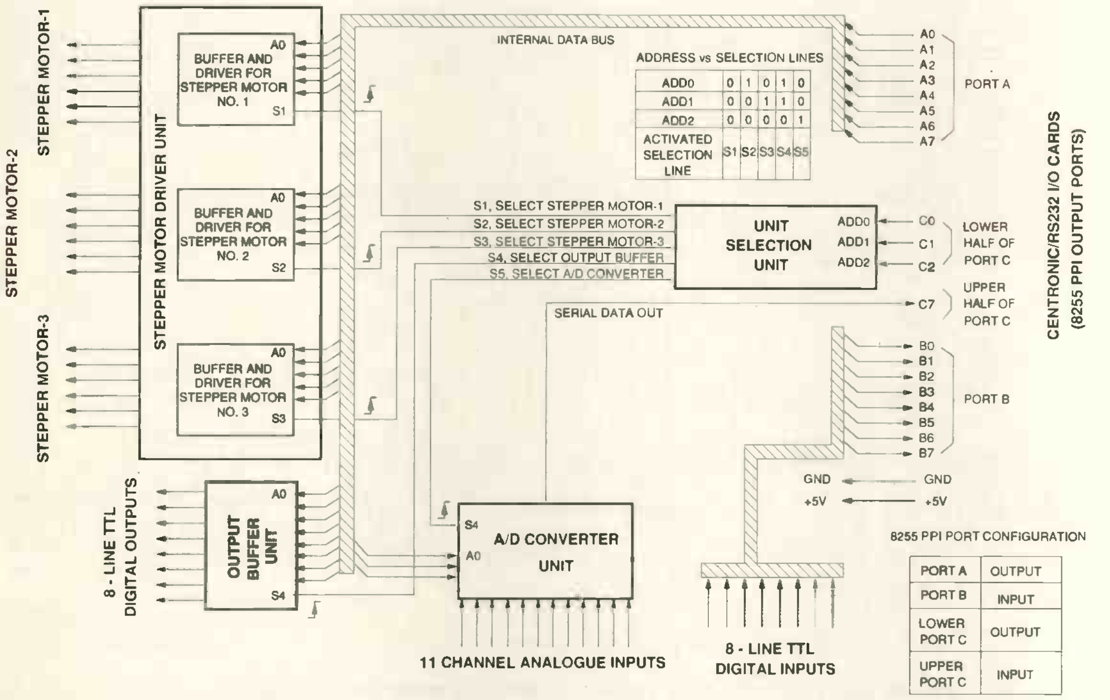


Fig. 1. Stepper motor driver modules, combined, provide control for three motors plus 11 analogue monitoring channels and eight digital outputs.

Technical support

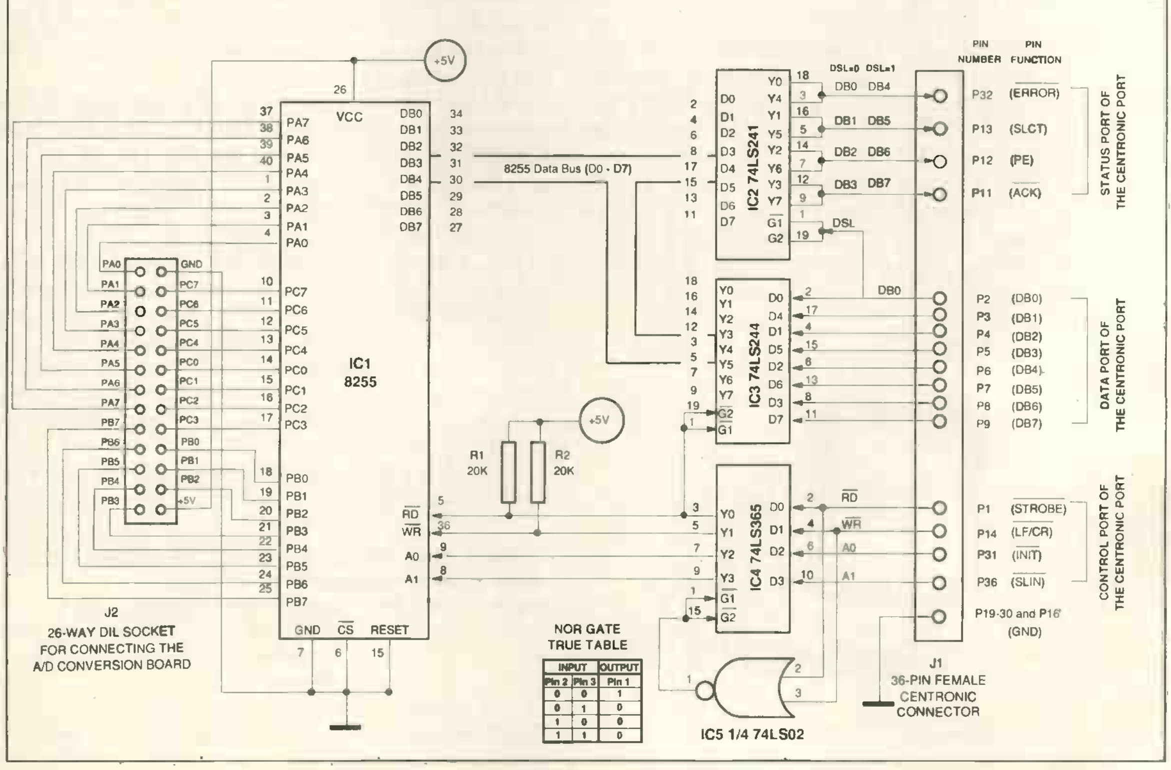
The Centronics 24-line i/o card, the RS232 24-line i/o card and the stepper motor controller board are all available from the author both in the designer's kit form and in assembled and tested form. The designer's kit includes the pcb and all the necessary components. Demonstration control software written in Turbo Pascal 6 – source code and EXE file – are included in the packages. Please contact Dr Pei An at 58 Lamport Court, Lamport Close, Manchester M1 7EG, Tel/Fax/Ans: +44-(0)161-272-8279.

Input/output for the pc

Two i/o cards are available for connecting the stepper motor controller to the pc. The first interfaces with the Centronics port, and the second with the RS232 port. Details of the Centronics i/o card were presented in 'Catching Data from LPT1' *EW+WW*, Feb 1995.

Both i/o cards incorporate an industrial standard interface chip – the *8255* peripheral programmable interface – which provides 24 i/o lines. These lines are organised into four groups: port A, 8 lines, port B, 8 lines, upper half port C, 4 lines, and the lower half port C, 4 lines.

All four ports can be programmed as i/o ports via software. In this application, Port A and lower of half port C are programmed as output while port B and the upper half of port C are programmed as input.



Versatile interface for translating pc i/o from the LPT port to three parallel i/o ports. By adding a uart, a similar interface for connecting to a COM port can be produced.

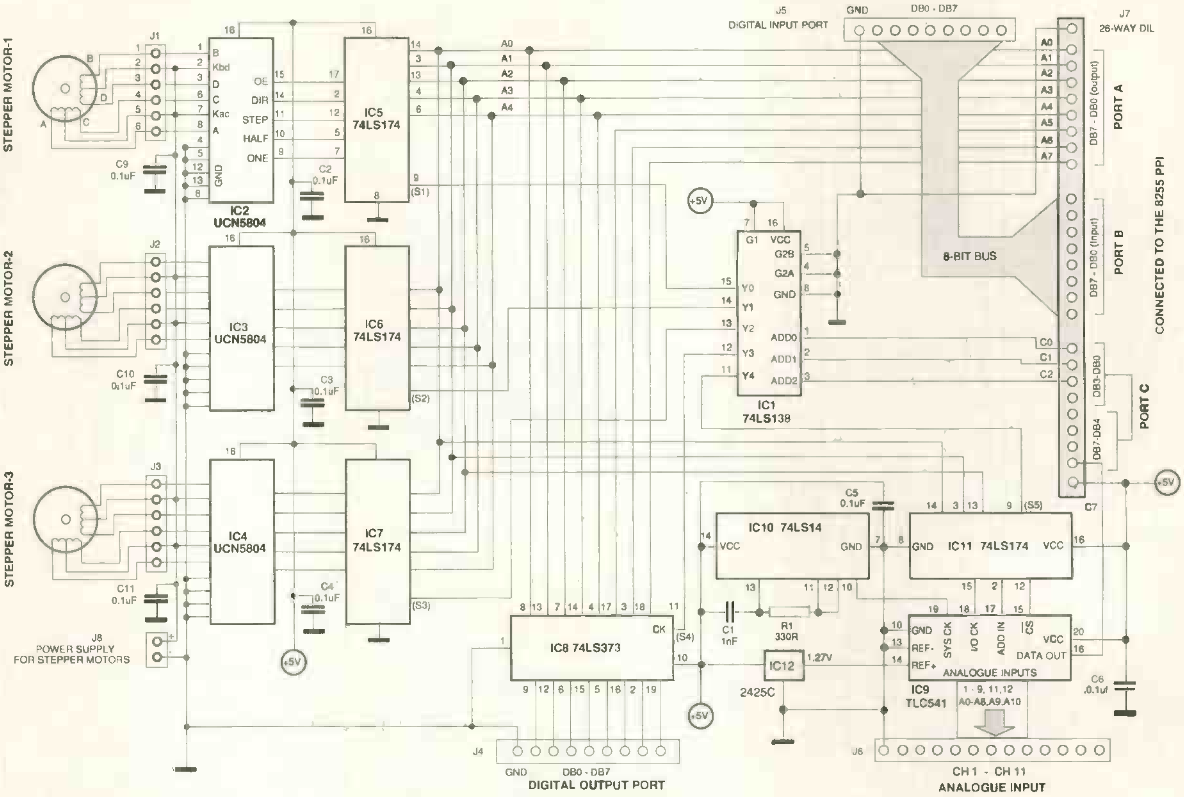


Fig. 2. With the addition of three eight-bit ports from a common 8255 parallel i/o chip and control software, this analogue, digital and stepper-motor i/o card is controllable from a pc. Note that output of IC_{12} is 2.5V, not 1.27V as shown.

in turn, completing a full revolution after four steps. Positions of the rotor and the energising patterns of the winding are shown in **Fig. 4a**.

By energising the windings in reverse order, the rotor turns in the opposite direction. As only one winding is energised at a time, motor torque is rather low. To improve this 'full step' drive is used.

Full-stepping involves a similar four step sequence as the wave alternative, except that two windings are energised for each step. The rotor aligns its magnetic poles with the strongest magnetic field between the two poles of the stator, Fig. **4b)**. Because two windings are energised for each step, motor torque is improved.

Half-step drive is a combination of wave and full-step drive. It takes advantage of the rotor's ability to align alternately with the stator's poles and between them – doubling the number of steps available for one revolution, Fig. **4c)**. Using this method, motor torque varies with steps, but the motor runs more smoothly.

Stepper motors are normally used in precision control applications, which usually require accuracy of movements rather than speed. There is no lower speed limit for stepper motors but there is an upper limit which varies according to motor type.

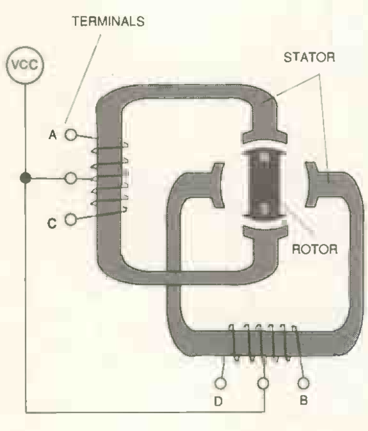


Fig. 3. Stepper motor essentials. This version is simplified – it has only 4 steps per revolution – making it easy to see how energising the coils polarises the stator and causes rotation.

Stepper motor driver ICs

For the stepper motor described, drive sequences are readily accomplished by several industrial standard stepper motor drivers. Stepper motor drivers often use several *UCN5804* ICs, which are capable of driving four-phase unipolar stepper motors in full, half and single-phase modes, **Fig. 5b)**.

Two power supplies are required by the IC, one to drive its logic circuits and the other to drive the stepper motors. Pin 16, V_{cc}, connects to the positive rail of the logic power supply, with a maximum voltage of 7V. Pins 2 and 7 connect to the power supply for the stepper motors. Pins 4, 5, 12 and 13, are all wired to the ground of the power supplies.

Four outputs, pins 1, 3, 6 and 8 each with internal protection diodes, are connected to four internal Darlington transistors which have a maximum rating of 35V at 1.5A. A heat sink may be needed.

Logic high applied to the output enable pin disables outputs connected to the stepper motor. Pin 14 sets the rotation direction of the motor while pin 11 is the step input. With a negative transition the stepper motor rotates one step. Drive modes are configured by setting the logic levels at pin 9, 'one-phase' and pin 10, 'half-step'.

Control signals to each *UCN5804* are supplied by a data buffer based on a *74LS174*. This hex D-type bistable device latches data to the outputs on the low-to-high logic clock transition. Data buffers IC_{5-7} share the internal data bus. Clock inputs of the buffers are wired to Y_{0-2} of the *74LS138*.

Data bus lines DB_{0-4}, connected to A_{0-4} of port A, correspond to output-enable, direction, step input, half-step and one-step signals.

When writing data to a particular buffer, it is sent to the data bus by initially writing the data to Port A of the *8255*

Table 2. Logic signals applied to the stepper motor IC determine the operating mode.

Pin 9	Pin 10	Stepper motor mode
L	L	Two-phase
H	L	One-phase
L	H	Half-step
H	H	Step-inhibit

During operation, pins 9, 10 and 14 should only be changed when the step input is logic high.

PPI. A low-to-high-then-low pulse is then applied to the clock of that particular buffer.

Output/input unit

A *74LS373* D-type octal latch, IC_8 performs i/o. Data inputs connect to the internal data bus and the clock is wired to Y_3 of IC_1. Data to be written to the bus is initially sent by writing the data to Port A and then applying a positive pulse to pin 11 of IC_8. This pulse is generated by the *74LS138* decoder by sending the corresponding address to the decoder via port C. Lines of the input port are connected directly to port B, configured as an input port.

Converter analogue to digital

The a-to-d converter module incorporates a *TLC541*. This is an eight-bit successive-approximation a-to-d converter that uses switched capacitor technology. It includes on-chip sample-and-hold facilities and a 12-channel analogue multiplexer.

Interfacing between the 40ksample/s a-to-d converter and the peripheral circuits is serial. **Figure 5a)** shows the pin-out of the *TLC541*, which has a typical power dissipation of 6mW. An external band-gap voltage reference is used.

The 12-channel analogue multiplexers divide into two groups. The first provides 11 inputs for connecting external analogue signals on pins 1-9, 11 and 12. These correspond to analogue inputs 0-11. In the other group, one input connects internally to a voltage reference for self testing purposes. To select an analogue input, a 4-bit address has to be written into the IC via the serial interface.

Serial interfacing consists of five ttl compatible three-state i/o lines. The system clock controls data conversion and has a maximum clock frequency of 2.4MHz. This results in a data conversion rate of 4kHz. The i/o clock synchronises i/o operations.

Addressing for the analogue multiplexers is provided via serial input 'Add-in' while 'Data out' provides access to the serial data.When the enable pin is high, all i/o is disabled, allowing several such devices to be used on a shared bus.

System and i/o clocks are used independently, so there is no need for special speed or phase relationships between them.

Writing and reading sequences of the IC are as follows, with reference to **Fig. 6**.

- Chip-select is brought low to start the read/write cycle. To minimise errors caused by noise at the select input, internal circuitry waits for two rising edges. It then waits for a falling edge of the system clock after the high-to-low transition is detected on the select pin, before it is accepted. The most-significant bit of the previous conversion result, DB7, automatically appears on the data out pin.

- A new multiplexer address, $A_{0\text{-}3}$, is shifted into the IC on the first four rising-edges of the i/o clock. Level A_3 is shifted in first. Negative edges of the i/o clock shift out $DB_{6\text{-}3}$ of the previous conversion result. Sampling of the newly addressed analogue input begins after the fourth falling edge of the i/o clock.

- Three further clock cycles are applied to the i/o clock. Data bits $DB_{2\text{-}0}$ of the previous conversion result are shifted out on each negative edge of the 'i/o clock'.

- On the eighth and final clock cycle applied to the i/o clock, the falling edge completes the sample process and initiates the hold function. Data conversion is then carried out during the next 36 system clock cycles. After this, either the select pin must go high or the i/o clock remain low for at least 36 system clock cycles to allow for the data conversion.

Select can be kept low during periods of multiple conversion. But prevent noise from getting into the i/o clock, since this could cause the device and external interface circuit to lose synchronisation. If the select line is taken high, it must

(a) One phase drive sequence

STEP	A	B	C	D	POSITION OF ROTOR
1	ON	OFF	OFF	OFF	
2	OFF	ON	OFF	OFF	
3	OFF	OFF	ON	OFF	
4	OFF	OFF	OFF	ON	

(b) Two phase drive sequence

STEP	A	B	C	D	POSITION OF ROTOR
1	ON	OFF	OFF	ON	
2	ON	ON	OFF	OFF	
3	OFF	ON	ON	OFF	
4	OFF	OFF	ON	ON	

(c) Half-step drive sequence

STEP	A	B	C	D	POSITION OF ROTOR
1	ON	OFF	OFF	OFF	
2	ON	ON	OFF	OFF	
3	OFF	ON	OFF	OFF	
4	OFF	ON	ON	OFF	
5	OFF	OFF	ON	OFF	
6	OFF	OFF	ON	ON	
7	OFF	OFF	OFF	ON	
8	ON	OFF	OFF	ON	

***Fig. 4.** Energising sequences of stepper-motor windings, comparing single, dual and half-step drive methods.*

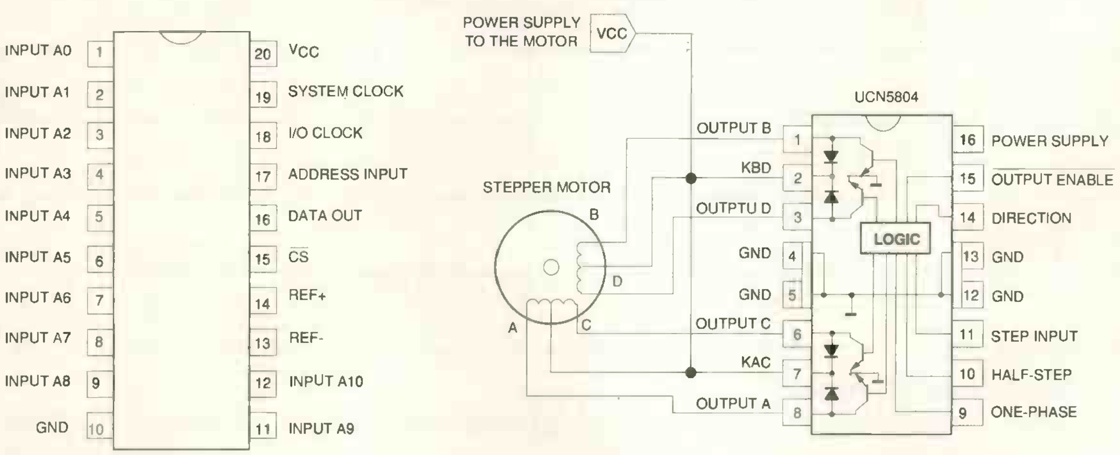


***Fig. 5.** Analogue input channels of the TLC541 converter, left (a), are arranged in order to simplify pcb design. Pin designations and typical application of the 5804 stepper-motor driver are shown on the right (b).*

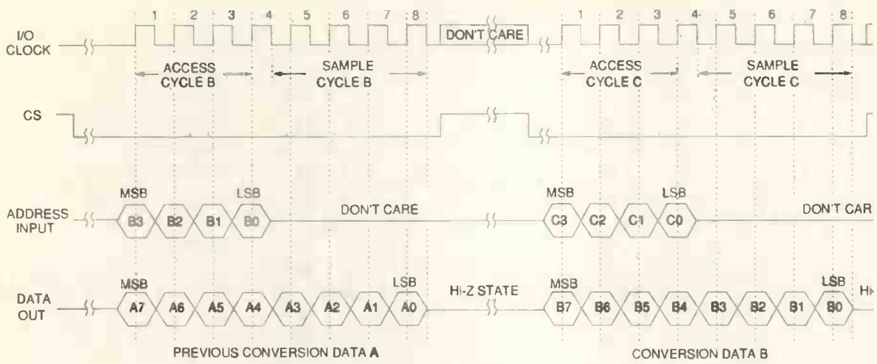


Fig. 6. Interfacing of the TLS541 a-to-d converter is greatly simplified since addressing and reading are carried out serially. When deselected, the chip places all i/o in its third state, allowing multiple chips to be connected on a common bus.

remain high until the end of the conversion – a valid falling edge of the chip-select will cause the device to reset and abort its present conversion.

System clocking is provided by a 2MHz *74LS14* oscillator. The i/o clock, address input and chip select are controlled by A_{0-2} of port A via data buffer *74LS174*, IC_{11}. Its clock pin connects to Y_4 of the decoder. Serial data out, pin 16, connects to DB_7 of port C.

A 2.5V, ±0.8%, reference for the a-to-d converter is provided by the *TLE2425CLP*. Power supply for the 5V logic circuits is supplied directly from the i/o cards. Power for the stepper motors is supplied from a separate supply, the requirement of which will depend on the types and the number of motors used in the application.

Programming

A Centronics or RS-232 24-line i/o card is needed to control the stepper motor board.

Controlling the stepper motors – to write control data to a particular stepper motor driver, it is first written to port A. It is then latched to the specified data buffer following a clock signal from IC_1. Address inputs to decoder IC_1 connect to the lower half of port C, namely C_{0-2}.

Initially, address inputs DB_{0-2} and selection lines S_{1-5} are logic high. When an address is sent to IC_1, it makes one decoded line go high to low. This results in latching data present on the internal data bus to the data buffer.

Sending data from the output port – Data buffering for the output port is controlled by Y_3 of the *74LS138*. To send data to the output port it is first written to port A. Next a clock signal is issued to that buffer.

Reading data from the input port – Control software reads data from port B directly.

Controlling the a-to-d converter – Initially, the select line is brought high to low to start the read/write cycle. The most-significant bit of the new multiplexer address, B_3, is sent from A_1 of port A. Port C, upper half, starts to read DB_7 of the previously converted result. It is followed by a positive-going pulse via the i/o clock connected to A_0 port A via IC_{11}.

At the low-to-high transition of the pulse, the address bit is latched into the a-to-d converter. At the high-to-low transition, the next bit of the conversion result appears on the data out. These procedures are repeated seven times to latch the four-bit address into the IC and to transfer the eight-bit conversion data into the pc.

The chip-select line connects to A2 port A and is brought high to allow a-to-d conversion. Latching data to the data buffer, IC_{11} occurs as described earlier. ■

In a lab on a keyboard

This virtual electronics lab – Electronics Workbench – was originally intended as a teaching aid but is now being offered as a serious design tool for electronics engineers. Review by Allen Brown.

It has become general engineering practice for designers to simulate their designs before any building or construction takes place. To help the electronics engineer in this phase of the design process, a number of software simulation packages have become commercially available.

Spice is now particularly well known for this purpose – especially among analogue designers. A relatively new contender is *Electronics Workbench*, from Interactive Image Technology of Ontario. This package started life as an educational aid and is now attempting to make an impact as a serious design tool for electronics engineers.

Running under Windows, dos or on the Apple Mac, Version 4 is a simulation environment that permits mixed-mode or analogue and digital design simulations. Engineers familiar with the mouse driven graphics user interface, GUI, will experience very few problems in mastering *Electronics Workbench*.

One of the basic ideas behind the design of *Electronics Workbench* was to make it appear like an electronics lab. It is therefore furnished with a number of laboratory instruments and a vast store of electronics components – over 500 op-amps for example. The electronic components are grouped into various categories and accessed via the appropriate icon at the top of the screen. Likewise the general purpose instruments are accessed in the same way. They comprise:

- Digital voltmeter
- Oscilloscope
- Logic word generator
- Logic analyser
- Function generator

There are two other facilities not usually realised in laboratory instrument format – a Bode Plotter and a Logic Converter. These instruments can be used in a variety of modes depending on requirement. However the user must expect limitations that real instruments do not possess, for example the time base on the 'scope is rather basic – no delayed triggering.

Instruments

The Oscilloscope in the *Electronics Workbench* product is a two channel device with standard triggering. The 'scope icon is dragged into the working area and a double click produces a miniature scope. The 'scope can then be expanded as shown in **Fig. 1**. Both channels of the 'scope are updated during the simulation process and have independent gain controls with a common time-base. The instrument can also display Lissajous figures from the two channel inputs.

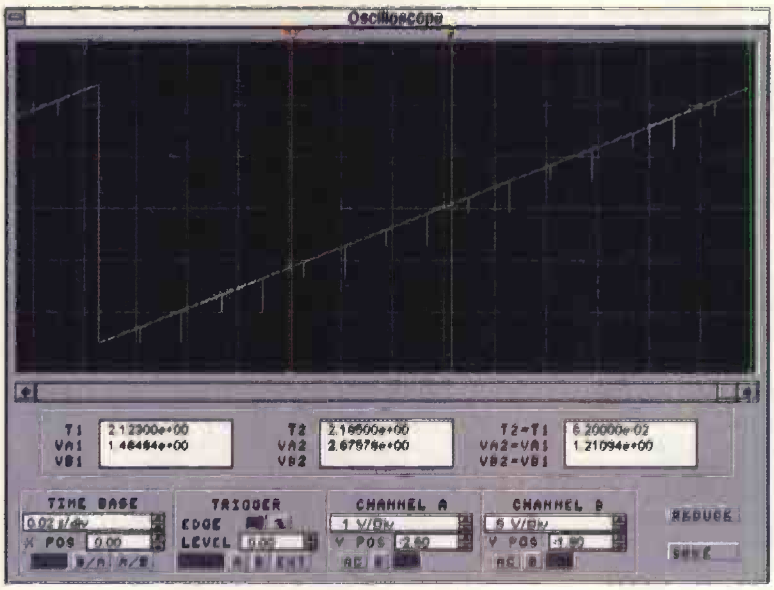


Fig. 1. Blow-up of the oscilloscope showing the output of a the d-to-a converter when fed with the outputs of two cascaded generic counters – the effects of the propagation delays are clearly present.

The logic analyser is an eight channel device, triggerable in one of three ways – trigger terminal, burst mode and pattern definition. It also has an adjustable time-base, but the other options on the logic analyser are pretty meagre so don't expect too much.

The function generator provides three waveforms, sine, triangle, and square wave, all with variable frequency, amplitude, duty cycle and dc offset. By adjusting the duty cycle on the triangle wave both positive or negative saw-tooth waveforms can be generated. I would have expected to have seen a provision for adding random noise to the waveforms.

There appears to be no way of injecting noise into a design. Considering the abundance of noise in the real world I would have thought it was essential to have a method of simulating it. Also there does not appear to be a

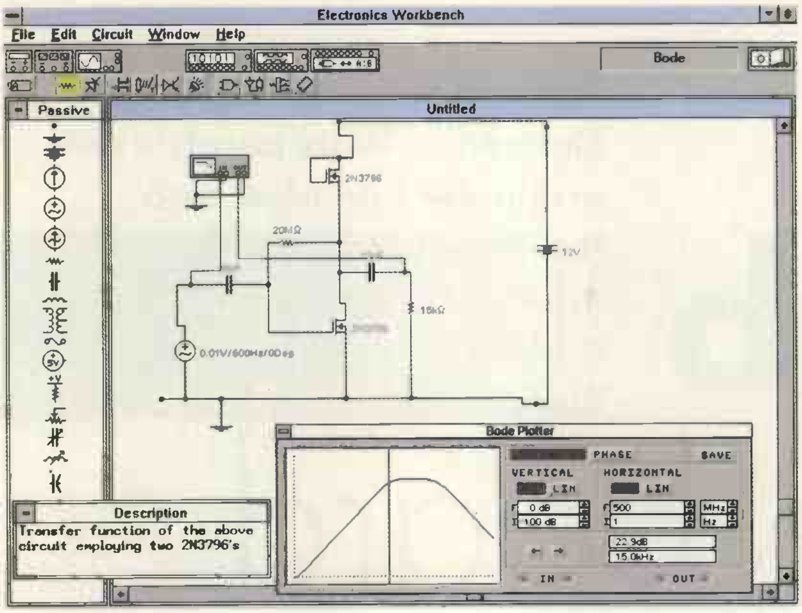


Fig. 2. Determining frequency response of a circuit can be achieved using the Bode Plotter. Unfortunately there isn't a great deal of information on the Plotter graph although the moveable cursor is very useful.

method for injecting a signal stored on disk into the circuit. This would be a useful aid for estimating the performance of a circuit with pre-recorded signals.

It would also have been nice to have had a permanent ttl output from the function generator without having to set it up on each occasion. As part of a wish list for the next version of *Electronics Workbench* I would also be pleased to see a pulse generator instrument included.

The logic word generator can generate up to sixteen eight-bit patterns and is useful for verifying performance of small-scale digital circuits. When constructing patterns, a 17in monitor is useful as bits are very small and tend to strain the eyes. However the generator performs its task well and is useful for verifying sequential logic designs.

What is missing though is a device for generating serial data streams. Fortunately the user can fabricate this device using a shift register and logic word generator.

Determining frequency characteristics of a circuit can be accomplished by using the Bode Plotter. The user chooses the initial and final frequencies together with initial and final dynamic ranges.

Once the transfer function is drawn the user can move a cursor line which provides a reading in decibels – or phase angle – with the corresponding frequency. An example of the Bode Plotter is shown in **Fig. 2**. There is a number of features missing from this instrument. The Bode Plotter cannot be expanded in the same way as an oscilloscope and the display has no labelled axis. Also it would have been nice to see the phase plot in conjunction with the magnitude plot in order to provide an easier reading of phase margin.

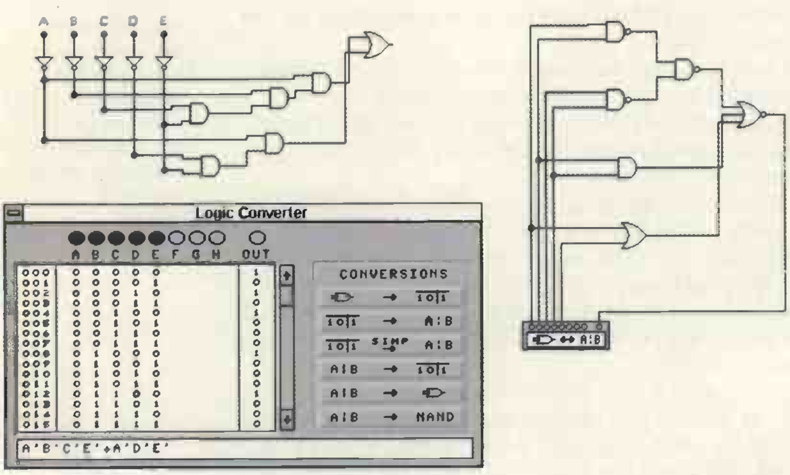


Fig. 3. An example of the logic word generator, the original schematic is on the right and the simplified design is above the pattern table. The reduced Boolean expression can be seen at the base of the table – no need for Karnaugh Maps any more!

Digital design

A design comprising combination and sequential logic can be constructed from generic components that have ideal characteristics. They can then be replaced by equivalent family components – ttl, cmos or others. Alternatively a logic design can be constructed directly from 74 series ICs.

The number of 74 series ICs in the model set ranges from 7400 to 74466 including various family variants. Alternatively there is a large number of cmos 4000 series devices to choose from. Both devices are selected using the sub-window on the left hand side of the screen as seen in the figures.

Wiring up individual components or gates is relatively easy to implement. However behaviour of the wiring algorithm is somewhat strange and sometimes results in contorted wiring schemes which cannot be automatically corrected. Once the design is complete the user can attach coloured monitors to wires to determine their status as the circuit is operating.

The logic converter is a smart idea for combinational logic design, taking up to eight inputs and dispensing with the need for Karnaugh maps. The user can enter the bit pattern and the desired response. Alternatively the user can enter the logic gates and convert the logic to derive the Boolean expression and simplify it. The simplified design is then redrawn via the logic-converted routine.

Although this is a neat idea, there are two problems in this version of the software. Firstly, the logic design generated can overlay the original design location on the screen. Secondly, the logic design generated only uses two-input logic gates instead of multiple input gates which is normal. **Figure 3** shows an example of a combinational logic design using the 'logic word generator'.

For sequential logic design *Electronics Workbench* has a choice of flip-flops – RS, D-type and JK – with or without the asynchronous input controls, preset and clear. When cascading a design the user must be careful to keep a substantial distance between flip-flops because of the wiring problem mentioned previously.

As an illustration **Fig. 4** shows a design of a Mealy machine for detecting the binary sequence 10110. The input sequence is generated with the word generator – using one bit only. *Electronics Workbench* also provides 8-bit generic a-to-d and a digital converters.

Analogue simulation

Via the schematic entry facility, it is very easy to construct an analogue circuit with *Electronics Workbench.*

To begin with the user can enter ideal components and then replace them with actual components from the vast libraries available with the product. Devices come in model sets which are constructed to conform to the Spice syntax model standard. Model set 1 is supplied as part of the product. This comprises diodes, n-p-n and p-n-p transistors, op-amps, j-fets, mosfets, scrs, diacs and triacs. Model sets 2 to 5 are optional and comprise an enhanced range of the above list – all in all an impressive list of components.

If you have your own data base of components conforming to the Spice standard, these too can be imported into *Electronics Workbench.*

There is a large number of components for building analogue simulation and these are accessed from the component windows. Capacitors, resistors and the like, all have adjustable values. However, it would have been nice

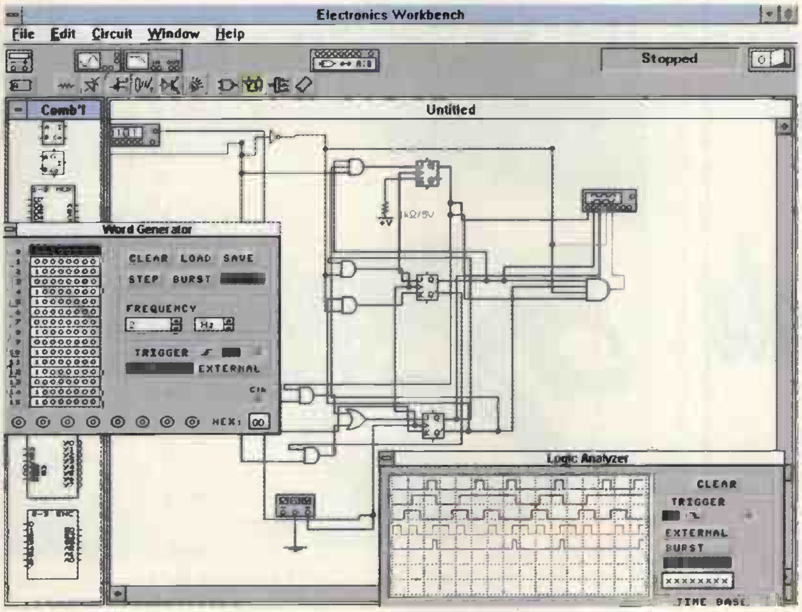
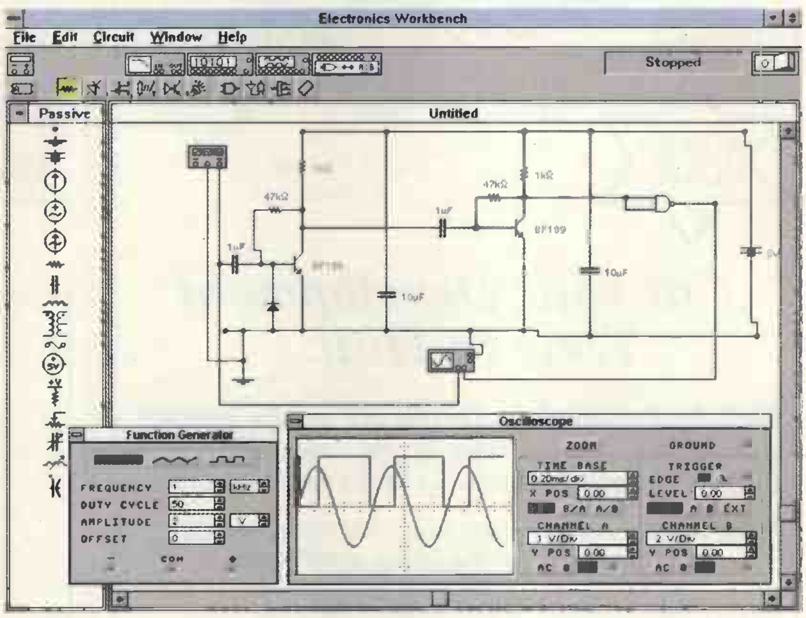


Fig. 4. Logic Word Generator used in combination with the logic analyser can serve as a useful tool for verifying sequential designs. In this example, a detector for the sequence 10110 has been constructed from three JK flip-flops. The output of the circuit is the last trace on the Logic Analyser.

Fig. 5, below. An example of ac Response Analysis of a circuit for converting a sine wave into a digital output.



to see tolerance values attached to components as well. This would allow performance envelopes to be derived for a simulation – worst and best case analysis for example.

Electronics Workbench performs its analogue simulation according to the Spice 2 model and is able to perform dc analysis, ac analysis using the Bode Plotter and transient time-domain analysis.

Circuit modelling often involves the use of simultaneous equations. *Electronics Workbench* employs sparse matrices coupled with the partial pivoting algorithm for finding solutions very quickly. Modelling integral and differential behaviour relies on the trapezoid rule of integration. This is by no means the most effective method of performing numerical integration and it would be useful if future versions employed other integration algorithms such as the Runge Kutta – second and fourth order.

A question often asked of simulation software relates to the size of the model. It appears that *Workbench* is limited by the amount of available memory in the pc. Normally 10Mbyte is allocated using virtual memory for the modelling environment, i.e. making the pc hard-disk act as ram. This figure can be expanded. However, any computational process that needs to use virtual memory will be greatly impeded. The rule is; if you are likely to require the simulation of circuits containing several tens or even hundreds of components it would be wise to increase the amount of ram in your pc to a minimum of 8MB.

An example of the ac time-response analysis is shown in **Fig. 5**. This circuit was taken from page 559 of the July edition of *EW & WW*.

Conclusion

On the whole *Electronics Workbench* is a good product that is easy to use and has a lot to offer design engineers working on a tight budget. Its ability to mix analogue and digital is an attractive feature. However the a-to-d and d-to-a converter options are somewhat limiting.

The 'technical reference' and 'user guide' supplied with the software are well presented. There is a number of tutorials and model circuits for the new user who will have very little difficulty in getting into the software.

The package represents very good value for money and will serve as an invaluable teaching aid. Its success as a professional engineering tool for large scale circuits will have to be proved somewhat.

In this review there are several 'it would be nice to see' comments. If these are taken on-board in future versions I believe that *Electronics Workbench* will be an acceptable software product for serious design purposes. ■

Software availability

Electronics Workbench is produced by Robinson Marshall, Nadella Buildings, Progress Close, Leofric Business Park, Coventry CV3 2TF. Tel 01203-233216, fax, 01203 233210. Its price is £199.

LETTERS

Letters to *"Electronics World"* Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Electromagnetic incompatibility

In the course of checking some details points regarding the EMC directive the following has come to my attention.

The issue of harmonic currents drawn from the mains supply is addressed within the generic emissions standard EN 50081-1 by another standard EN 605552. This standard applies only to domestic appliances and similar equipment.

A new standard, EN 61000-3 2 has been prepared to replace EN 60055B 2 covering all electrical and electronic equipment up to 16A per phase. Equipment drawing less than 75W are effectively exempt.

I have been informed that it is currently proposed that EN 61000-3-2 will supersede EN 80555-2 without any of the transitional arrangements that normally apply when a new standard is introduced. At present it is not even possible to buy a copy of EN 61000-3 2 – from BSI Sales at least – yet it is suggested that all equipment should comply with it by 1 January 1996. A similar document IEC 1000-3-2 is also available, though similar problems in obtaining it have occurred.

If your organisation manufactures or indeed imports a product which draws more than 75W from the mains supply then EN 61000-3-2 will apply to you. If you have not already addressed the issue of mains harmonics such as through the use of power factor correction or other means, then it is quite likely that you will not be able to meet the limits set in EN 61000-3-2. In particular those using 'conventional' as opposed to switchmode supplies may find particular difficulty without radical product redesign.

Representations are already being made by some industry sectors regarding the impossibility of this situation. You may wish to add your own, either through a trade association or directly. Contact points at the DTI and BSI are as follows. David Sutherland, Department of Trade and Industry, 3.120 Red Zone, 151 Buckingham Palace Rd, London, SW1W 955, fax 0171n215 1529/2909. John Baker, Electrical section, Technical help to Exporters, BSI standards, 389 Chiswick High Rd, London W4 4AL. Fax 0181 996 7048.

Graham Stevenson
Studiomaster
Luton

Dynamo turns again

I have been reading with interest the letters concerning cycle lighting systems and would like to refer readers back to the road proven circuit I had published in circuit ideas Dec'94 . Note that the upper speed limit of 15mile/h is a misprint. There is no practical upper speed limit.

The circuit operates in a switch mode that matches the generator output into a standard 3W load while incorporating a progressive changeover battery/generator section. Extra power obtained by operating the generator into a higher impedance compensates for any circuit losses.

No modifications are needed to either the alternator or the lamp systems thus enabling any component part to be easily replaced from most cycle shops. Further, a bypass switch can then be used to instantly switch back to a standard system – in slow moving traffic it saves battery drain.

Backup batteries can be Ni-Cd or dry cells if the charge resistor is omitted. I use a 2.4W halogen headlamp and given that there is no overvoltage at any road speed, a full lamp life is achieved. As previously mentioned high brightness leds give an acceptable rear light with a small power saving. Given the variable output between the makes of generator I recommend that the cheap, readily available Union 'Bottle Dynamo' Cat 6701 is used with my circuit.

Recently introduced by Union is a 26 pole samarium-cobalt magnet hub generator which claims to meet the German standard of 3W at 15km/h. Having no frictional losses this device claims an efficiency of 65% at 15km/h.

However, as a final point, given that some people trundle along at 5mile/h while others cruise for miles at 20, what is the ideal cycle light system?

PW Fry
Holbury
Southampton

What's that noise

I read Research Notes 'LF noise', July '95 and 'Mains hum or ear drum' June '94 with interest. I hear a low-frequency sound, comparable with the descriptions given, and those presented in a New Scientist article, – 'Officials eat humble pie over mystery noise' in 1992.

John Sargent's report mentioned in research notes is known to me. We exchanged information but I do not agree with *all* his conclusions. For example, the conclusion that a sound proof room should be isolated from the acoustical environment is not necessarily true for the low frequencies under investigation. Anyone involved with loudspeaker measurements knows that a sound proof room is only sound proof above a certain frequency.

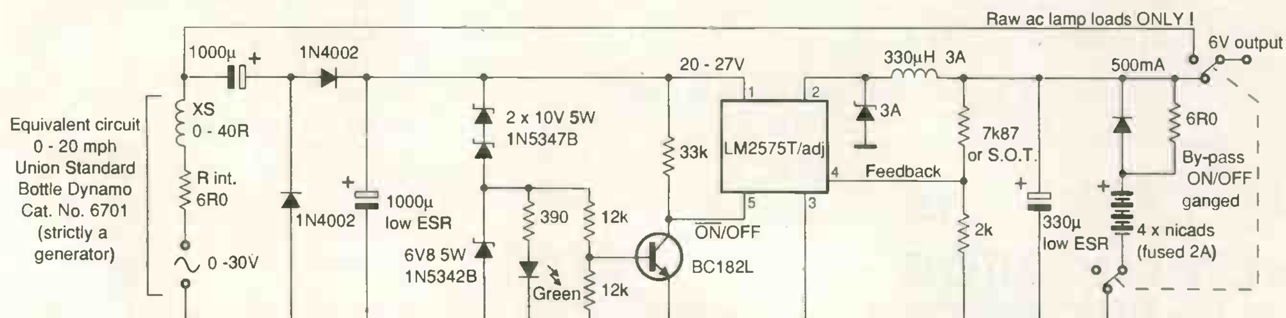
I came across the origin of the sound that I hear by accident. Finding the source was impossible since the human ear cannot distinguish the direction from which sound comes since the frequencies involved are below 200Hz. Even travelling in the direction where the sound level increases failed.

My assumption was that the ground underneath my feet was part of the propagation path. From a point source, the level decreases by 6dB for each doubling of distance; for a line source this is only 3dB and for a flat source, 0dB.

I found the cause of the sound by accident when I was holidaying in France. A sewerage pump went out of order for a few days, and the low-frequency tone disappeared – there was no other pump for several miles around.

Back in the Netherlands I studied the sewerage system and found that the frequency I heard – a noisy signal of about 30dB in the range 8-74Hz just at the hearing threshold – was made by the pumps.

In a village or city the sewerage system is based on the fall of the water in large pipes. At the lowest



Battery-backed dynamo cycle lighting works from walking speed upwards.

point there is a basin and a pump. Outside the built up area, there are thin metal pipes for the transport of waste and dirty water. When the basin is full, the pump starts to run, stopping after about 20 minutes, when it is empty. The next basin is within a few hundred metres.

The sound level of such a pump is almost independent of distance up to about half a mile – maybe reaching people with sensitive ears even after a few miles. All these pumps have the same construction, thus generating sound with the same frequency. The frequency is not constant. It depends on the load, which varies continuously. These interfering sources are summed, resulting in the noisy tone that I hear.

I learned from a researcher in the field of human ear perception that some people observe a tone when low bandwidth noise is fed to the ears. Other people do not hear anything apart from background noise.

I found that it is possible to train people to hear the noise using a 70Hz tone. After gradual attenuation to zero, the tone was still there for some listeners.

I have had a few reactions that are doubtful. Tinnitus aurium for example can cause comparable sounds sensations. So if you have doubts, the most reliable method to identify such sources is a tone comparison. An audio tone generator and a loudspeaker will do. If you find another frequency – it is still possible that you are listening to another sound.

Ir F. Sessink
Nuenen
The Netherlands

Field hazards

The coal mining industry was so grateful for the invention of the Davy lamp by the first Director of the Royal Institution that it asked Davy to investigate the violent explosions to which mines were then subject, which typically threw men and machinery high in the air above the shaft mouth. He delegated the job to Michael Faraday who duly implicated coal dust as the prime element. The industry proceeded to ignore this finding for 25 years, one person being sacked for supporting it.

I am confident that alternating magnetic fields cause brain cancer, leukemia, miscarriages and birth deformities such as spina bifida. In this connection I find the letter from J C Williams chief executive of the IEE, obfuscatory (Aug. 1995 issue). Nominally it concerns itself with "low-frequency electric fields" and the big point here is that they are recognised as deleterious in the US owing to a legal precedent. There is also concern about power-frequency magnetic fields and about proximity to radio or radar transmitters. The three matters are dealt with in Brodeur's three articles 'The Annals of Magnetism' published in The New Yorker in 1989. The term 'electromagnetic fields' is a new one and until now I was only aware of electric fields, magnetic fields and electromagnetic waves. I understand it has to be qualified in parenthesis if you want to refer to electric or magnetic fields these days. But Mr Williams does not do this. I begin to wonder if the IEE Working Party is going to get even the title of its report right.

And what a shame the IEE has not felt able to speak out against magnetic fields, given the fun we are all going to have proposing splitting live current in 240/440V overhead lines into two equal halves to run on two separate wires above and below the neutral, and so on. (This will boost the economy.) It matters *now* because companies and computer owners should be asking themselves if it would be better to get computers with screens of a type used in laptops, for health reasons, rather than subject themselves to the leakage field arising from forcing fields across the one-inch gap across the neck of the cathode-ray tube. Of course other screen types will yield desk computers with a smaller 'footprint' which might be economically worth while in some locations.

But do I trust the IEE to embark on research epidemiology? No it's not their business.

Bernard Jones
London

Arnold Sugden – pioneer

The announcement of Arnold Sugden's death is especially sad, since his pioneering work still remains unhonoured by the Audio Engineering Society despite an initiative taken a considerable time ago by the late Raymond Cooke.

His achievement in single-handedly developing stereo LPs two years before anyone else in the world, alone earns him a prime place in audio history. It also brings closer the extinction of a vanishing breed of audio worker, who were involved because of a love of music – not, as is so often the case now, the noise it makes.

I hesitate to suggest it, but could it be he lacked the academic qualifications of those that dominate its membership? I suspect there are many who have never even heard of him.

Reg Williamson
Kidsgrove
Staffordshire

'Arnold Sugden – Pioneer of Single Groove Stereo' Reg. Williamson *EW+WW* June 1994.

Switchers for the Masses – free disk

In the August 1995 issue, we omitted to mention that a design software disk is available to support the article 'Switchers for the Masses'. Free to designers, this disk can be obtained, together with an information pack, by faxing National Semiconductor in Germany on 00 49 89 2471 1222. Request National Semiconductor Information Pack Reference No. 700 005.

Aplea for constructive exploration

Recent articles concerning audio amplifiers and subsequent letters to the Editor have been interesting and stimulating, although it seems that a few personal axes have been ground.

The volume of discussion and disagreement generated provides strong evidence that we still don't fully understand all aspects of audio amplification and sound reproduction relevant to satisfying the human ear/brain. We are not able to define and quantify factors which generate clearly audible effects.

Surely, the best way of improving understanding is for us to continue exploring various avenues of research, to report results and to have these constructively reviewed. In the past some of the most apparently harebrained ideas have resulted in new discoveries. Most importantly, try to remain objective and suppress personal interests.

It is very difficult to remain unbiased and objective in any assessment of a situation. Especially so when we are unable to properly measure or otherwise quantify observations.

My interest relates only to personal satisfaction in developing circuitry for the reproduction of music. I don't have access to sophisticated test equipment as used by 'professionals' but use only a signal generator, oscilloscope and a dmm. I have done measurements of harmonic distortion levels, but no longer do so as results did not correlate with what I heard.

I now limit my bench testing of amplifiers to checking dc conditions, setting quiescent currents and checking square wave response under various loads.

Readers might be interested in some of my own observations relating to the use of bipolar and fet output devices. I have compared the operation of an amplifier using a complementary compound follower output stage consisting of bipolar devices for driver and output devices[1] with one comprising bipolar drivers and fet output devices[2].

The bipolar-only stage could be made to generate crossover spikes when fed with 20kHz sine waves. The spikes could be made smaller by optimal setting of quiescent current, but could not be entirely eliminated.

In contrast, the bipolar/fet stage could not be induced to generate spikes – even when fed with 80kHz sine waves. At low bias settings clean step changes were seen at the crossover point which disappeared totally as bias was increased.

Perhaps this goes a long way to explaining why fets can give such a clear and open sound under normal listening conditions, despite their 'poor linearity'. The very fast response of fets is likely to allow negative feedback to keep better control of the circuit than is possible with relatively sluggish bipolar output devices – especially in the crossover region.

I am currently using amplifiers with class-B complementary source follower fets *(2SK134/2SJ49)* with complementary class-A bipolar emitter-follower drivers. This has resulted in the cleanest sounding and most stable amplifier that I have yet built. Quiescent current in the output stage is not critical and I cannot detect any audible benefit in increasing this above 100mA or so.

The input stage consists of a conventional emitter degenerated long tailed pair with current mirror, but includes cascode transistors. A cascode voltage amplifier stage is used, buffered from the input stage via an emitter follower stage.

Open loop gain of such an amplifier is high. Despite this, the amplifier is very stable with C_{dom} at 44pF. It is still stable with C_{dom} at less than 22pF when driving reactive loads, for example 7.5Ω in parallel with 2μF. The usual output inductor//resistor combination has been omitted. Under these conditions only a very small amount of overshoot is detectable on square wave response. I have not been able to come even close to this using bipolar output devices.

I have learned much from reading papers by Self and others, but have been forced to the conclusion that conventional circuit analyses do appear to overlook some important aspects. John Linsley-Hood's recent article supports this view[3]. Come on all you bipolar and other buffs – Doug included. Let's have an unbiased (ugh !) exploration of *real life* operation of audio amplifiers.

Ken Hough
Amersham,
South Bucks

References

1. Self, D., 'Distortion in Power Amplifiers', *EW+WW* Nov. 1993, p. 930, Fig. 3(a).
2. Self, D., 'Distortion in Power Amplifiers', *EW+WW*, Nov.1993, p. 931, Fig. 4(c).
3. Linsley-Hood, J., 'Expert Witness', *EW+WW*, Aug 1995.

Super symmetry misunderstood?

Having read Douglas Self's analysis (Sept. '95) of my 'super-symmetrical' amplifier (Dec '94) with great interest, I feel there is a need to clarify two issues – the nature of the 'virtual complement' and the feedback.

Self refers to "...the sharp-eared Batman effect in Fig. 5", describing it, "They also show sharp changes in gain" and "there are always sharp gain changes" *EW+WW* May 1995. It is obvious that the sharp gain changes are the reason for his analysis of my design.

The odd-looking Batman curves can be traced back to two causes – output clipping, which is not visible in Fig. 5, and gain. The latter is the differentiated characteristic, thus very sensitive to even small curvature changes in the characteristic.

Vertical sides of the Batman profile (g, f) represent constant output current at clipping, when gain immediately drops to zero, (r, q) in Fig. 3. An omission has been made by Self in not entering the implications of these curves.

The 'ears' (a, c) will in fact continue up and outward when the power supply voltages are increased. Judgement should be made on the basis of the characteristic in Fig. 3. The sharp gain change at clipping should not be used as an argument, since all amplifiers clip at overload. Self's own amplifier has the same 'sharp changes in gain'. I haven't noticed him mentioning this.

Incidently, the Batman curves are the same as I pointed out as correct in my letter 'Impossible Curves', July 95, although Self believed that his old 'jagged wingspread' curves were right. It is with great pleasure I note this change of opinion.

Self believes his analysis is fair, but to be fair one needs to be knowledgeable. He knows that the feedback factor is zero at 20kHz. Thus, open-loop gain bandwidth is 0.4MHz. How likely is that? But this statement has one implication – my measured thd 0.015% at 20kHz must be wrong, since there is no feedback at 33kHz, where the third-harmonic is. In fact, the real distortion would be equal to raw distortion.

The clue to this is in Self's remark later. He has placed a 3nF capacitor between the drain and gate of Tr_3 for compensation purposes. This capacitor is neither neccessary, nor desirable. Self will not find it in my schematics, where the proper way to compensate is shown (see C_8 in Fig. 11, used only with the 'twin current mirror', *EW+WW* July 95). One advantage with the 'super-symmetrical' amplifier is that internal capacitances alleviate the need for compensation. Thus it has a high feedback factor and low distortion. The ultimate phase shift is 180° in a two-stage amplifier so it cannot be unstable – a great advantage.

This is in contrast to Self's claim that my amplifier is more complex than the old three-stage topology. It

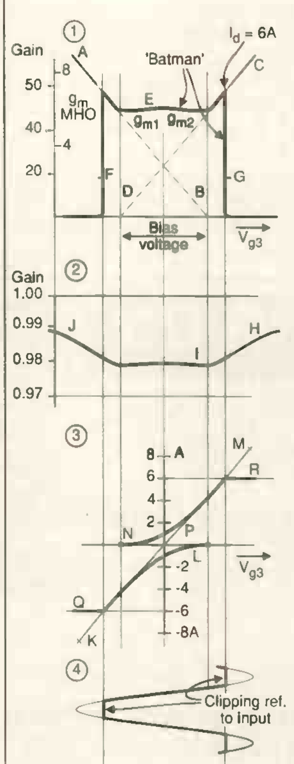


Fig. 1. Clarified Batman g_m curve (a-e-c) at 1A bias is the sum of (a-b) for Tr_2, and (d-c) for Tr_1. gm is the slope of the real characteristic in Fig. 3. The 'curvilinear' range (e) is equal to the bias voltage.

Fig. 2. gain in source-follower connection (j-i-h) cannot be higher than 1,0. It is the curve (a-e-c) compressed by emitter feedback, the way Self prefers to show it.

Fig. 3. Composite characteristic (k-p-m) is Tr_1 minus Tr_2 since $Tr_{1,2}$ have output current in opposite directions. Output stage clips at +48V, ie at 6A in 8Ω, curve (q) and (r), where gain becomes zero. This corresponds to curve (f) and (g) in Fig. 1. Curvilinear range (p) is equal to the bias voltage, and corresponds to (e) in Fig. 1. Increasing bias means increased linearity.

Fig. 4. Excessive gate drive causes output clipping at a level set by the power supply voltage. This in turn determines the position of the Batman sides (f) and (g) since clipping level is 6A.

may be a little harder to grasp, but it is in fact the most easily compensated I have known in my 30 years of amplifier design.

There is more to be said but I will point to one detail – the PSpice shows a slight dissymmetry from the gate of Tr_3 to the output. It is because of the small gate signal voltage required to change the current in Tr_3 (symmetry from gate to output of Tr_1 and Tr_2 is perfect).

Self now focusses on this error in a whole page with four major misleading statements about "...the lack of symmetry about the output line". (The error is insignificant since the gate really belongs to the input stage and is current driven so the error is not visible, only at the voltage drive used in his PSpice). This is to my mind exaggerating and only aimed at discrediting my amplifier since the real cause is never explained.

On the whole my feeling is that Self's analysis is lacking in insight into feedback an stability and the possibility of driving mosfets with unconventional means.

Bengt Olsson
Saltsjo-Boo
Sweden

Self on Olsson

Mr Olsson's subject, discussed in the July 1995 issue, is so close to my interests that I am sure he will understand I feel bound to comment on his double mirror article (*EW+WW* July'95) I hope that he will not feel that I am taking on a Judge Self role with respect to his material in particular.

As far as I can see, the whole article is based on the premise that amplifiers usually have insufficient open-loop gain, and so lack enough negative feedback to reduce the distortion adequately. I think that this statement is quite wrong. The amount of negative feedback that can be applied to an audio amplifier is ultimately limited by the need for reliable hf stability, and it is a matter of regret that no-one answered my previous call for an informed debate on the amount of global feedback that could be considered safe. To restate my own experience; given the generic amplifier configuration with dominant-pole compensation and an output inductor, 30dB at 20kHz seems to be reliably stable under all conditions. Will anyone else contribute their view?

To return to double mirrors, if it were necessary to increase the open-loop gain, then why not simply reduce dominant-pole C_3? This would increase the gain and the slew rate at the same time. Alternatively, the input pair degeneration resistors R_1,R_2 could be reduced, so long as the input linearity is not unduly degraded; this will not improve slewing, however.

Mr Olsson states that a tail-current of 10-20mA is impossible. This is certainly untrue, and I cannot fathom why he thinks so; the only bad consequences of increased tail-current would be an increased dc offset spread due to the greater base currents drawn by $Tr_{1,2}$ through the circuit resistances. Mr Olsson's article omits his preferred tail-current value, and indeed just about every concrete quantity that might allow us to assess the success of his scheme. In particular, a real measured, before/after distortion plot is conspicuous by its absence; presumably we are expected to take this on trust, and I don't do that.

The only other question I would like to ask: how is stability attained if the o/l gain at all frequencies is increased by 12dB (I got this value from Olsson's Fig. 2) unless the amplifier was already over-compensated? Fig. 2 shows the second pole at 1MHz, and a stable 6dB/ octave Nyquist intersection is only obtained because the demanded closed-loop gain is also falling by 6dB/octave from 300Hz. This is presumably due to the presence of phase-advance capacitor C_2 across feedback resistor R_9; if so this is a vital, if not the vital part of the scheme, and I would like to know more about it, not least because I have always found such a capacitor to worsens stability rather than improve it. This appears to be because Tr_2 is liable to parasitic oscillation with C_2 present, though of course the true explanation may be that I am hopeless at compensating amplifiers.

I read Mr Olsson's article with great interest, but found it raised many more awkward questions than it answered; I hope he will feel able to give a more comprehensive explanation of the thinking behind it.

Self on J. Linsley-Hood

As someone who has always read John Linsley-Hood's m
aterial with interest, I was sorry to see that his article 'expert witness' in the August issue failed to provide valid information. I admire his determination in making some real tests, which other critics have apparently not felt to be necessary, and it is regrettable that I have to disown the results.

The bjt output stage used for these tests, is, I'm afraid completely wrong. JLH's diagram shows to 100Ω resistors inserted in the emitters of the bjt drivers. Why he put them there I cannot guess. They are most certainly not present in any bjt circuitry I have advocated, and they ruin the linearity. The effect of adding the 100Ω on output gain is shown as the lower curve in he wingspread gain-diagram below. It can be seen that the drop-off in gain with load excursion is dramatic, and I am sorry to say that this renders his results fallacious.

I am also concerned that the amplifier used is nowhere near Blameless- the distortion to be expected with bjts is sub-0.001%, as I have shown many times in the past. Anything higher than this indicates that one of the eight distortion mechanisms has not been properly dealt with, and so the result is a complicated mixture of distortions that tell us nothing.

It is not my purpose to analyse the design decisions taken in the JLH small-signal stage. But I can see no provision for preventing the non-linear input impedance of the output stage from affecting the voltage amplification stage. The function of C_{12} in the input current-mirror is obscure, but it looks as if it does something drastic and unusual to the put g_m.

One major omission from the article is the amount of global negative feedback in use. It is clearly essential to know this before judging linearity.

It is regrettable that a better oscillator was not available, for 0003% oscillator distortion will completely swamp the actual amplifier non-linearities – in the bjt case at least. Oscillator distortion an order of magnitude lower is highly desirable. I would remind readers that my conclusions about fet linearity are not simply based on simulation, but also on practical measurements that were reported in the Distortion In Power Amplifiers series. (Oct 94-Feb 95).

If fets really were as linear as claimed, then there should be no difficulty in building an fet amplifier that equals or exceeds the performance of the Class-B amp I presented in *EW+WW* January 1994, while using the same amount on negative feedback. I shall wait with interest to see if any one can do it.

Self on Duncan

Since Mr Duncan appears to have dispensed with the usual courtesies and conventions of public debate, I find I have better things to do than argue with him for example, the grass needs cutting.

However, I feel should correct a couple of his mis-statements to prevent others from being misled. There is really no doubt of any kind that hf levels in music, etc are much below the lf levels, and I append below two references (reaching over no fewer than forty years) so that anyone who chooses can verify this.

I expect Roland will be less than pleased to have their magnificent *U110* described as a 'supermarket keyboard', when it is actually a professional Midi master keyboard that cost £1600 when I acquired mine. The rest of Duncan's letter is to a similar standard of accuracy.

Douglas Self
London

Langthorne-Smith, Radio designers handbook, Ch. 14.7, p. 622 4th edn, pub Iliffe 1953.
Dibble, K., 'Hearing loss and music' p. 261, *JAES* Apr 1995.

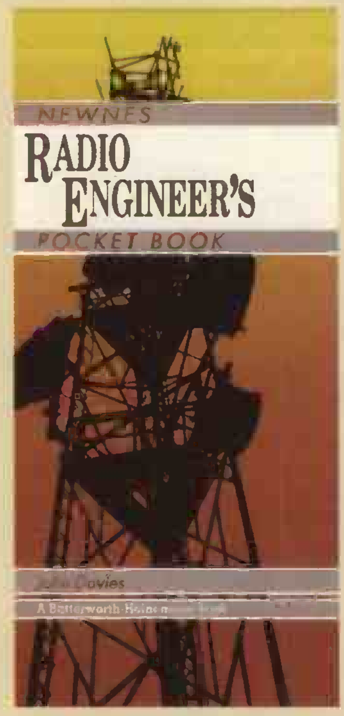
Fair comment

Douglas Self, *Electronics World* Sept 95, refers to Bengt Olssen's amplifier article, *E W* Dec. 94, and presents an equal number of pages in antithesis, as if 'fairly' establishing that Bengt's design has problems and no benefits.
Mr Self's Spice plots graphically show the non linearities we fully expect with reduced Class-A quiescent current and voltage drive directly to base-emitter or gate-source inputs. This Fig. 2 simulation circuit is quite different from other output stages and in analysing without high impedance drive (Bengt, Fig. 5) he has not compared like with like.

I surmise that his own Blameless Class-A, *EW+WW* Mar'94, would also behave 'fairly' non-linearly with a voltage source input connected directly to the base input of its second stage.

What is important is that both designs use similarly elegant 'p-to-n' voltage amplifying configurations, 'p' input differential to n common emitter or common source, and, while Bengt's simpler design does have less gain for negative feedback, when his Fig. 11 includes Self's Tr_{12}, it outputs a beneficial 100W into 4Ω with 10kHz distortion measured at only 0.01% – A most acceptable non-linearity.

Graham Maynard
Newtownabbey
N Ireland



Radio Engineer's Pocket Book

by John Davies, 240pp, hardback
Order – ISBN 0 7506 1738 1
Price £12.99

Contains: Propagation; decibel scale; transmission lines; antennas; resonant circuits; oscillators; piezo-electric devices; bandwidth requirements and modulation; frequency planning; radio equipment; Microwave comms; information privacy and encryption; multiplexing; speech digitisation and synthesis; vhf and uhf mobile communication; signalling; channel occupancy, trunking; mobile systems; base station management; instruments; batteries; satellite comms; connectors and interfaces; broadcasting; abbreviations and symbols; tables and data; glossary.

Covers all aspects of radio and communications engineering from **very low frequencies to microwaves,** with particular emphasis on mobile communications. Wave principles and the decibel scale, instrumentation and power supplies, equipment types and encryption methods, connectors and interfaces, are all included in this book.

Audio Recording and Reproduction

Michael Talbot-Smith, 204pp, paperback
Order – 0 7506 1917 1
Price £12.99

Contains: Physics of sound waves; hearing; basic acoustics; microphones; loudspeakers; public address; stereo; simple mixing equipment; recorders; introduction to digital audio; music and sound effects; miscellaneous data.

This book gives a simple and straightforward approach to audio techniques, **detailing technical and practical information** for those with no specific training in the subject.

Circuit Designer's Companion

by T Williams, 320pp, paperback
Order – 0 7506 1756 X
Price £15.99

Contains: grounding and wiring; printed circuits; passive components; active components; linear integrated circuits; digital circuits; power supplies; electromagnetic compatibility.

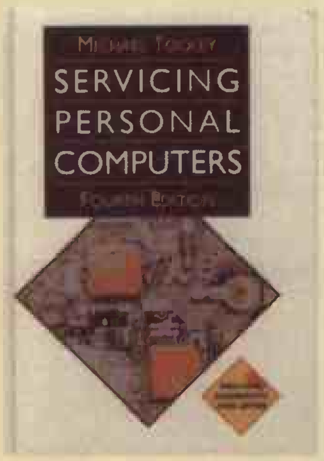
Valued by linear and digital designers alike, this guide explains and outlines solutions that take into account the imperfect behaviour of real components, interconnections and circuits.

Servicing Personal Computers

by Michael Tooley, 304pp, hardback
Order – ISBN 0 7506 1757 8
Price £25.00

Contains: Microcomputer systems; test equipment; fault diagnosis; tape and disk drives; printers and monitors; servicing IBM pc compatibles and 68000-based computers.

This completely rewritten fourth edition still covers the whole range of microcomputer equipment but now also **includes a guide to developments and trends** such as the new generation of diagnostic software – code included – and applications such as serial communication, and memory and hard disk management..



Newnes Audio and Hi-Fi Handbook

by Ian Sinclair, 656pp, hardback
Order – ISBN 0 7506 0932 X
Price £40.00

Contains: Sound waves and acoustics; studio acoustics; microphones; sound synthesis; introduction to digital principles; compact disc technology; other digital systems – DAT, NICAM, DCC, MD – analogue tape recording; noise reduction systems; LP records; disc reproduction; tuners and radio receivers; preamps and inputs; voltage amplifiers/controls; loudspeakers and enclosures; Headphones; public address; in-car audio; interconnections; the future.

Covers a **wide perspective of high-quality sound reproduction,** including reproduction under adverse circumstances, from less conventional sources and with regard to the whole technology from studio to ear.

TV & Video Engineer's Reference Book

by Boris Townsend, 876pp, paperback
Order – ISBN 0 7506 1953 8
Price £40.00

Contains: Materials; components and construction; colour tv fundamentals; broadcast transmission; distributing broadband; DBS; tv studios; mobile and portable equipment; tv sound; tv receivers; servicing tvs; video recorders; teletext etc; HDTV; other applications of tv; performance measurements.

Covers information on every aspect of modern broadcast technology. Of value to all practicing engineers and managers involved with broadcast, cable and satellite services.

Masts, Antennas and Service Planning

by Geoff Wiskin, 256pp, hardback
Order – ISBN 0 240 51336 3
Price £49.50

Contains: Antennas; antenna support structures; service planning.

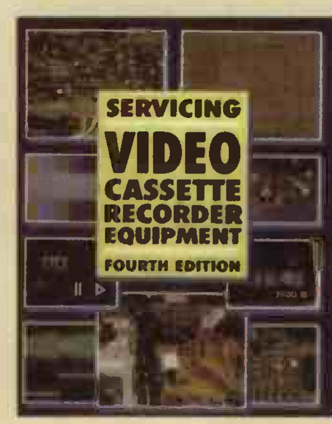
Covers all aspects of information conveyance via radio-wave transmission. Invaluable to anyone planning for broadcast and mobile-radio coverage, or designing, installing and maintaining antenna systems.

Operational Amplifiers

by Jiri Dostal, 400pp, hardback
Order – 0 7506 9317 7
Price £40.00

Contents: The operational amplifier; basic concepts; operational amplifier parameters; operational amplifier properties; the operational circuit; the ideal operational circuit; analysis of the real operational circuit; static and dynamic errors in the frequency domain; dynamic errors in the time domain; input and output impedances; offset; noise; stability; good laboratory practices.

Presents an extensive treatment of applications and a practically oriented, unified theory of operational circuits. Provides the reader with practical knowledge necessary to select and use operational amplifier devices.



Servicing Video Cassette Recorders

by Steve Beeching, 250pp, hardback
Order – ISBN 0 7506 0935 4
Price £25.00

Contains: Vcr systems; azimuth tilt;.Frequency modulation; servo mechanisms; colour systems; systems control; long play; VHS-C & camcorders; a-v sockets.

Written for students and people involved with vcr servicing, this book is an invaluable guide and reference covering all aspects of modern vcrs. Contains new material on basic magnetic theory to C&G 224

Principles of Transistor Circuits

by S W Amos, 384pp, paperback
Order – 0 7506 1999 6
Price £17.99

Contains: Semiconductors and junction diodes; basic principles of transistors; common-base and common-gate amplifiers; common-emitter and common-source amplifiers; common-collector and common-drain amplifiers; bias and dc stabilisation; small-signal af amplifiers; large-signal af amplifiers; dc and pulse amplifiers; rf and if amplifiers; sinusoidal oscillators; modulators, demodulators, mixers and receivers; pulse generators; sawtooth generators; digital circuits; further applications of transistors and other semiconductor devices.

This seminal work has now been presented in a clear new format and completely updated to include the latest equipment such as laser diodes, Trapatt diodes, optocouplers and GaAs transistors, and the most recent line output stages and switch-mode power supplies.

Logic Designer's Handbook

by Andrew Parr, 488pp, paperback
Order – 0 7506 0535 9
Price £30.00

Contains: Simplified data on a comparative basis of ttl and cmos ics; storage devices; logic circuits; timers; counters; drivers; interface circuits; logic gates; definitions of ic characteristics; event driven logic; communication and highways; analogue interfacing; practical considerations; summaries by function of all relevant circuits; individual pin-out diagrams.

Easy-to-read, but nonetheless thorough, this book on digital circuits is for use by students and engineers, and is a readily accessible source of data on devices in the ttl and cmos families.

The Art of Digital Audio

John Watkinson, 490pp, hardback
Order – 0 240 51320 7
Price £49.50

Contains: Why digital?; conversion; AES/EBU; digital audio coding and processing; digital compact cassette (DCC); advanced digital audio processing; digital audio interconnects; digital recording and channel coding; error correction; rotary head recorders; stationary head recorders; NAGRA and data reduction; Digital Audio Broadcasting (DAB); the compact disc/mini disc.

New edition, completely updated to include all the latest developments, including DCC, the mini disc and digital audio broadcasting.

Microphone Engineering Handbook

by Michael Gayford, 384pp, hardback
Order – 0 7506 1199 5
Price £65.00

Contains: Microphone techniques; precision microphones; optical microphones; high quality rf microphones and systems; radio microphones and ir systems; microphone testing; ribbon microphones; microphone preamplifiers; stereo microphones; microphone standards.

Comprehensive and authoritative book for engineers, technicians, students and anyone else concerned with the design and use of microphones.

MIDI Systems and Control

by Francis Rumsey, 256pp, paperback
Order – 0 240 51370 3
Price 19.95

Contains: Introduction to principles and terminology; synchronisation and external machine control; common implementations; systems control sequences and operating systems; implementation of midi with peripheral devices; practical systems designs.

Second edition is updated and enlarged to take MIDI evolution into account. More examples of real implementations, more diagrams and the whole book has been rewritten to include a far greater practical element, to complement its existing technical strengths. Several completely new sections and complete chapters have been added including a new opening chapter as an introduction to principles and terminology; MIDI timecode; librarians and editors.

Loudspeaker and Headphone Handbook

by John Borwick, 224pp, hardback
Order – 0 240 51371 1
Price £35.00

Contains: This book brings together in a single volume every aspect of loudspeaker and headphone theory and practice in sufficient depth to equip students and practitioners alike with a solid working knowledge of the subject. A comprehensive technical reference on the theory and practice of loudspeaker and headphone performance, design and operation.

The Art of Linear Electronics

by John L Hood, 400pp, paperback
Order – 0 7506 0868 4
Price £16.99

Contains: Electronic component symbols and circuit drawings; passive components; active components based on thermionic emission; active components based on semi-conductors; practical semi-conductor components; dc and low frequency amplifiers; feedback negative and positive; frequency response; modifying circuits and filters; audio amplifiers; low frequency oscillators and waveform generators; tuned circuits; high frequency amplifiers/oscillators; radio receiver circuitry; power supplies; noise and hum; test instruments and measurements.

This practical handbook gives a complete working knowledge of the basics and technology of linear electronics – with application examples in such fields as audio, radio, instrumentation and television.

Servicing Audio and Hi-Fi Equipment

by Nick Beer, 304pp, hardback
Order – 0 7506 2117 6
Price £25 .00

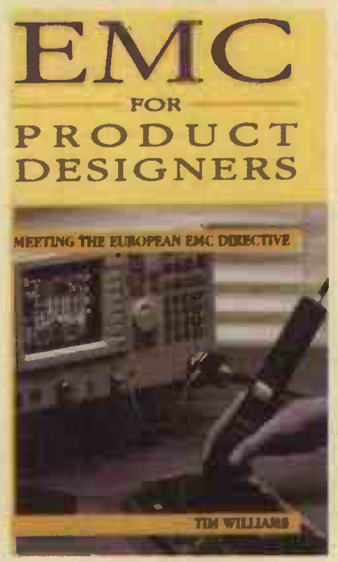
Contains: Introduction; tools and test equipment; radio receivers; amplifiers; power supply circuits; portable audio; cassette deck mechanics; cassette electronics; turntables; system control; motors and servo circuits; compact disc; mini disc; digital audio tape; digital compact cassette; speakers, headphones and microphones; repair, addresses.

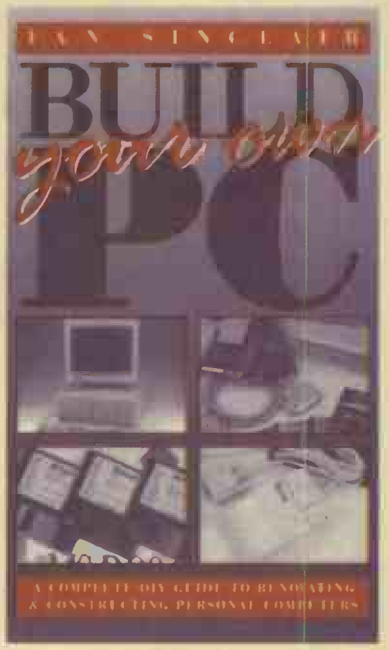
As a bench-side companion and guide, this work has no equal. Its purpose is to ease and speed up the processes of fault diagnosis, repair and testing of all classes of home audio equipment: receivers, amplifiers, recorders and playback machines.

EMC for Product Designers

by Tim Williams, 304pp, hardback
Order – ISBN 0 7506 1264 9
Price £25.00

Contains: What is EMC? standards; EMC measurements; Interference coupling mechanisms; circuits; layout and grounding; interfaces; filtering and shielding.





'This book is likely to become essential reading for those designing electronic products for the European market,' according to *New Electronics*. Widely regarded as the standard text on EMC, providing all the information needed to meet requirements of the EMC Directive.

Build Your Own PC

by Ian Sinclair, 256pp, paperback
Order – ISBN 0 7506 2006 4
Price 16.95

Contains: Assembly from scratch – mainly for masochists; fundamentals and buying guide; case, motherboard and keyboard; disk-drive details; improvers and modifiers for graphics and i/o; DOS operation and hints; Windows; connecting printers; glossary.

Covers Building your own pc from scratch or from modules. Written at a level suitable for beginners *and* those with experience of computers or electronics. In addition, this work provides a useful guide for anyone wanting to save money by upgrading their pc themselves.

Return to Jackie Lowe, Room L333, Quadrant House, The Quadrant, Sutton, Surrey, SM2 5AS

Please supply the following titles:

Qty	Title or ISBN	Price

Please add £2.50 UK Postage, £5.00 Europe £7.50 Rest of World

Total__________

Name ____________________

Address ____________________

Post code __________ Telephone __________

Method of payment *(please circle)*

Access/Mastercard/Visa/Cheque/PO

Cheques should be made payable to Reed Business Publishing

Credit card no____________________

Card expiry date Signed

Analysing circuits via energy

Andrew Gibson and Bernice Dillon detail a new circuit analysis technique offering benefits over traditional network analysis. It covers dc, ac and transient sources – as well as reactive elements.

Electrical circuit theory concerns the calculation of voltages and currents in electrical networks. The voltages and currents of a circuit describe the exchange of energy between power supplies and circuit elements.

Components such as capacitors and inductors store energy whereas resistors dissipate energy. In circuits with alternating current sources, these components exhibit an impedance, Z. This impedance value together with the element voltage or current can be used to define the energy stored or dissipated in individual components. For example the power consumption, *P*, of an impedance, Z, with terminal voltage, *V*, may be defined as,

$$P=\frac{V^2}{Z}. \qquad (1)$$

Developing on this definition, a novel circuit analysis technique can be introduced.

A power characteristic equation is formed by summing the individual power consumptions of each individual circuit impedance. A power curve or surface may be plotted using this characteristic equation. At the correct voltage and current values for the circuit, the curve or surface has a stationary turning point. This energy based approach has a number of advantages over conventional nodal and mesh circuit analysis techniques. It has the following features,

- easy implementation,
- one equation describes the entire circuit – no matter how many circuit components,
- the method avoids difficulties with voltage and current polarities,
- the solution can be illustrated graphically,
- it exercises simple calculus and the theory of maxima/minima,
- the method is equally applicable to non-linear components,
- the method can be extended to include magnetic circuits and electromagnetic field devices.

Analysis techniques

Voltage and current distributions in electric circuits comply with a stationary power condition. An alternative circuit analysis technique can be derived from this property.

The unknowns can be varied until power consumption of the circuit is calculated to be unchanging. At this point the voltages and currents are at their true solution. A formal procedure is summarised below,

- identify the unknown nodal voltages in the circuit,
- express power dissipated in each component as a function of the unknown nodal voltages,
- add all of the power terms together to form a power equation,
- find the stationary turning point of the power equation.

As a starting example consider the simple, two component circuit of Fig. 1. Two resistors in series are connected across a 10V dc source. In this case the impedance of each resistor is simply its resistance value in ohms.

An unknown voltage V_1 exists at the junction of the two resistors. The terminal voltages for resistors R_1 and R_2 are,

$$(V_1-10), V_1 \qquad (2)$$

respectively. Using this result together with equation 1, the total power dissipated in the circuit may be written in terms of the unknown voltage, V_1, as,

$$P(V_1)=\frac{(V_1-10)^2}{4}+\frac{V_1^2}{6}. \qquad (3)$$

This characteristic equation describes the power consumption $P(V_1)$ of the circuit. As variable V_1 is varied so will $P(V_1)$. The stationary turning point of $P(V_1)$ can be determined graphically or analytically using some simple calculus.

Firstly, the graphical technique is illustrated in Fig. 2. You can see that the power is plotted as a function of V_1. It clearly has a turning point at the true solution of V_1=6V. This result can also be determined using differentiation techniques.

Differentiate the power equation with respect to the unknown voltage V_1 and set the result to zero as,

$$\frac{dP(V_1)}{dV_1}=2\frac{(V_1-10)}{4}+2\frac{V_1}{6}=0. \qquad (4)$$

This equation also has the correct solution of V_1=6V.

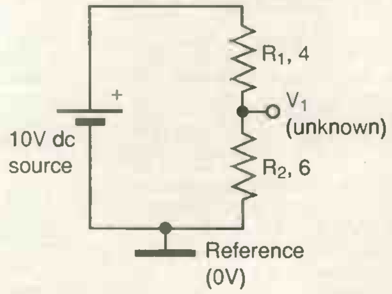


Fig. 1. Schematic diagram of a two resistor potential divider circuit with one unknown voltage V_1.

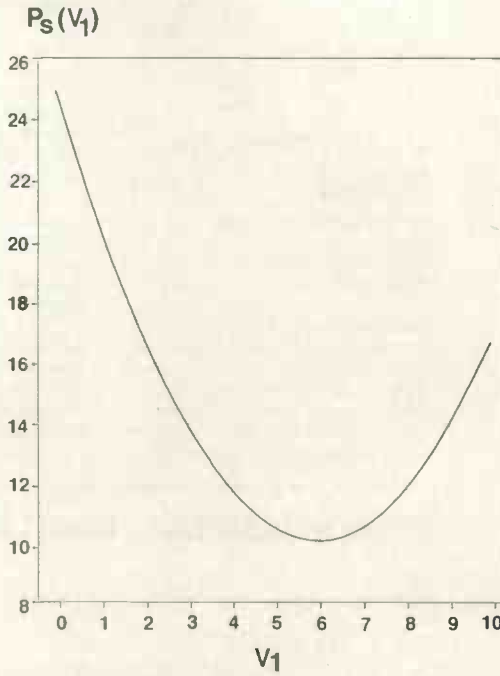


Fig. 2. Power curve $P(V_1)$ plotted as a function of V_1 for the circuit in Fig. 1.

Surplus always wanted for cash!

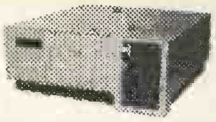
THE *ORIGINAL* SURPLUS WONDERLAND!

THIS MONTH'S SELECTION FROM OUR VAST EVER CHANGING STOCKS

Surplus always wanted for cash!

LOW COST PC's - ALL EXPANDABLE - ALL PC COMPATIBLE

SPECIAL BUY
AT 286



40Mb HD + 3Mb Ram

LIMITED QUANTITY only of these **12Mhz HI GRADE 286** systems Made in the USA to an industrial specification, the system was designed for *total reliability*. The compact case houses the motherboard, PSU and EGA video card with single 5¼" **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)
CALL FOR QTY DISCOUNTS

Optional Fitted extras: VGA graphics card	£29.00
1.4Mb 3½" floppy disk drive (instead of 1.2 Mb)	£24.95
NE2000 Ethernet (thick, thin or twisted) network card	£49.00

PC SCOOP
COMPLETE COLOUR SYSTEM
ONLY £79.00

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, 5¼" 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.** Good used condition - Fully guaranteed for 90 Days. **£79.00** (E)
Order as PC99COL

Optional Fitted extras: 640k RAM	£29.00
2nd floppy drive, specify 5¼" 360k or 3½" 720k	£29.95

Above prices for PC99 offer ONLY.

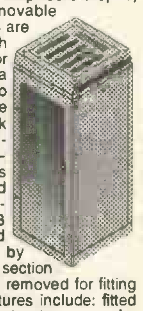
19" RACK CABINETS

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

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

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

32U - High Quality - All steel RakCab



Made by Eurocraft Enclosures Ltd to the **highest possible spec, rack features all steel construction** with removable side, front and back doors. Front and back doors are **hinged for easy access** and all are lockable with five secure 5 lever barrel locks. The front door is constructed of double walled steel with a **'designer style'** smoked acrylic front panel to enable status indicators to be seen through the panel, yet remain unobtrusive. Internally the rack features full slotted reinforced vertical fixing members **to take the heaviest of 19" rack equipment.** The two movable vertical fixing struts (extras available) are pre punched for standard 'cage nuts'. A **mains distribution panel** internally mounted to the bottom rear, provides 8 x IEC 3 pin Euro sockets and 1 x 13 amp 3 pin **switched utility socket.** Overall ventilation is provided by fully louvered back door and double skinned top section with top and side louvres. The top panel may be removed for fitting of **integral fans** to the sub plate etc. Other features include: fitted castors and floor levelers, prepunched utility panel at lower rear for cable / connector access etc. Supplied in **excellent,** slightly used **condition with keys. Colour Royal blue. External dimensions** mm=1625H x 635D x 603 W. (64" H x 25" D x 23¾" W)

Sold at LESS than a third of makers price !!

A superb buy at only £195.00 (G)

Over 1000 racks in all sizes 19" 22" & 24" 3 to 44 U. Available from stock !! Call with your requirements.

FLOPPY DISK DRIVES 3½"- 8"

5¼" from £22.95 - 3½" from £24.95

Massive purchases of standard 5¼" and 3½" 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 3½" supported on your PC).

3½" **Panasonic** JU363/4 720K or equivalent	£24.95(B)
3½" **Mitsubishi** MF355C-L. 1.4 Meg. Laptops only *	£36.95(B)
3½" **Mitsubishi** MF355C-D. 1.4 Meg. Non laptop	£29.95(B)
5¼" **Teac** FD-55GFR 1.2 Meg	£29.95(B)
5¼" **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" double sided *NEW*	£275.00(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!	£499.00(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)

3½" **FUJI** FK-309-26 20mb MFM I/F RFE	£59.95(C)
3½" **CONNER** CP3024 20 mb IDE I/F (or equiv)RFE	£69.95(C)
3½" **CONNER** CP3044 40mb IDE I/F (or equiv.)RFE	£89.00(C)
3½" **RODIME** RO3057S 45mb SCSI I/F (Mac & Acorn)	£99.00(C)
5¼" **MINISCRIBE** 3425 20mb MFM I/F (or equiv.) RFE	£49.95(C)
5¼" **SEAGATE** ST-238R 30 mb RLL I/F Refurb	£69.95(C)
5¼" **CDC** 94205-51 40mb HH MFM I/F RFE tested	£69.95(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

VIDEO MONITOR SPECIALS

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

Mitsubishi FA3415ETKL 14" SVGA **Multisync** monitor with fine 0.28 dot pitch tube and guaranteed resolution of 1024 x 768. A variety of inputs allows connection to a host of computers including **IBM PC's** in CGA, EGA, VGA & SVGA modes, **BBC, COMMODORE** (including Amiga 1200), **ARCHIMEDES** and **APPLE.** Many features: Etched faceplate, text switching and **LOW RADIATION MPR** specification. Full 90 day warranty.

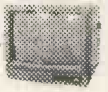
Supplied in EXCELLENT little used condition. **Only £139**(E)
Order as **MITS-SVGA**

Tilt & Swivel Base £8.00 Leads for IBM PC £8.95 (A)
External Cables for other computers £ CALL

PHILIPS HCS35 (same style as CM8833) attractively styled 14" colour monitor with <u>both</u> **RGB and standard composite 15.625 Khz video inputs** via **SCART socket** and separate phono jacks. Integral **audio power amp and speaker for all audio visual uses.** Will connect direct to **Amiga and Atari** BBC computers. Ideal for **all monitoring / security** applications with **direct connection to most colour cameras.** High quality with many features such as front concealed flap controls, VCR correction button etc. Good used condition - fully tested with a 90 day guarantee
Dimensions: W14" x H12¾" x 15½" D. **Only £99** (E)

Special Offer save £16.95 - Order **TELEBOX ST & HCS35** together - giving you a quality colour TV & AV system for **Only £122.50** (E)

KME 10" high definition colour monitors. Nice tight 0.28" dot pitch for superb clarity and modern styling. Operates from any 15.625 khz sync RGB video source, with RGB analog and composite sync such as Atari, Commodore Amiga, Acorn Archimedes & BBC. Measures only 13½" x 12" x 11". **Only £125 (E)**
Good used condition. 90 day guarantee.



KME 10" as above for PC EGA standard £145.00 (E)

PHILIPS HCS31 Ultra compact 9" colour video monitor with standard **composite 15.625 Khz video** input via SCART socket. Ideal for all monitoring / security applications. High quality, ex-equipment fully tested with a 90 day guarantee (possible minor screen burns). **In attractive square black plastic case** measuring W10" x H10" x 13½" D. Mains powered **Limited Quantity - Only £79.00 (D)**

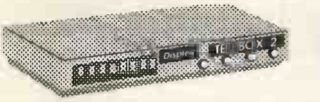
20" 22" and 26" AV SPECIALS

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

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

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 makers such as **MICROVITEC, ATARI, SANYO, SONY, COMMODORE, PHILIPS, TATUNG, AMSTRAD** etc. The composite video output will also plug directly into most video recorders, allowing reception of TV channels not normally receivable on most television receivers* (TELEBOX MB). Push button controls on the front panel allow reception of 8 fully tuneable 'off air' **UHF** colour television channels. **TELEBOX MB covers virtually all television frequencies VHF and UHF including the HYPERBAND as used by most cable TV operators.** A composite video output is located on the rear panel for direct connection to most makes of monitor or desktop computer video systems. For complete compatibility - even for monitors without sound - an integral 4 watt audio amplifier and low level **HI Fi** audio output are provided as standard.

TELEBOX ST for composite video input type monitors	£34.95
TELEBOX STL as ST but with integral speaker	£37.50
TELEBOX MB Multiband VHF/UHF/Cable/Hyperband tuner	£69.95

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

FANS & BLOWERS

MITSUBISHI MMF-D6D12DL 60x60x25 mm 12v DC	£4.95 10 / £42
MITSUBISHI MMF-09B12DH 92x92x25 mm 12v DC	£5.95 10 / £53
PANCAKE 12-3.5 92x92x18 mm 12v DC	£7.95 10 / £69
EX-EQUIP 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 (B)
IMHOF B26 1900 rack mnt 3U x 19" Blower 110/240v NEW	£79.95

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

IC's -TRANSISTORS - DIODES

OBSOLETE - SHORT SUPPLY - BULK

5,000,000 items EX STOCK

For ***MAJOR SAVINGS*** - Send SAE or CALL FOR LATEST LIST

DC POWER SUPPLIES

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

SPECIAL INTEREST

MITS. FA3445ETKL 14" Industrial spec SVGA monitors	£245
Computar MCA1613APC 16mm auto iris lenses 'C' mount	£125
Seaward PAT 2000 dual voltage computerised PAT tester	£585
INTEL SBC 486/133SE Multibus 486 system. 8Mb Ram	£1200
Zeta 3220-05 A0 4 pen **HPGL RS232** fast drum plotter	£1950
MOTOROLA VME Bus Boards & Components SAE / CALL	£POA
Trio 0-18 vdc linear, metered 30 amp bench PSU. . New	£470
Fujitsu M3041 600 LPM band printer	£1950
VG Electronics 1035 TELETEXT Decoding Margin Meter	£3750
Andrews LARGE 3.1 m Satellite Dish + mount (For Voyager!)	£950
KNS EMC / Line interference tester NEW	£1200
Thurlby LA 160B logic analyser	£375
GEC 1.5kw 115v 60hz power source	£950
Brush 2Kw 400 Hz 3 phase frequency converter	£850
Anton Pillar 75 kW 400 Hz 3 phase frequency converter	£POA
Newton Derby 70 KW 400 Hz 3 phase frequency converter	£POA
COMPONEDEX T1000 Portable **TELEX** tester **NEW**	£250
Sekonic SD 150H 18 channel digital Hybrid chart recorder	£1995
HP 7580A A1 8 pen HPGL high speed drum plotter	£1850
Densei MUD 0185AH 1KVa UPS system with batts NEW	£575

TOUCH SCREEN SYSTEM

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

LOW COST RAM & CPU'S

INTEL 'ABOVE' Memory Expansion Board. Full length PC-XT and PC-AT compatible card with **2 Mbytes** of memory on board. Card is fully selectable for Expanded or Extended (286 processor and above) memory. **Full data and driver disks supplied.** RFE. Fully tested and guaranteed. Windows compatible.
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** *or* **512k £38.95** (A1)

<u>SIMM SPECIALS</u>

1 MB x 9 SIMM 9 chip 120ns	Only	£19.50 (A1)
1 MB x 9 SIMM 3 chip 80 ns **£23.50**	or 70ns	£26.00 (A1)
1 MB x 9 SIMM 9 chip 80 ns **£22.50**	or 70ns	£28.00 (A1)
4 MB 70 ns 72 pin SIMM ***with parity***	Only	£105.00 (A1)
SPECIAL OFFER - **INTEL 486-DX33 CPU**		£79.99 (A1)

PHILIPS - LOW COST PRINTERS

A masterpiece of engineering, the **PHILIPS model NMS 1436 fully featured *MULTIMODE*** matrix printer packs a host of features into a unit weighing just over 4Kg and measuring only 40 x 12 x 28 Cm! **Fully Epson compatible** with adjustable paper tractor which accepts upto 9.5" sprocket fed paper and adjusts down to handle the smallest labels. The 9 needle head produces Near Letter Quality in a **host of fonts** and type sizes and in draft mode 'whizzes' along at 120 characters per second! Many other features include most European character sets, **IBM, EPSON, MSX** & Prestel emulations.
Good used condition, IBM Cable £6.95 Only **£49.95** (B)

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

DISPLAY -ELECTRONICS-

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

ALL MAIL & OFFICES
Open Mon-Fri 9.00-5:30
Dept WW. 32 Biggin Way
Upper Norwood
LONDON SE19 3XF

NEW **DISTEL©**
The Original
FREE On line Database
Info on 15,000+ stock items!
COMING SOON !!

ALL ☎ ENQUIRIES
0181 679 4414
FAX 0181 679 1927

MasterCard VISA

ESTABLISHED 25 YEARS

All prices for UK Mainland. UK customers add 17.5% VAT to TOTAL order amount. Minimum order £10. Bona Fide account orders accepted from Government, Schools, Universities and Local Authorities - minimum account order £50. Cheques over £100 are subject to 10 working days clearance. Carriage charges (A)=£3.00, (A1)=£4.00, (B)=£5.50, (C)=£8.50, (D)=£12.00, (E)=£15.00, (F)=£18.00, (G)=CALL. Allow approx 6 days for shipping - faster CALL. Scotland surcharge CALL. All goods supplied to our Standard Conditions of Sale and unless stated guaranteed for 90 days. All guarantees on a return to base basis. All rights reserved to change prices / specifications without prior notice. Orders subject to stock. Discounts for volume. Top CASH prices paid for surplus goods. All trademarks etc acknowledged. © Display Electronics 1995. E & O E. 6/5

CIRCLE NO. 1?? ON REPLY CARD

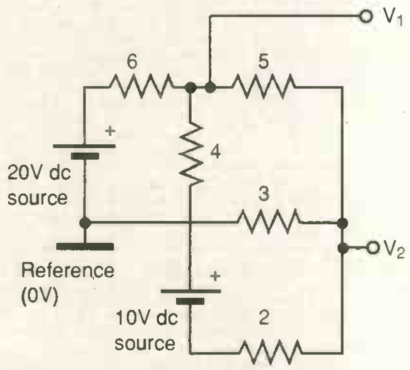


Fig. 3. Schematic of a resistor circuit with two unknown potentials V_1 and V_2.

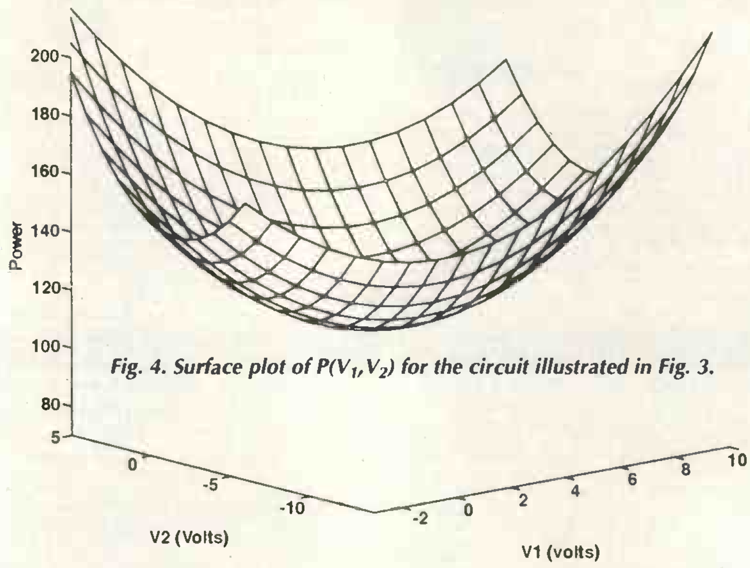


Fig. 4. Surface plot of $P(V_1,V_2)$ for the circuit illustrated in Fig. 3.

A circuit with two unknown voltages V_1 and V_2 is treated next, illustrated in **Fig. 3**. There are six branch resistances so there will be six power entries in the characteristic equation $P(V_1,V_2)$. It is constructed as,

$$P(V_1,V_2)=\frac{(V_1-20)^2}{6}+\frac{V_1^2}{4}+\frac{(V_1-V_2)^2}{5}+\frac{V_2^2}{3}+\frac{(V_2+10)^2}{2}. \quad (5)$$

Since there are two unknowns, two equations are required to make a solution. The first is found by partially differentiating $P(V_1,V_2)$ with respect to V_1 only, and by setting the result to zero as,

$$\frac{\partial P(V_1,V_2)}{\partial V_1}=2\frac{(V_1-20)}{6}+2\frac{V_1}{4}+2\frac{(V_1-V_2)}{5}=0 \quad (6)$$

The second equation is similarly derived by partially differentiating with respect to V_2 only and by setting the result to zero as,

$$\frac{\partial P(V_1,V_2)}{\partial V_2}=-2\frac{(V_1-V_2)}{5}+2\frac{V_2}{3}+2\frac{(V_2+10)}{2}=0 \quad (7)$$

The simultaneous solution of equations 6 and 7 provide the correct solution of V_1=4.096V and V_2=–4.046V. The solution can also be illustrated graphically by plotting $P(V_1,V_2)$ as a function of V_1 and V_2. A minimum is exhibited in **Fig. 4** at the correct solution.

AC analysis methods

The energy method is equally applicable to electrical circuits with ac sources and reactive elements. In this case impedance rather than resistance is used to determine individual power consumption in each component. The 'j' operator is used to introduce a 90° phase shift caused by capacitor and inductor impedances.

Consider the circuit in **Fig. 5**. There is one unknown nodal voltage V_1 which is a complex quantity. Total power consumption of the circuit is the linear combination of the power in the inductive ($j5\Omega$), capacitive ($-j1\Omega$) and resistive (2Ω) impedances.

$$P(V_1)=\frac{(V_1-10)^2}{2}+\frac{V_1^2}{-j}+\frac{V_1^2}{j5} \quad (8)$$

As V_1 is a complex quantity then it has real and imaginary parts which can be varied until a stationary point is deduced. This graphical technique is illustrated in **Fig. 6**.

Instead of a minimum power point the reactance circuit displays a stationary inflection point. This relates to the two types of energy in impedance circuits – stored and dissipated. In the usual way, the circuit solution can also be deduced analytically. Differentiate the power equation with respect to the unknown, V_1, and set the result to zero to find the stationary point as,

$$\frac{dP(V_1)}{dV_1}=2\frac{(V_1-10)}{2}+2\frac{V_1}{-j1}+2\frac{V_1}{j5}=0 \quad (9)$$

This equation has a solution of V_1=2.8–j4.5V.

Conclusion

Power circuit analysis techniques provide a new, easy to understand alternative to Kirchoff for network analysis. The same procedure applies to dc, ac or transient signal sources and to linear/non-linear electric or magnetic circuits.

It introduces the concept of a characteristic power equation to describe the behaviour of a circuit. By finding the stationary point of this equation the unknown circuit voltages can be defined. As power methods are already used for electromagnetic fields and in other areas it becomes possible to solve hybrid type structures in a unified way. ■

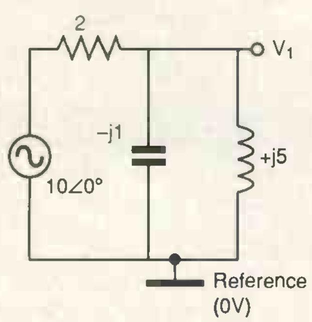


Fig. 5. Schematic diagram of a resistor, capacitor inductor circuit with an ac source and one unknown complex potential V_1.

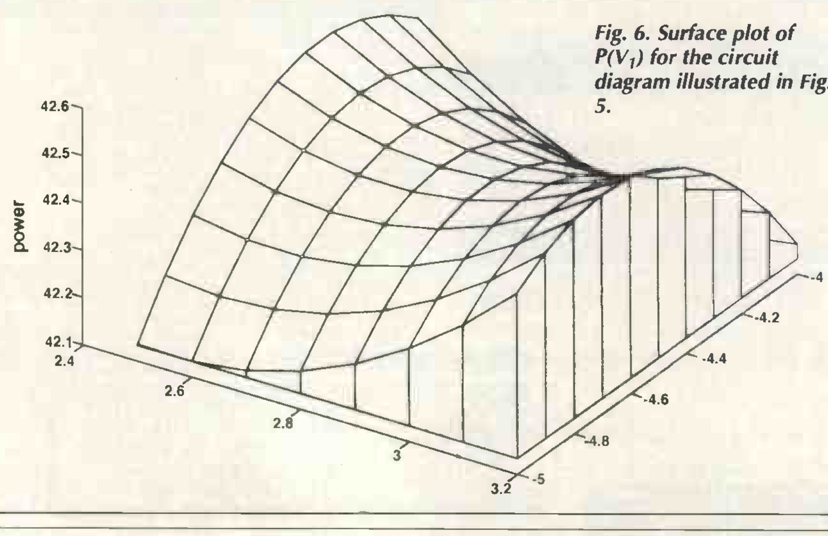
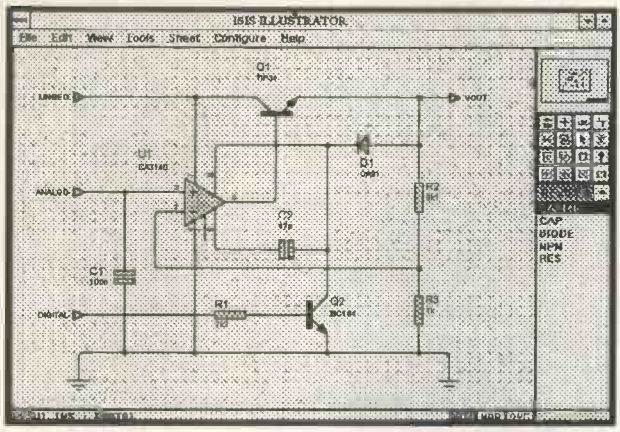


Fig. 6. Surface plot of $P(V_1)$ for the circuit diagram illustrated in Fig. 5.

CADPAK for Windows

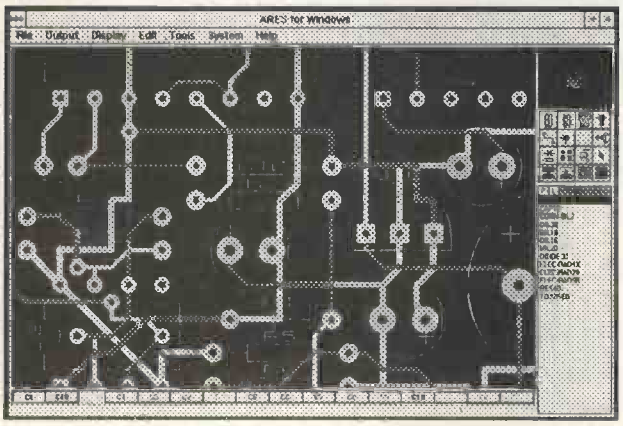


CADPAK is especially suited to educational, hobby and small scale schematic and PCB design. CADPAK includes both schematic drawing and 32-bit PCB drafting tools but as an entry level product, there is no netlist link between them.

CADPAK FOR WINDOWS ... £ 149

CADPAK FOR DOS .... £ 79

PROPAK for Windows



PROPAK has all of the features in CAPAK plus netlist based integration, automatic power plane generation and a powerful auto-router. PROPAK includes enough schematic capture and PCB design functionality for all but the most demanding applications.

PROPAK FOR WINDOWS .... £ 495

PROPAK FOR DOS .... £ 395

Call or fax today for a demo pack. Please state whether you would like a DOS or Windows pack.

labcenter

E l e c t r o n i c s

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

Tel: 01756 753440 Fax: 01756 752857

Prices exclude postage (£5 for UK) and VAT. All manufacturers' trademarks acknowledged.

CIRCLE NO. 144 ON REPLY CARD

New Mini Camera & Special Offers

New mini waterproof TV camera 40x40x15mm requires 10 to 20 volts at 120mA with composite video output (to feed into a video or a TV with a SCART plug) it has a high resolution of 450 TV lines Vertical and 380 lines horizontal, electronic auto Iris for nearly dark (1 Lux) to bright sunlight operation and a pinhole lens with a 92 degree field of view, it focuses down to a few CM. It is fitted with a 3 wire lead (12v in gnd and video out) .... £93.57+VAT = £109.95 or 10+ £89.32+VAT = £104.95

High quality stepping motor kits (all including stepping motors) 'Comstep' independent control of 2 stepping motors by PC (Via the parallel port) with 2 motors and software .... Kit £67.00
Ready built £99.00

Software support and 4 digital inputs kit £27.00

Power interface 4A kit £36.00

Power interface 8A kit £46.00

Stepper kit 4 (manual control) includes 200 step stepping motor and control circuit £23.00

We are now stocking a range of stepping motors and kits to drive them, please ask for the stepping motor data sheet for full information.

Invertor toroidal transformers 225VA 10.5-0-10.5 primary 0-260-285 secondary £29.95

LEDs 3mm or 5mm red or green .... 7p each
Yellow .... 11p each

Cable ties, 1p each, £5.95 per 1000, £49.50 per 10,000

Rechargeable Batteries

AA (HP7) 500mAH £0.99	AA 500mAH with solder tags £1.55
AA 700mAH £1.75	C(HP11) 1.8AH £2.20
C 2AH with solder tags £3.60	D(HP2) 1.2AH £2.60
D 4AH with solder tags £4.95	PP3 8.4V 110mAH £4.95
1/2AA with solder tags £1.55	Sub C with solder tags £2.50
AAA (HP16) 180mAH £1.75	1/3 AA with tags (Philips CTV) £1.95

Standard charger charges 4 AA cells in 5 hours or 4Cs or Ds in 12-14 hours + 1xPP3 (1, 2, 3 or 4 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 4s £10.95

Nickel Metal Hydryde AA cells high capacity with no memory. If charged at 100ma and discharged at 250ma or less 1200mAH capacity (lower capacity for high discharge rates) £3.75

Special offers, please check for availability.

Stick of 4 42x16mm Nicad batteries 171x16mm dia with red & black leads 4.8v £5.95

5 button cell 6V 280mAh battery with wires (Varta 5x250DK) £2.45

115v AC 80v DC motor 4x22mm shaft 50mm dia x 60 long body (excluding the shaft) it has a replaceable thermal fuse and brushes .... £4.95 each (£3.95 100+)

7 segment common anode led display 12mm £0.45

LM337k T03 case variable regulator £1.95
.... £1.44 100+

GaAs FET low leakage current S8873 ..... £12.95 each
.... £9.95 10+, £7.95 100+

BS250 P channel mosfet £0.45

BC559 transistor .... £3.95 per 100

BC547A transistor .... 20 for £1.00

74LS05 hex Invertor .... £10.00 per 100

Used 8748 Microcontroller £3.50

SL952 UHF Limiting amplifier LC 16 surface mounting package with data sheet £1.95

AM27S02 .... £1.25 each (90p 100+)
CD4007UB .... 10p 100+ (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 convertor 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 240v AC 50Hz £1.45

QWERTY keyboard 58 key good quality switches new £6.00

Airpax A82903-C large stepping motor 14v 7.5' step 27ohm 68mm dia body 6.3mm shaft .... £8.95 or £200.00 for a box of 30

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+

1uf 50v bipolar electrolytic axial leads .... 15p each
.... 7.5p 1000+

0.22uf 250v polyester axial leads .... 15p each
.... 7.5p 100+

Polypropylene 1uf 400vdc (Wima MKP10) 27.5mm pitch 32x29x17mm case .... 75p each
.... 60p 100+

Philips 123 series solid aluminium axial leads - 33uf 10v & 2.2uf 40v .... 40p each
.... 25p 100+

Philips 108 series long life 22uf 63v axial..... 30p each
.... 15p 1000+

Multilayer AVX ceramic capacitors all 5mm pitch 100v 100pf, 150pf, 220pf, 10,000pf (10n) .... 10p each 5p.....100+ 3.5p.....1000+

500pf compression trimmer 60p

40 uf 370vac motor start capacitor (dialectrol type containing no pcbs) .... £5.95 or £49.50 for 10

Solid carbon resistors very low inductance ideal for RF circuits – 27ohm 2W, 68ohm 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, fan 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 Hfe 9v and 1.5v battery test £12.95

AMD 27256-3 Eproms .... £2.00 each £1.25 100+

Inmac delux anti-glare static control panal window size 228x161mm, overall size 264mmx200mm held to the monitor with hook & loop tape pads .... £7.95 each

DIP switch 3PC0 12 pin (ERG 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 or £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

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

JPG Electronics, 276-278 Chatsworth Road, Chesterfield S40 2BH

Access/Visa Orders (01246) 211202 Fax: 550959 Callers welcome

CIRCLE NO. 145 ON REPLY CARD

EMBEDDED C ASSEMBLY SIMULATION

8051

C compiler, first released in 1991, now features:

- Easy to use interrupt support with register bank switching
- IEEE floating point arithmetic
- IEEE 695 source level debug output
- Intergrated relocatable assember

Simulator running under Microsoft Windows provides extensive support for the 8051 code development

68000

Our first C compiler/assembler package

- now supports floating point arithmetic
- has been widely adopted by many OEM's to support their 68000 and 68307 hardware

CPU32

68020 C compiler/assembler, originally developed to accompany Motorola's 68020 and 68EC020 evaluation models

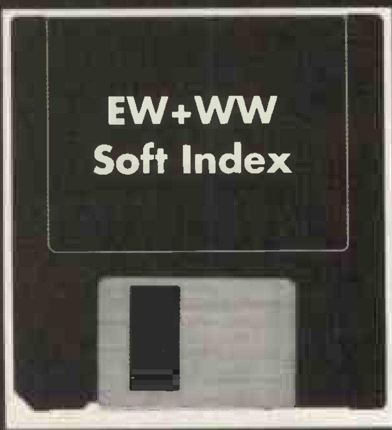
- Now supports the CPU32
- 68881 co-processor support
- IEEE 695 source level debug output

Further information from:
CROSSWARE PRODUCTS
St John's Innovation Centre, Cowley Road, Cambridge, CB4 4WS , UK
Tel: +44 (0) 1223 421263, Fax: +44 (0) 1223 421006
BBS: +44 (0) 1223 421207 (8-N-1), Internet: sales@crossware.com

CROSSWARE

CIRCLE NO. 138 ON REPLY CARD

SOFT INDEX ON DISK



A computerised index of *Electronics World+Wireless World* magazine is now available. It covers the five years 1990 to 1994 – volumes 96 to 100 – and contains over 1400 references to feature articles, circuit ideas and applications, with a synopsis for each. The software is easy to use and very quick. It runs on any IBM or compatible PC with 512K ram and a hard disk. Each disk is scanned before shipping with the current version of Dr Solomon's Anti-Virus Toolkit.

For the UK, the five year index is priced at £20. Please specify $5\frac{1}{4}$ or $3\frac{1}{2}$in format. This price includes UK postage and VAT. Add an extra £1 for overseas EC orders or £5 for non-EC overseas orders.

Photo copies from back issues of *EW+WW* are available at 50p per page plus VAT (in EC) and a flat postage charge of 50p (UK), £1 (rest of EC), and £2 (rest of world). For enquiries about photo copies send an sae to Video Interface Products.

Please allow up to 28 days for delivery. Cheques should be made payable to **Video Interface Products,** not *EW&WW* or Reed Business Publishing.

Please post your request to **Video Interface Products Ltd, 1 Vineries Close, Cheltenham GL53 0NU, UK.**

NEW PRODUCTS CLASSIFIED

Please quote *"Electronics World + Wireless World"* when seeking further information

ACTIVE

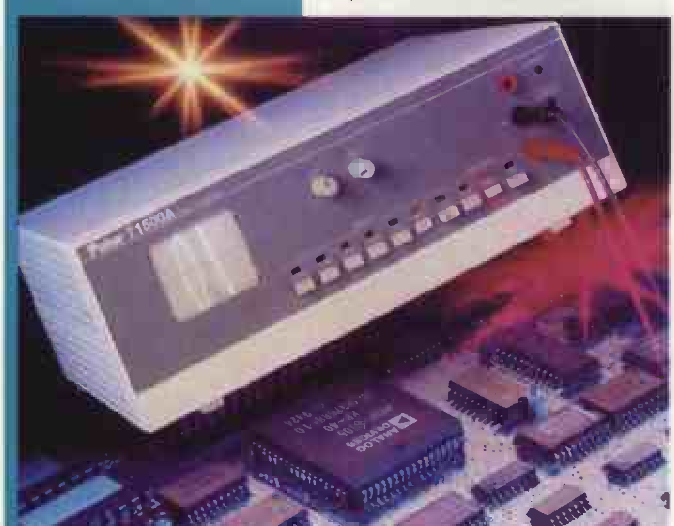
A-to-d and d-to-a converters

Multi-range, 12-bit a-to-d. *MAX197* from Maxim is an 8-channel analogue-to-digital converter, each of the channels being software programmable to take inputs of 0-5V, 0-10V, ±15V and ±10V, while working from a +5V supply. Bandwidth of the track/hold is 5MHz, throughput 100ksample/s and the reference is either an internal 4.096V or an external one. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

Discrete active devices

240V mosfet. *ZVP4424G* by Zetex is a surface-mounted, 240V mosfet in SOT223 exhibiting a maximum on resistance of 12 at 100mA, with a gate/source voltage of 3.5V. Rise and fall times are 8ns and 20ns at 250mA; input capacitance is 100pF. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

Pcb fault locator. Polar Instruments has a low-cost analogue signal analyser in the *T Series*, the *T1500A*, which provides component-level fault diagnosis on unpowered pcbs, the user needing no detailed knowledge of the circuitry. A built-in crt displays the analogue impedance signature. There is a comprehensive range of test ranges and functions, some of them taken from Polar's much more expensive automatic analysers. Test frequencies are 90Hz, 500Hz and 2kHz and the instrument also measures capacitance from 35pF to 12nF. Polar Instruments Ltd. Tel., 01481 53081; fax, 01481 52476.



Memory chips

4Mb sram. *TC554161FTL*, a 256K by 16 static ram in 0.5μm silicon-gate cmos from Toshiba, provides a high-density, high-bandwidth memory with an access time of 70ns. Toshiba expects the device to cost the same as 4Mb of sram in four 1Mb srams by the end of the year. Toshiba Electronics UK Ltd. Tel., 01276 694600; fax, 01276 694800.

16Mb nvsram. Benchmarq announces the *bq4017* 16-megabit, non-volatile static ram which, organised as 2M by 8, has the largest memory of any such device. It acts as flash, eeprom, eprom, standard ram or silicon disk, offering the characteristics of an ordinary ram but with data retention. The device is effectively four 4Mb static rams with two lithium cells and power control. When the external 5V power supply is in tolerance, access time is 70ns and if it falls out of range, the memory is write-protected and power taken from the cells for up to five years. There are no limits to the number of writes that can be performed. Sequoia Technology Ltd. Tel., 01734 258000; fax, 01734 258020.

Optical devices

Full-colour leds. Red, green and two blue chips in the *Lumex Opto* full-colour single-package leds are individually addressed via six leads, varying the power to each and therefore the colour, from any of the three primaries to white light. Two types are made: a diffused model providing 0.5-100mcd at 20mA and a narrow-angle, high-intensity, clear lens type giving 7-200mcd at 20mA. Power needed is 5-30mA at a forward voltage of 1.7-3.2V. Lumek Opto/Components Inc. Tel., 001 708 359-2970; fax, 001 708 359-8904.

PASSIVE

Passive components

Mica capacitors. RS Components has a range of silvered-mica capacitors working up to 500V in values from 2.2pF to 47,000pF to tolerances less than ±1% over the whole range. RS Components Ltd. Tel., 01536 201234; fax, 01536 405678.

Metal-oxide Varistors. Harris has the eight-member *0805 series* of multi-layer, metal-oxide Varistors for surface mounting, to IEC801.2. These bidirectional, 2 by 1.25mm devices are available in 3.5V, 5.5V, 14V and 18V versions and are meant to protect equipment from surges or esd. For each voltage version, there are standard and lower-capacitance, lower-energy types for electrostatic discharge protection in high-speed data buses. Harris Semiconductor UK. Tel., 01276 686886; fax, 01276 682323.

Wire chip coils. 54-880nH *LQN1H* wire-wound chip coils by Murata have ferrite cores for use at hf and possess stability, high *Q* and low resistance at frequencies in the 30-150MHz range. At 3.2 by 1.6 by 1.8mm, parallel mounting on a 2.5mm pitch is possible. Murata Electronics (UK) Ltd. Tel., 01252 811666; fax, 01252 811777.

Precision reference. Zetex introduces the *ZR285* reference, claimed to be the smallest and lowest power device presently obtainable in SOT23. Minimum operating current is 13μA; maximum is 20mA. Slope resistance at 1mA is typically 0.2Ω and is maintained at a low value over the operating range – at 100μA it is 1Ω. It will cope with surges to 200mA. Zetex plc. Tel., 0161-627 5105; fax, 0161-627 5467.

Connectors and cabling

Power inlets. Rendar's new power inlets to IEC320 are rated at 10A, 250Vac, are available in hot or cold condition Class I and II and have either 6.3mm push connector or solder tags. The range of shuttered outlets includes a snap-in type with positive locking to prevent accidental withdrawal and fitting panels from 0.8mm to 3mm in thickness. Rendar Ltd. Tel., 01243 866741; fax, 01243 841486.

Audio products

Power amplifier. Putting out 23W, the *TDA1561Q* dual audio power amplifier by Philips is meant for use in car radios, one aim being to reduce the size of heat sinks needed. It operates in an automatically switched dual mode: when high output power is needed for only a short time, as in music signal, an efficient, 23W single-ended connection is in use, but if longer periods of higher power are called for, it switches to the bridge-tied, 5W load connection in which, nevertheless, if temperature exceeds a safe level, the single-ended mode is re-established. A mode pin accepts various voltages to force single-ended working, mute and standby. As further safety precautions, the amplifier is protected against load dump transients, shorted loads and shorts to rails; an on-chip zero-crossing detector delays entry or exit to mute until the input passes zero to avoid clicks and mutes the amplifier if the supply drops below 7V during engine starting. Philips Semiconductors (Eindhoven). Tel., 00 31 40 722091; fax, 00 31 40 724825.

Surface-mount coaxials. Transradio has a wide range of s-m coaxial connectors, including those suitable for on board MMS and MC cards and for use with printed boards or as PCMCIA card edge connectors. All are said to offer extremely low vswr and insertion loss and models are available to work in the 0-8GHz range. The MC-card series is claimed to be the smallest true coax. connector in the world. A range of accessories is offered. Transradio Ltd. Tel., 0181 997 8880; fax, 0181 997 0116.

Displays

10.4in colour lcds. Two new colour liquid-crystal display modules are announced by Hitachi. They are both supertwist, 10.4in diagonal units offering a saving in power over earlier models at 2.2W for the VGA type and 2.5W for the SVGA. Display area is 211.2 by 158.4mm, the total size being 243 by 179 by 8mm, which is the same as the company's tft models. There is a single fluorescent backlight and contrast ratio is 30:1 for both models. Response time is 270ns. Hitachi Europe Ltd. Tel., 01628 585163; fax, 01628 585160

Filters

Emi filters. Surface-mounted pi-section filters by Oxley are for use in

Please quote *"Electronics World + Wireless World"* when seeking further information

Audio test. *System Two*, by Audio Precision, is an extremely comprehensive , PC-controlled signal generator and analyser system for testing analogue and digital audio, facilities for both being kept separate; no data converters are used. It is said to be the only instrument capable of testing for every parameter specified in AES3, which governs serial digital audio transmission. Some of the measurements are jitter and FFT of jitter, pulse amplitude, eye height, delay, word width, bit activity, sample rate and high-level decoded status bits, jitter and various other deformations being injected, if required. Analogue measurements include noise down to −117dBμ, thd to −110dB with FFT analysis following the notch filter to −140dB. The hardware is accompanied by *Apwin* Windows-based software, which allows the assembly of a virtual test bench, displaying test-instrument panels, bargraphs and x/y graphs simultaneously, test procedures being produced by the user, with no programming being needed, and made into 'scripts'. Thurlby Thandar Instruments Ltd. Tel., 01480 412451; fax, 01480 4504

filtered lead-through connection to shielded printed-board enclosures. Filters have capacitance values of 15-22nF and handle up to 10A at 200Vdc. Insertion loss of the *SM3* is up to 65dB at 10GHz. Oxley Developments Co. Ltd. Tel., 01229 582621; fax, 01229 585090.

Low-pass filters. Low-pass emi filters by Steatite are now available in solder-in, resin sealed bolt-in and high-current/voltage resin sealed types, approved to the MIL replacement Muahag listing. They are in multiple configurations of C, pi-type elements with tubular or disc capacitors and are rated to 500Vdc. High-current versions take 100A continuously at up to 1250V dc. Steatite Insulations Ltd. Tel., 0121 6436888; fax, 0121 643 2011.

Hardware

Stainless steel enclosures. Intek has a range of stainless steel computer enclosures to protect computers in a hostile world, holding at bay fluids, dust, hard knocks and tampering and foiling theft. Units hold a screen and either computer or terminal, the membrane keyboard being housed in a steel compartment. Other peripherals can go inside or be connected outside the enclosure. Frontal protection is to IP65 and a fan and filter are provided. Even water is excluded by baffles. Intek Electronics Ltd. Tel., 01352 810603; fax, 01352 810403.

Industrial computing. *500/700 Series* of industrial computer enclosures comprises an 8U monitor rack-mounting kit for up to 17in displays, an all-steel computer chassis meeting EIARS-310G to take the Intel *Superfast MX Xpress* motherboards, 8-20 slot passive backplanes or a variety of motherboards and the Raid chassis holding up to eight removable SCSI hard disk drives with optional redundant power supplies and individual fans. There is also a 1U keyboard drawer. The company can supply a range of computers, backplanes and drives. Sight Systems Ltd. Tel., 01903 242001; fax, 01903 504494.

Instrumentation

200Msample/s dso. Yokogawa's *DL1450* is the replacement for the earlier *DL1000* series, with sample rate and memory size doubled to 200Msample/s and 120Kword. Familiar shape is kept, so that the 7in screen instrument takes up less bench space than a copy of *EW+WW*. It is a four-channel instrument with a 150MHz bandwidth; a GPIB interface is standard, as is a 3.5in floppy drive to allow data to be exported to a pc. The built-in printer can be used in real-time mode and there is a 'snap-shot' facility to compare two signals on screen at one touch of a button. The history memory can recall up to 100 earlier displays and the rapid update of 60 displays/second emulates the display of an analogue oscilloscope. FFT analysis is provided as standard. Martron Instruments Ltd. Tel., 01494 459200; fax, 01494 535002.

'Smallest' 100MHz oscilloscope. The *V-1565* 100MHz oscilloscope, said to be the smallest of its type available, has been redesigned and upgraded. It measures 275 by 130 by 360mm, weighs 6kg and uses 40W, while offering sweep-time autoranging, cursor readout, auto-trigger level, selectable signal output and a 100MHz frequency counter. Numerical screen data includes sweep speed, delay time and voltage sensitivity. Sensitivity is 2mV-5V/div and rise time 3.5ns. Trigger lock allows the display of a variety of irregular pulse trains without adjustment of trigger level. Hitachi Denshi (UK) Ltd. Tel., 0181 202 4311; fax, 0181 202 2451.

Radar performance monitor. Ranatec's *Model 9000* radar monitor may be installed permanently on site to measure continuously, in the 1.25-17.1GHz range, the output and reflected power of the transmitter and the noise figure of the receiver, showing alarm conditions on-screen. The instrument can be controlled remotely by means of an RS232 interface, an optional GPIB or by modem. Rf heads are available to mount in the antenna transmission line to avoid interfering with normal radar operation. Anglia Microwaves Ltd. Tel., 01277 630000; fax, 01277 631111.

Little dpm. *DPM 3* by Lascar is an autopolarity, autozero digital panel meter that presents its readings in 11mm high characters, consumes 150μA and has a full-scale reading of 200mV. It snaps into place in the panel and is provided with a pcb socket strip. Lascar Electronics Ltd. Tel., 01794 884567; fax, 01794 884616.

Hand-held, 5-digit multimeter. In addition to its accuracy of within 0.025%, the 50,000-count *MX56* multimeter by Metrix has a combination of facilities including true rms, a 100kHz bandwidth, a timer-counter, audio power measurement and mains-disturbance indication. Resolutions are 10μV, 10nA, 10mΩ and 0.01dB. Metrix UK Ltd. Tel., 01256 311877; fax, 01256 23659.

Seven-in-one. The Australian McVan company announces the *BWD 604 Mini-Lab* which, in the one case, contains a 13MHz function generator with am and fm and a log/lin sweep, a frequency counter, a power amplifier, a ±15V 1A bi-polar psu, a +15V/–15V dual psu, a –5V 3A psu and a 3.5-digit multimeter. All outputs are short-proof. Tandem Technology Ltd. Tel., 01243 576121; fax, 01243 576119.

Interfaces

Motion controller. Compumotor has introduced the *OEM-AT6400* motion controller, which provides up to four axes of open-loop control for standard stepper and direction motor drives, controlled by pcs on the ISA bus; it occupies an expansion slot in the pc. It handles position data up to ±2,147,483,648 steps, up to 1,600,000 steps/s and acceleration up to 30steps/s/s. Control programs are implemented in the Windows-based *Motion Architect* software, the board having 63Kbyte of battery-backed ram for program storage. Parker Hannifin

Please quote *"Electronics World + Wireless World"* when seeking further information

Coils for inductive joysticks. Gardners is making the coils for a new design of inductive joystick by Penny and Giles. Compared with the carbon track type, the joysticks are more reliable. Gardners coils, now in large-scale production, consist of a central primary surrounded by four smaller secondaries, all wound to a very high degree of accuracy to ensure exact balance when the lever is centred. Gardners Ltd. Tel., 01202 482284; fax, 01202 470805.

plc, Digiplan Division. Tel., 01202 699000; fax, 01202 695750.

Literature

Cells and batteries. In 64 pages, a technical catalogue from *Saft Nife* gives the necessary information on selecting the appropriate rechargeable cells and batteries for portable equipment, including descriptions of the chemistry involved, cell construction, charging methods and battery configurations, power source design and a glossary. There are fourteen ranges of nickel cadmium and nickel-metal-hydride cells. Saft Nife Ltd. Tel., 0181 979 7755; fax, 0181 783 0494.

Interfacing. The IEEIE has produced a new edition of the monograph Interfacing Standards for Computers; it is nine years since the first one appeared, so publication has clearly not been precipitate. If you have managed to hold out this long, £9.50, which includes postage, will bring you a copy. IEEIE. Tel., 0171 836 3357; fax, 0171 497 9006.

Shielding and insulation. *Warth International's* new 84-page catalogue describes electromagnetic shielding and thermally-conductive insulation products, with technical notes. Warth International Ltd. Tel., 01342 315044; fax, 01342 312969.

Motors, gearboxes. *Bodine Electric* has an eight-page spreadsheet 'Motor & Gearmotor Selection Guide', which details all the Bodine equipment. Determination of speed and torque are explained, as is the calculation of gear ratio. Bodine Electric Company. Tel., 01252 811800; fax, 01252 811801.

Materials

Shielding bags. 3M's newest plastic static-shielding bags are in a 25µm polyester film with a thin metal coating near the outside of the film so that continuity testing can be done more easily. Inside, the bags are resistant to friction charge, since an anti-static material is compounded with the polyester before extrusion rather than being applied as a coating. 3M United Kingdom plc. Tel., 01344 858000; fax, 01344 858758.

Power supplies

Current-sharing psu. Astec's *LP series* of power supplies now includes the *LP150*, a range of units offering 150W in single or quad output form with six voltage configurations, with single-wire current sharing and auto-ranging input and housed in a U channel with or without a cover. All have remote sensing and inhibiting and all quad output models and the 5V single have a 'power good' option on the 5V output. Two of the quad units have a floating output variable between ±5V and ±25V. Full protection is incorporated and the supplies are certified to all manner of standards. Astec Standard Power Europe. Tel., 01384 440044; fax, 01384 440777.

Voltage regulator with watchdog. *CS-8141* from Cherry Semiconductor is a voltage regulator and watchdog providing reset and enable to a microcomputer, all in the one ic. The regulator provides 5V±4% at 500mA. A pulse train from the computer feeds the watchdog, a reduction in frequency causing a reset to avoid erroneous operation; a reset is also emitted if the regulator output falls out by more than ±4% for longer than 2µs. Frequency of the watchdog input also controls status: if it falls below a threshold, the regulator powers down gracefully and sleeps. Cherry Semiconductor. Tel., 001 401 885-3600; fax, 001 401 885-5786. Internet info@cherry-semi.com.

Fast charge ic. Benchmarq's *bq2031* lead acid fast charge ic controls constant-current or constant-voltage charging, conforming to recommendations for both cyclic and float charging. It displays charge status and fault conditions, testing first for shorted, open or damaged cells and conditions the battery for fast charge, which is also controlled by user-selected temperature and voltage limits. Sequoia Technology Ltd. Tel., 01734 258000; fax, 01734 258020.

10A voltage regulators. Having a dropout at 1.3V maximum, the *EZ1082* from Semtech has output of 1.3-3.45V at full current to power the *Pentium P54C-VRE* or some of the *PowerPCs*. Output variation due to all causes is ±2% and the output is fixed or adjustable. Semtech Ltd. Tel., 01592 773520; fax, 01592 774781.

Universal desktop power. For low-power desktop equipment, Powerbox's *PUP553 range* of 55W universal external supplies consists of six models. There are five single-output units with outputs from 5V to 24V and a triple-output type providing 5V, 12V and –12V. A range of output connectors is available. Emi filtering is included and all outputs are voltage and current protected. Electrospeed. Tel., 01703 644555; fax, 01703 610282.

Battery-management ic. *LTC1325* from Linear is a software-programmed battery charger to cope with most types of battery. It is an 18-pin cmos device containing a programmed pwm constant-current switcher, a 10-bit a-to-d converter, programmable battery voltage divider, timer, fault sensor interfaces, current monitor, discharge controller and a serial interface to the system microcontroller. Other components needed to make a complete charger are the controller, which can be shared with other applications, battery sensors and components for the switching power supply. Micro Call Ltd. Tel., 01844 261939; fax, 01844 261678.

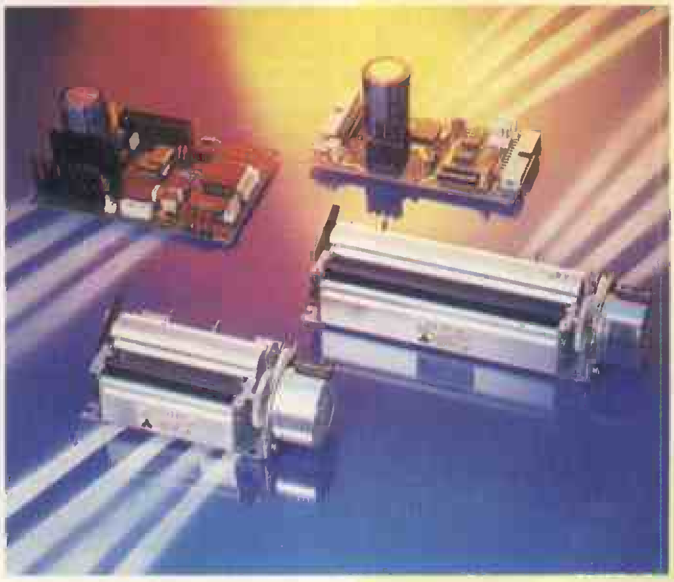
Radio communications products

Telemetry transceiver. Wood & Douglas's *SX450* miniature telemetry transceiver is now emc approved to ETS300 339, ETS 330 220, MPT1329 and ETS 300 086. Weighing a mere 70g, the unit measures 85 by 55 by 13mm and is for use in industrial applications such as bar-code reading, GPS and modem, being capable of tuning any of up to 256 channels in a 10MHz range in the 400-470MHz band. It puts out 500mW with a current consumption of 400mA at 7.2V on transmit and 50mA when receiving. Wood and Douglas Ltd. Tel., 01734 811444; fax, 01734 811567.

1GHz transmitter IC. From Maxim, the *MAX2402*, a transmitter IC containing a double-balanced mixer, buffered local oscillator, a variable-gain stage and 100mW power amplifier, for use in the 800-1000MHz band. It is compatible with direct-sequence and frequency-hopping

Printers and controllers

Thermal printers. Sixteen models in a range of high-definition, static-head thermal printer mechanisms by Panasonic are intended for use in measuring instruments and data terminals. *EPL1100* printers are available to take paper widths of 60, 80 and 112mm at print speeds of 8 and 16lines/s. All models are capable of graphics and can be ordered with or without a paper-end sensor and with a straight paper path for labels. Able can supply its own serial interface boards for the whole range, but there are parallel boards for the higher-speed models. Able Systems Ltd. Tel., 01606 48621; fax, 01606 44903.



Please quote *"Electronics World + Wireless World"* when seeking further information

spread-spectrum modes in the 902-928MHz ISM band. Limiting amplifier takes single-ended or differential signal at between –6dBm and +6dBm. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

Switches and relays

Pcb relays. BLP's *AZ942* series of low-cost, industry-standard miniature relays for pcb mounting have contacts rated at 5A, 30Vdc/125Vac in the medium-duty version and 6A,30Vdc and 10A,125Vac. Both types have dc coils taking 48Vdc that dissipate 230mW. Versions are available sealed in epoxy to withstand wave soldering at up to 270°C. BLP Components Ltd. Tel., 01638 665161; fax, 01638 660718.

Sealed, 10A relays. Three versions of LRE's *F600* 6-pole changeover balanced force relay are now available, all in a 1.5 cubic in case. *F670* is for electrically powered vehicles and switches 1A resistive at 72Vdc, with a 1×10^6 operation life. With the same life expectancy, the *FD670* is a 3-pole double-break type and switches 3A resistive at 72Vdc or 1A resistive at 110Vdc. *F600* is a military version, lives for 100,000 operations and switches 10A at 28Vdc, coping with 1400A under 10A circuit breaker protection. Several varieties of terminal, socket and coil suppression are offered. LRE Relays + Electronics Ltd. Tel., 01962 734433; fax, 01962 734685.

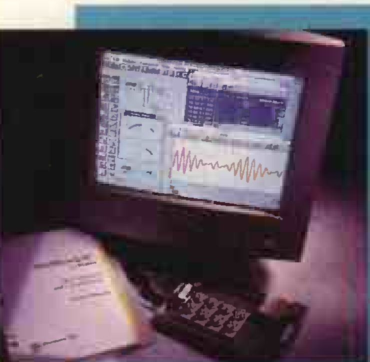
Quad spdt switch ics. Maxim's *MAX394* contains four single-pole, double-throw analogue switches, operating from either ±2.7-8V or +2.7-15V. On resistance is under 35Ω and matches to within 2Ω between channels, staying flat within 4Ω over the input range of 0.8-2.4V. Switching is break-before-make, turning off in 75ns and on in 130ns. Quiescent current is 1μA. Maxim Integrated Products UK Ltd. Tel., 01734 303388; fax, 01734 305511.

Tough switch. A 240Vac, 21A miniature snap switch in Cherry's *D48* range is designed to cope with the kind of treatment domestic equipment often receives and for industrial and amusement machine use. Contact gap is under 3mm and contacts are silver. There are spst/no, nc or spdt types and a selection of actuators and terminals. Cherry Electrical Products Ltd. Tel., 01582 763100; fax, 01582 768883.

Gray-code rotaries. Grayhill has added a range of rotary switches giving a Gray code to the *Series 26* binary-coded models. Stops can be supplied to give any number of 22.5° or 45° positions or with continuous rotation. The switches are rated at 200mA for make and break. EAO-Highland Electronics Ltd. Tel., 01444 236000; fax, 01444 236641.

Transducers and sensors

Thermocouples. Precious metal thermocouples in pairings and precision classes complying with IEC 584 are supplied by *Heraeus* in Germany. Types S, R and B are available to cover the 1400-1800°C range, the 0.05mm or 1mm diameter platinum and platinum-rhodium material being supplied in reels or rings in which the wires are wound side by side. Certification with each batch is traceable to the German Calibration Service. W C Heraeus GmbH. Tel., 0049 6181/35-5957; fax, 0049 6181/35-888.



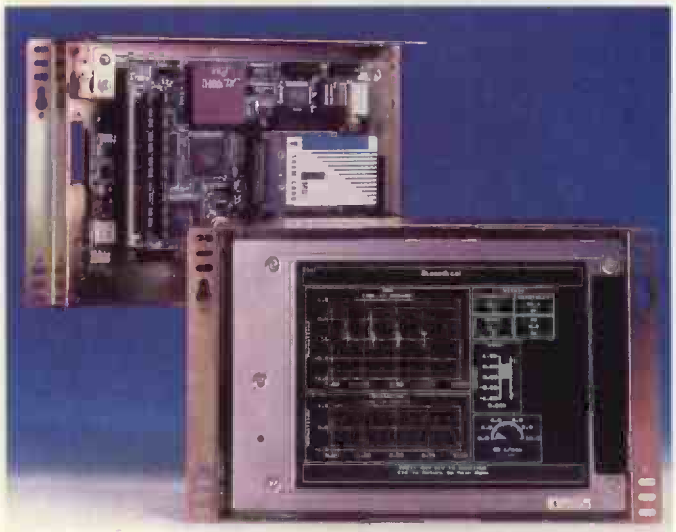
Coder for LabWindows/CVI. National Instruments has a new version of *LabWindows/CVI* visual data acquisition and instrument control development software for Windows PCs and Sun SPARCstations, using Ansi C. New development tools include *CodeBuilder*, which generates code automatically. There are also more custom components and new graphing and image display facilities. National Instruments UK. Tel., 01635 572400; fax, 01635 523154.

COMPUTER

Computer systems

Hand-held computer. AMD offers the *Pen*Key 6100*, a Windows-based hand-held computer using the Elan 386 processor chip. This is a 32-bit, PC AT-compatible chip, available in 25MHz and 33MHz versions, intended for use in telephones and pocket organisers, as well as computers, supporting all standard pc operating systems. *Pen*Key* measures 7 by 4.5 by 1.2in, has a 240/320 pixel display and two PCMCIA slots. Advanced Micro Devices (UK) Ltd. Tel., 01483 740440; fax, 01483 756196.

Master and slave PCs. Blue Chip's *MasterConsole* reduces the cost of a multiple-pc network by controlling up to 16PCs from one station, which is the only one having keyboard, monitor and mouse. *MasterConsole* has intelligent processors at each port for keyboard and mouse emulation in booting and operation, 'plug-and-play' facilities allowing any mix of pc types to be used. Built-in commands eliminate the need for extra software for communication between master and slaves. Blue Chip Technology. Tel., 01244 520222; fax, 01244 531043.



Component PCs. From Advanced Modular Computers comes the *AMC-EP486 Embedded Panel PC*, which effectively treats the computer as a component in a system. It consists of an open frame containing all the usual pc hardware, fronted by a flat-panel display, which can be specified as anything from a mono lcd to a bright active-matrix colour super-VGA tft.

The pc itself consists of a single cpu board, which is the ANC 4860, using a 486. Ethernet is on-board, as is a solid-state disk. Two serial ports are provided, a parallel port, IDE hard-disk drive controller for two disks, NE2000-compatible network interface, a floppy drive controller and a keyboard/PS/2 interface; a watchdog timer is included to reset the system in case of trouble. There is a three-slot bus expansion unit.

Since the computer is an operating PC, it will handle all the usual operating systems, software and development tools. Power needed is 3A at 5V. Advanced Modular Computers Ltd. Tel., 01753 580660; fax, 01753 580653.

Data acquisition

60Msample/s digitiser. Steatite offers the *DA60* waveform digitiser board, which is a 12-bit type capturing 60 megasamples/second on a single channel or 30 on two channels simultaneously, which is claimed to make it the fastest of its type in existence. The board is ISAbus-compatible with an analogue bandwidth of 30MHz on each channel and 512K samples of memory on board. Digitally controlled attenuators set the gain of each channel over a 34dB range in 0.2dB steps. A library of C functions and source code come with the board. Four input signals are two analogue inputs, an external trigger and external clock, the analogue inputs having full-scale voltage ranges of 100mVpk-pk to 5Vpk-pk at 50Ω. Triggers are single-shot and segmented, level being adjusted by the built-in d-to-a. Steatite Insulations Ltd. Tel., 0121 643 6888; fax, 0121 643 2011.

Transient data capture. *Falcon* from Endevco is modular transient data capture system that uses multiprocessing and Windows-based software for control, display and analysis. Data acquisition modules connect by way of a serial comms bus, each module comprising four simultaneously sampled 12-bit a-to-d converters with data storage of up to 1Msample/channel and each module has its own 32-bit processor. Using modules in this way eliminates loss in performance when more channels are needed in an ordinary multi-channel system; sampling rate stays the same, as does front-end performance. Channel specifications include ±2.5V single-ended or differential input, 1-50 gain, selected by resistor value and DDE Windows 3.1 compatibility. Endevco UK Ltd. Tel., 01763 261311; fax, 01763 261120.

Boards with software. Low-cost plug-in data-acquisition cards from Computer Instrumentation now come with free data logging, virtual oscilloscope and multimeter software for Windows and language drivers for programmers. The *SoftLogger* handles up to 24 channels at 10 scan/s, providing graphical display and data storage and direct digital exchange with other software. *SoftScope* is a two-channel dso with facilities including FFT and storage to disk, while the *Virtual Multimeter* simulates a hand-held instrument with digital or analogue display. Computer Instrumentation Ltd. Tel., 01903 765225; fax, 01903 765547.

Development and evaluation

68HC05 emulation. Pentica offers more *68HC05* device adaptors for the *Mime-600* in-circuit emulator – now the X4, P6 and E6 variants of the Motorola processor are supported.

The Pentica emulator for each chip recognises all the configuration registers and on-chip integrated support hardware, so that, in a system, it behaves in the same way as the processor hardware. Pentica Systems Ltd. Tel., 01734 792101; fax, 01734 774081.

PIC development. Microchip's *PICSTART-16B1* is a development system for the 18-pin and 28-pin *16C5X* and *16Cxx* microcontrollers that can be used on any host pc to read, program and verify *PIC*s. The system comprises a simulator for symbolic debugging and i/o stimulus and an eprom programmer and macro assembler. There are also windowed parts for prototype use , sample software routines and documentation. Combined Precision Components plc. Tel., 01772 654455; fax, 01772 654466.

Data logging

Sliced data logger. Delta-T Devices announces the *DL3000* modular data logger, which comes in slices. It is based on Windows and is provided with *Acquire!* software to allow the definition of conditional and event-driven logging and to program inter-channel calculation. Resolution is typically 17 bits with 24-bit internal a-to-d and the inputs, which accept counter, digital, frequency, period, voltage, resistance and current, are expandable from 24 to 384 channels. Physically, the logger is modular, each module being in an aluminium slice, so that the instrument may be up-graded in the field by adding more slices or fitting a *PCMCIA* memory card module. Since the characteristics of many sensors are held in a software sensor library or can be added by the user, many can be connected to 'plug-and-go'. Delta-T Devices Ltd. Tel., 01638 742922; fax, 01638 743155.

Software

Workbench for Windows 2.0. Version 2.0 of Strawberry Tree's *Workbench for Windows* has 5kHz real-time display rate, 100kHz streaming direct to disk and transient capture in burst mode at up to 1MHz. *Workbench* allows users to establish data acquisition, analysis and control systems on screen, data being collected in a matter of seconds, with no programming needed. Signal-conditioning, meters, chart recorders and all the other hardware are software items from a comprehensive library that can be selected on a point-and-click basis. Multiple displays can be used for one experiment to give different views of the data, without interrupting data capture, and historical trending for slow changes is carried out in real time. Hardware required is *486 DX33* or better with 8Mb of ram and Dos 5.0, with Windows 3.1. Adept Scientific Micro Systems Ltd. Tel., 01462 480055; fax, 01462 480213.

68000 debugger. Intermetrics's *PassKey* high-level debugger is now available in a Pentica emulator version for the *68XXX* processor family. PassKey presents the most critical data updated each time the target halts, this among other extra features for point-and-click debugging. Other features include C expression evaluation, stack tracing, breakpoints with action lists, session record and playback and user-specified command lists after each line of source code. Pentica Systems Ltd. Tel., 01734 792101; fax, 01734 774081.

Stock control. *Stockit* is a stock control software package for smaller companies who have no need of the extensive, accounts-based type of program. It is, nevertheless, tailored for the job and is not simply a cut-down version of the more exotic types. It holds complete records of parts lists, stock levels and suppliers and will allocate stock when a batch is needed, being able to include cable lengths, consumables and labour in calculations and printing enquiry sheets for quotations. It is not necessary to convert from existing systems immediately; the process can be gradual, while still realising the benefits of the package. Number One Systems Ltd. Tel., 01480 461778; fax, 01480 494042.

Schematic/pcb design. *Quickroute 3.5* has been completely restructured to incorporate a wide range of new features all compatible with Windows 3.1 and Windows 95. Features include 'design vectorisation' for enhanced Gerber generation, 'design quantisation', copper fill, better import/export support and an improved auto-router. The software comes with a new user interface – multiple button-bars giving instant access to editing and placement tools, a new 'parts bin' for storing components, track and pad styles etc. A free demonstration disk and brochure is available. Quickroute Systems Ltd, 14 Ley Lane, Marple Bridge, Stockport, SK6 5DD. Tel/fax 0161 449 7101.

Factory layout. Deneb Solutions offers *Quest* for Windows NT, an interactive, three-dimensional simulator for the design of batch processes that produces a textured, virtual-reality walk-through factory layout, complete with accurate representations of machinery. Intelligent System Solutions Ltd. Tel., 0161 745 7384; fax, 0161 7458264. ■

TELFORD ELECTRONICS

OSCILLOSCOPES

- Gould OS250A 15MHz Dual Trace ... £120
- SE Labs 111 18MHz Dual Trace ... £85
- Telequipment D1011R 10MHz Dual Trace ... £75
- Telequipment DM63 50MHz 4 Trace storage ... £150
- Trio CS1566A 20MHz Dual Trace ... £150
- Cossor CDU150 35MHz Dual Trace ... £95
- HP1740A 100MHz Dual Trace/storage ... £325
- HP180A + 1801A + 1821A 50MHz ... £150
- HP1742A 100MHz Dual Trace/storage ... £350
- Tektronik 453 100Mhz Dual Trace ... £150
- Tektronik 465 100MHz Delay sweep/Dual Trace ... £375
- Tektronik 7854 c/w 7511 plug-in/7111 fitted with S1 sampling head 1GHz ... £1,600
- Tektronik 7834 c/w 7A26 x2 + 7B92A x2 200MHz ... £900

OTHER SCOPES AVAILABLE

SIGNAL GENERATORS

- HP8654B 10-520MHz ... £400
- HP8654A 10-520MHz ... £350
- HP8614A 0.8-2.4GHz signal generator ... £300
- HP8616A 1.8-4.5GHz signal generator ... £400
- Marconi TF2015 AM/FM 10MHz-520MHz ... £165
- Marconi TF2016 AM/FM 10Hz-110MHz ... £170
- Marconi TF2019 80KHz-1040MHz ... £1,900
- Racal 9081 520MHz synthesized ... £400
- Racal 9082 1.5-520MHz synthesized ... £480
- Wavetek 3000 1-520MHz ... £300
- Wavetek 193 sweep/modulation 20MHz ... £250
- Wavetek 164 30MHz Sweep generator ... £300

LF OSCILLATORS

- Gould J3B 10Hz-100KHz sine/square wave metered· very low distortion ... £150
- HP4204A 10Hz-1MHz ... £150
- HP3200B VHF Oscilator ... £200
- HP651B Test Oscillator ... £125
- HP203A Variable phase LF generator ... £125
- Advance H1E 15-50KHz sine/square 200uf/20V ... £50
- Radford LD04 Low distortion Oscillator ... £300
- Radford LDMS2/2 Low distortion measuring set ... £300
- Global Specialities 20MHz pulse/LF generator Type. 8201 GPIB ... £POA
- Philips PM5132 function generator 0.1Hz-2MHz AS NEW ... £350
- Philips PM5715 pulse generator 1Hz-50MHz ... £750
- Adret Type; 2230A ... £250
- Rhode & Schwarz Type; SUF2 ... £200

POWER SUPPLIES

- Farnell TSV70 MK2 0-70V/5A 0-350V/0-10A ... £200
- Farnell TS70 MK2 0-70V/5A 0-35V/0-10A ... £250
- HP6111A DC 0-20V 0-1A ... £70
- HP6291A DC 0-40V 0-5A ... £100
- HP6261B 0-20V 0-50A ... £700
- HP6002A 0-50V 0-10A 200W ... £POA
- HP6209B DC 0-320V 0-0.1A ... £75
- Lambda LPD422A FM regulated; DC 0-40V/1A x2 ... £100
- Heiden Type; 1108/16 0-16V 0-20A ... £POA

VARIOUS SWITCH MODE POWER SUPPLIES & HT TRANSFORMERS IN STOCK – PLEASE PHONE

CALIBRATION EQUIPMENT

- Haven temperature calibrator DTB5 oil/water bath ... £500
- Haven thermocal i.s. thermocouple simulator/calibrator ... £600
- Time CD millivot pot source Model 404N c/w DC current source Moder 505 ... £250
- Leader LDC705 Scoper calibrator AS NEW ... £1,200
- Casella W.B.G.T. ... £200
- PPM 411F Current reference ... £250
- Cropico resistance standards various in stock from ... £75
- H. Tinsley resistance bridge Type; 5761 ... £350
- Bradley AC calibrator type; 125B ... £POA
- Bradley LF generator digital type; 235 ... £250
- Bradley DC calibrator type; 123B c/w 126B ... £150
- Keithley Picoammeter type; 417 ... £250
- Wallace & Tiernan precision pnuematic calibrator ... £POA
- Schwarzbeck HF interference measuring receiver 85KHz-30MHz ... £300
- Microdine telemetry receiver c/w spectrum display unit 2.2-2.3GHz ... £700

DIGITAL & ANALOGUE MULTI METERS

- Avo 8 MK5 + 6 c/w case, leads, prods etc., (c/w Cal cert NPL) ... From £85
- Solartron 7045 4.5 digit bench multimeter battery/mains ... £60
- Avo DA116 ... £50
- Fluke 3000A ... £45

FREQUENCY COUNTERS

- HP5342A Microwave 18GHz ... £1,400
- HP5308A 75MHz counter/timer ... £100
- HP5305A 1100MHz counter ... £275
- Marconi TF2431 200MHz digital frequency counter ... £150
- Marconi TF2438 520MHz universal counter/timer ... £250
- Marconi TF2440 20GHz ... £1,300
- EIP Type; 331 Microwave 25MHz-18GHz ... £650
- Racal 9904(M) 50MHz ... £100
- Racal 9913 10Hz-200MHz Fitted FX standard ... £125
- Racal 9914 10Hz-520MHz Fitted FX standard ... £125
- Racal 9915(M) 10Hz-520MHz Fitted FX standard ... £125
- Racal 9916 10Hz-520MHz Fitted FX standard ... £125
- Racal 9917(A) 10Hz-560MHz Fitted FX standard ... £195
- Racal 1992 1300MHz ... £700
- Systron Donner 6054B microwave counter 20Hz-18GHz ... £650

REEL TO REEL RECORDERS

- Nagra T instrumentation tape recorder ... £1,200
- Nagra E mono single speed (7½") ... £350
- Nagra 1VS-J stereo ... £500
- HP3964A instrumentation recorder ... £600
- Racal 4DS ... £500
- Racal 7DS ... £700
- Racal Wordsafe 8 track ... £POA
- Dictaphone 2x tape decks ... £POA
- Racal ICR recorder ... £POA
- SE Labs eight-four ... £POA
- Uher 4200 4400 in stock from ... £125

TRANSMITTING EQUIPMENT

- Racal TA1885 Auto tuned HF transmitter freq. 1.6-30MHz 1KW output ... £POA
- Racal TA1800 HF linear amplifier freq 2-30MHz 10KW output ALL MODE OP. ... £POA
- Pye T300AM 68-174MHz 300W output ... £350
- Redifon GA484 400W solid state amplifier c/w 1KW aerial filter unit/drive unit, PSU ... £350
- Harris ATU type; 601A 1-30MHz 1KW AS NEW ... £650

MISCELLANEOUS

- Datalab DK1080 programmable transient recorder ... £300
- Tektronix T912 10MHz Storage scope ... £175
- Rotek AC/DC Precision Calibrator ... £500
- Racal 9084 Synthesized generator c/w GPIB Interface 9934A (As new condition) ... £700
- Iwatsu SS-5416A Synchroscope DC-40MHz ... £350
- Roland drafting plotter A2. DPX-2200 Various interfaces 8 pen ... £1200
- Roland DG X-Y plotter A3. DXY-980A Various interfaces 8 pen. ... £375
- Krohn-Hite filter Model 3202R ... £150
- Cabletron Systems MR-9000C c/w Lanview Multiport Ethernet/IEEE 802 3 Repeater ... £POA
- Cabletron Systems FR-3000 c/w Lanview Fibreoptic/IEEE 802.3 Repeater Unit ... £POA
- Anritsu Channel Selector MS120A ... £POA
- Bruel & Kjaer Vibration programmer ZH0100 ... £POA
- Watkins & Johnson Microwave Tuning Frame MtF102A 4-8GHz ... £250
- Watkins & Johnson Frequency Extender FE2.4.5A 2-4 5GHz ... £275
- Watkins & Johnson Demodulator DM112.5 ... £450
- Watkins & Johnson (CEI) Frequency Extender Unit FE1.4 5A 0.95-2GHz + 2-4 5GHz ... £500
- Watkins & Johnson Signal Monitor SM9403A ... £400
- Sullivan Automatic Component Analyzer AC5555 ... £POA
- Yew Digital AC Power Meter 2503 ... £POA
- Altech Noise Monitor ... £POA
- Minolta TV Colour Analyzer c/w Probe TV2140 ... £1250
- Phoenix Telecommunications Analyzer 5500A
  2nd Unit; Phoenix 5500-MSU 5500-200
  5500-555 5500A-828
  3rd Unit; Phoenix Control Module 5500-200 + 5500A-828
  The above 3 items come as one unit ... £POA
- Cornix 48-48 Audio Switch Matrix 9218-1 ... £1200
- HP8684B Signal Generator 5.4-12.5GHz ... £3000
- Marconi Power Meter 6960 c/w RF Head 6910 10MHz-20GHz ... £1100
- Racal Dana 1998 Frequency Counter 10Hz-1 3GHz ... £900
- Racal Dana 9303 True RMS Level Meter c/w Sensing Head 2GHz ... £650
- EIP Frequency Counter 545 10Hz-18GHz ... £1250
- Tektronix 76120 Programmable Digitizer ... £POA
- Bird Tenuline Coaxial Attenuator 30dB 500W 50ohm Model 8325
  Brand New Boxed £200 VARIOUS OTHERS IN STOCK – PLEASE ASK

MICROWAVE COAXIAL SWITCHES

- "N" Type connectors. R.L.C. Model S-2799
  2KW @ 100MHz 400W @ 6GHz ... £45
- Teledyne SMA connectors. Model CS38S16
  22GHz 1 in - 6 out ... £40

FLEXWELL COAXIAL CABLE

- Cu2Y size 1 5/8th" 50 ohm approx. 1200M available (NEW) ... £POA

SPECIAL OFFER WHILE STOCKS LAST

- HP180 50MHz Dual Trace/Delay timebase with probes ... £150

AN EXTENSIVE RANGE OF TEST EQUIPMENT IS AVAILABLE. PLEASE SEND FOR OUR NEW CATALOGUE

Postage and packing must be added. Please phone for price. VAT @ 17½% to be added to all orders. Please send large SAE for details.

Telford Electronics, Old Officers Mess, Hoo Farm, Humbers Lane, Horton, Telford TF6 6DJ

Tel: 01952 605451 Fax: 01952 677978

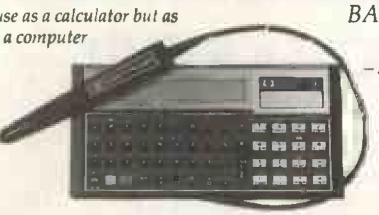
CIRCLE NO. 149 ON REPLY CARD

SCAN BAR CODES FOR £29.00
HEWLETT PACKARD HP71B

As easy to use as a calculator but as powerful as a computer

BARCODE READER

Smart wand – Automatically recognises and decodes all major bar-code standards.



- A powerful set of basic functions, statements and operators – over 230 in all – many larger computers don't have a set of basic instructions in this complete.
- Advanced statistics functions enabling computations on up to 15 independent variables.
- Recursive subprograms and user defined functions.
- An advanced internal file system for storing programs and data – the HP71 has continuous memory – when you turn the computer off it retains programs and data.
- A keyboard that can be easily customised for your specific application.
- HP-1L Interface pre-installed to create a system that can print, plot, store, retrieve and display information. Control or read instruments or speak to other computers, 5000 bytes/sec. Built in ROM includes 46 separate commands. Interface to HP-1L, HP-1B, RS232C, GPIO or series 80. Includes connection cables.

These are second user systems ex DHSS are fully tested and working but have no programming (THAT IS UP TO YOU)

- HP71B ... £29.95
- Bar-code Reader ... £12.95
- AC Power Supply ... £4.95
  (Works from batteries normally)
- Keyboard Overlay ... £1.00
  (Limited quantities)
- Unknown Program – Memory Modules ... £3.00
  (Limited quantities)
- Complete kit of HP71B, Bar-code Reader and power supply ... £39.50

(Prices include VAT – delivery £3.00)
(Currently selling in USA for US$500)
Allow 7 days for delivery

SPECIAL OFFER

Buy 2 Kits For **£59.00**

Other products at give-away prices

Numeric keypad for 'AT' computer

£5 + £2 Carriage (Carriage FREE if ordered with above).

INTERCONNECTIONS LTD

Unit 51, InShops, Wellington Centre, Aldershot, Hants GU11 5DB

Tel: (01252) 341900 Fax: (01293) 822786

CIRCLE NO. 150 ON REPLY CARD

ADD VALUE AND CREDIBILITY WITH REPRINTS

Multiple copies of your articles and advertisements published in this magazine make ideal promotional material for sales literature, exhibition handouts, direct mail, new product launches, distributor promotions, Public Relations etc.

You can add your own artwork and copy, utilise the front cover of this magazine, include your list of distributors, and/or your latest advertisement/s. Reasonably priced reprints can be tailor-made to your own specific requirements or simply reprinted in their original form. (Minimum order number 250)

For a FREE quotation please telephone Jan Crowther now on: 0181-652 8229 or fax: 0181-652 3978

Reprint Services, Reed Business Publishing, Room 1006, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS, England.

TELNET

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

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

OSCILLOSCOPES

Gould OS4000, OS4200, OS4100, OS1000B .... from £125
Gould OS3000 – 40MHz, dual ch. £250
Gould 4035 – 20MHz digital storage £600
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 54201A – 300MHz digitizing £1750
Hewlett Packard 54100D – 1GHz digitizing £4950
Nicolet 3091 – Low freq D.S.O. £1100
Philips 3295 – 350MHz dual ch. £1500
Philips 3315 – 60MHz D.S.O. £750
Lecroy 140 – 100MHz D.S.O. £3250
Tektronix 468 – 100MHz D.S.O. £800
Tektronix 2213 – 60MHz dual ch. £425
Tektronix 2215 – 60MHz dual ch. £450
Tektronix 2225 – 50MHz dual trace £450
Tektronix 2235 – 100MHz dual ch. (portable) £800
Tektronix 2335 – 100MHz dual ch. (portable) £750
Tektronix 464/466 – 100MHz, storage .... from £350
Tektronix 465/465B – 100MHz dual ch. .... from £350
Tektronix 7313, 7603, 7613, 7623, 7633, – 100MHz 4 ch. .... from £300
Tektronix 7704 – 250MHz 4 ch. .... from £650
Tektronix 7834 with 7B42, 7B80, 7B85 – Plug-ins (Storage 400MHz) £1500
Tektronix 7904 – 500MHz .... from £850
Telequipment D68 – 50MHz dual ch. £200
Philips 3206, 3211, 3212, 3217, 3226, 3240, 3243, 3244, 3261, 3262 – (2ch + 4 ch.) .... from £125 to £350
Philips PM3295A – 400MHz dual channel £1950
Hewlett Packard 54501A – 100MHz Digitising – 4 channel £1950
Hewlett Packard 2236 – 100MHz Dual Trace with Counter/Timer/Dmm £995
Iwatsu TS 8123 – 100MHz Dig Storage £850
Other scopes available too

SPECTRUM ANALYSERS

Hewlett Packard 3580A – 5Hz–50KHz £995
Hewlett Packard 3582A – 25KHz analyser, dual channel £2500
Hewlett Packard 182T with 8559A (10MHz–21GHz) £3750
Marconi 2370 – 110MHz £995
Marconi 2371 – 30Hz–200MHz £1250
Rohde & Schwarz – SWOB 5 Polyskop 0.1–1300MHz £2500
Schlumberger 1250 – Frequency response analyser £2500
Alltech 727 – 22.4GHz
Alltech 70727 – Tracking Generator for 727 (10KHz– 12.4GHz) } £2000
Tektronix 7L14 with 7603 – Mainframe (1.8GHz) £2000
Tektronix 7L12 with 7603 mainframe (1.8GHz) £1500
Tektronix 7L18 with 7603 mainframe (18GHz) £2950
Polrad 641-1 – 10MHz–18GHz £1500
Hewlett Packard 35601A – Spectrum Analyser Interface £1000
Hewlett Packard 8754A – Network Analyser – 4–1300MHz £3250
Hewlett Packard 3709B – Constellation Analyser with 15709A High Impedance Interface (as new) £6750
Advantest 4133B – 10KHz–20GH – (60GHz with ext. mixers) £8995
Eaton/Alltech 757 – 10KHz–22GHz £2750
Hewlett Packard 853A – with 8559A (0.1–1500MHz) £3500

Hewlett Packard 853A with 8559A (0.01–21GHz) £4250
Hewlett Packard 8565A (0.01–22GHz) £4000
Hewlett Packard 141T + 8552B + 8555A (10MHz–18GHz) £1600
Hewlett Packard 8756A – Scalar network analyser (10MHz–40GHz) £2250
Hewlett Packard 8505A – Network analyser (500KHz–1.3GHz) £4000

MISCELLANEOUS

Anritsu MG642A – Pulse pattern generator £1500
Ballantine 323 – True RMS voltmeter £350
Datalab DL 1080 – Programmable Transient Recorder £350
Datron 1061 – Precision multimeter £650
Dynapert TP20 – Intellipiace tape peel tester, Immac. cond. £1950
E.I.P. 331 – 18GHz frequency counter £850
E.I.P. 548A – frequency counter (26.5GHz) £3000
Farnell TSV70 MkII – Power Supply (70V–5A or 35V–10A) £225
Ferrograph RTS2 – Audio test set with ATU1 .... £500
Fluke 5101A – Calibrator AC/DC £3500
Helden 1107 – 30v-10A Programmable power supply (IEEE) £650
Hewlett Packard 3325A – 21MHz synthesiser/function gen. £1500
Hewlett Packard 3437A – System voltmeter £350
Hewlett Packard 3438A – Digital multimeter £200
Hewlett Packard 3490A – Digital multimeter £250
Hewlett Packard 3586A – Selective level meter £1750
Hewlett Packard 3711A/3712A/3791B/3793B – Microwave link analyser £3500
Hewlett Packard 3760/3761 – Data gen + error detector .... each £300
Hewlett Packard 3762/3763 – Data gen + error detector .... each £350
Hewlett Packard 3779A/3799C – Primary multi. analyser .... £600/£1000
Hewlett Packard 5150A – Thermal printer £275
Hewlett Packard 5385A – Frequency counter 1GHz (HPIB) with Opts 001/003/004/005 .... £995
Hewlett Packard 6181C – D.C. current source £150

Hewlett Packard 6261B – Power supply 20V–50A £500
DISCOUNT FOR QUANTITIES

Hewlett Packard 7402 – Recorder with 17401A x 2 plug-ins £300
Hewlett Packard 8005B – Pulse generator £250
Hewlett Packard 8011A – Pulse gen. 0.1Hz–20MHz £500
Hewlett Packard 8152A – Optical average power meter £1250
Hewlett Packard 8158B – Optical attenuator with opt's 002 + 001 .... £1100
Hewlett Packard 8620C – Sweep oscillator mainframe £400
Hewlett Packard 8750A – Storage normaliser £375
Hewlett Packard 3456A – Digital voltmeter £750
Hewlett Packard 8684A – 5.4GHz to 12.5GHz Sig Gen £3500
Hewlett Packard 8640B – AM/FM Signal Gen. (512MHz) £850
Hewlett Packard 5340A – 18GHz Frequency Counter £900
Hewlett Packard 5356A – 18GHz Frequency Converter Head £450
Hewlett Packard 432A – Power Meter (with 478A Sensor) £275
Hewlett Packard 435A or B – Power Meter (with 8481A/8484A) .... from £750
Hewlett Packard 4953A – Protocol analyser £2995
Hewlett Packard 5359A – Time synthesiser .... £P.O.A.
Hewlett Packard 5505A – Laser display .... £P.O.A.
Hewlett Packard 3488A – HP-IB switch/control unit (various plug-ins available) £650
Hewlett Packard 3581C – Selective voltmeter £900
Hewlett Packard 3708A – Noise and interference test set £8500
Hewlett Packard 4192A – L.F. impedance analyser (5Hz–13MHz) £8000
Hewlett Packard 4261A – LCR meter (digital) £500
Hewlett Packard 4271B – LCR meter (digital) £900
Hewlett Packard 4342A – Q meter £995
Hewlett Packard 4954A – Protocol analyser £3500

Hewlett Packard 8116A – Pulse/function generator (1MHz–50MHz) £2750
Hewlett Packard 8349B – Microwave broadband Amp (as new) 2–20MHz £4700
Hewlett Packard 8350B – Sweep oscillator mainframe (plug-ins avail) £2650
Hewlett Packard 8683A – Microwave signal gen. (2.3–6.5GHz) £3500
Hewlett Packard 8656A – Synthesised signal gen. (100KHz–990MHz) £1750
Hewlett Packard 8901B – Modulation analyser (150KHz–1300MHz) £4250
Hewlett Packard 8903A – Audio analyser (20Hz–100KHz) £2600
Hewlett Packard 8903B – Audio analyser (20Hz–100KHz) £3250
Marconi 2306 – Programmable interface £500
Marconi 2337A – Automatic dist. meter £150
Marconi 2356 – 20MHz level oscillator £300
Marconi 2432A – 500MHz digital freq. meter £200
Marconi 2830 – Multiplex tester £850
Marconi 2831 – Channel access switch £250
Marconi 893B – A/F power meter £295
Marconi 2019A – 80KHz–1040MHz synthesised sig. gen. £1950
Philips PM 5167 – 10MHz function gen. £400
Philips PM 5190 – LF synthesizer w/th GPIB £800
Philips PM 5565 – Waveform monitor £200
Philips PM 5567 – Vectorscope £600
Philips PM 8226 – 6-pen recorder £550
Phoenix 5500A – telecomms analyser with various interface options £2500
Powersence – Power line analyser £1950
Racal 9301A True RMS R/F millivoltmeter £300
Racal Dana 1992 – 1300MHz frequency counter opts 4B+55 .... £800
Racal Dana 3100 40–130MHz synthesiser £750
Racal Dana 5002 Wideband level meter £650
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/RF level meter £650
Racal Dana 9921 3GHz frequency counter £450
Rohde & Schwarz BN36711 Digital Q meter £400
Rohde & Schwarz SCUD Radio code test set £1500
Schlumberger SI 4040 – Stabilock, high accuracy 1GHz radio test set £5950
Schlumberger 4923 – Radio Code Test Set £1500
Schlumberger 2720 – 1250MHz Freq. Counter £600
Systron Donner 6054B or D – 18GHz or 24GHz Freq. Counter .... from £800
Tektronix DA59100 Series Logic Analyser £500
Tektronix – Plug-ins – Many available such as PG508, FG504, SC504, SW503, SG 502 etc.
Tektronix TM5003 + AFG5101 Arbitrary Function Gen. £1750
Tektronix 1240 Logic Analyser £750
Tektronix 576 – Cure tracer (with test fixture) £1250
Tektronix AM503 + TM501 + P6302 – current probe amplifier £995
Tektronix PG506 + TG501 + SG503 + TM503 – Oscilloscope calibrator £1995
Tektronix CG5001 – Programmable oscilloscope cal. generator £500
Time 9811 Programmable resistance £600
Time 9814 Voltage calibrator £750
Wayne Kerr N905 – Precision LCR meter £850
Wiltron 560 Scalar Network analyser £800

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. 151 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+
27C64-15	2.60	1.80	628128LP-85	8.30	7.20
27C128-15	2.40	1.80	62256LP10	3.00	2.60
27C256-15	2.20	1.70	6264LP-10	2.10	1.45
27C512-15	2.20	1.70	MM58274CN	4.90	3.75
27C010-15	3.95	2.80	ULN2003A	0.43	0.30
27C020-15	6.00	4.25	7805	0.32	0.25
27C040-15	8.60	6.45	MAX232	1.35	0.88
80C31-12	2.10	1.65	7406	0.35	0.23
8255AC-2	2.00	1.45	7407	0.35	0.23
Z80A CPU	1.80	1.00	74HC244	0.35	0.24
LM386N-3	0.50	0.35	74HC245	0.35	0.24
75176BP	1.35	0.85	74HC373	0.35	0.25
68w PLCC skt	0.90	0.70	74HC374	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: 0181-668 7522. Fax: 0181-668 4190.

CIRCLE NO. 152 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 TAS475 4 Channel 100MHz Delay Sweep Cursors £1300
TEKTRONIX TAS455 Dual Trace 60MHz Delay Cursors £900
TEKTRONIX 2465 4 Channel 300MHz Delay Sweep Cursors £1750
TEKTRONIX 2246A 4 Channel 100MHz Cursors/Voltmeter etc £1250
TEKTRONIX 2335 Dual Trace 100MHz Delay Sweep £750
TEKTRONIX 485 Dual Trace 350MHz Delay Sweep £750
TEKTRONIX 475 Dual Trace 200MHz Delay Sweep £500
TEKTRONIX 465 Dual Trace 100MHz Delay £400
H.P. 1740A Dual Trace 100MHz Delay Sweep £350
TEKTRONIX 2215 Dual Trace 60MHz Delay Sweep £400
TEKTRONIX 455 Dual Trace 50MHz Delay Sweep £400
PHILIPS PM3217 Dual Trace 50MHz Delay Sweep £400
HITACHI V223 Dual Trace 20MHz Delay Sweep £250
GOULD OS1100 Dual Trace 30MHz Delay Sweep £240
BECKMAN 9020 Dual Trace 20MHz Delay Sweep £240
IWATSU SS5702 Dual Trace 20MHz £200
KIKUSUI 5530A Dual Trace 35MHz £220
GOULD OS300 Dual Trace 20MHz (No handle) £180
GOULD 4030 Dual Trace 20MHz Digital Storage Cursors £350
GOULD OS4020 Dual Trace 10MHz Digital Storage £250
GOULD 4100 Dual Trace 10MHz Dig Storage/T-Y & X-Y Modes £225
GOULD OS4000 Dual Trace 10MHz Digital Storage £200
H.P. 1741A Dual Trace 100MHz Analogue Storage £400
THIS IS JUST A SAMPLE, MANY OTHERS AVAILABLE

EATON/AILTECH 380K11 Syn Sig Gen 1-2000MHz with PM3602 AM/FM Phase Mod .... P.O.A.
MARCONI 2019 Syn AM/FM Sig Gen 80KHz–1040MHz £1900
MARCONI 2018 Syn AM/FM Sig Gen 80KHz–520MHz £800
H.P. 8620C Sweep Osc 5.9–12.4GHz or 8–12.4GHz £350
H.P. 8620C Sweep Oscillator Main Frame only £200
RACAL 9081 Syn AM/FM Sig Gen 5–520MHz £450
MARCONI TF2337 Automatic Distortion Meter £200
MARCONI TF2331A Distortion Factor Meter 20Hz-20kHz 0.05% Un- used £225
MARCONI TF893B Audio Power Meter Sinad £250
MARCONI TF2163 Attenuator DC–1GHz £100
H.P. 8495B Attenuator DC-18GHz; 0-11dB in Steps £350
HATFIELD 2105 Attenuator 50 Ohm £75
TEKTRONIX TDR1502 .... £1250
R&S Video Noise Meter UPSF2 with UPSF2E 40–Hz–10MHz £1500
R&S Video Analyser type UVF .... £POA
H.P. 8160A Programmable Pre Pulse Gen 50MHz .... £POA
PHILIPS PM5134 Sweep Fun Gen 0.001Hz-20MHz Sine/Sq/Tri etc £500
PHILIPS PM5190 Syn Func Gen 0.001Hz-2MHz Sine/Sq/Tri £750

BRUEL & KJOER EQUIPMENT AVAILABLE PLEASE ENQUIRE

SPECTRUM ANALYSERS

IFR A7550 Synthesized 1GHz £4000
H.P. 8565A 0.01–22GHz £4000
H.P. 3580A 5Hz–50KHz £800
ANDO AC8281 with AC8211 1700MHz £1500
POLARAD 641-1 10MHz–18GHz £1000
H.P. 182 with 8558B 100KHz–1500MHz .... from £1500
H.P. 141T with 8555A & 8552B 10MHz–18GHz £1700
H.P. 141T with 8554B & 8552B 500KHz–1250MHz £1200
H.P. 141T with 8553B & 8552A 1KHz–110MHz £800
H.P. 141T MAIN FRAMES ONLY. GOOD TUBES £225
MARCONI TF2370 30Hz–110MHz £1000
TEKTRONIX 7L5 with Main Frame 20MHz–5MHz £1000

H.P. 5341A Frequency Counter 50MHz–1.5GHz LED £300
RACAL 1998 Frequency Counter 1.3GHz (Options GPIB & High Stab) £900
MARCONI 2437 Universal Counter/Timer DC–100MHz 8 digit £175
MARCONI 2430A Frequency Counter 10Hz–80MHz 8 digit £125
RACAL 9916 Frequency Counter 10Hz–520MHz £175
BLACK STAR Meteor 100 Frequency counter 100MHz £70
DATRON 1065 5½ digit Autocal Multimeter with AC/DC/Ohms. IEEE. £600
H.P. 3435A 3½ digit Multimeter AC/DC/Ohms/Current. LED £100
SOLARTRON 7065 6½ digit Microprocessor Voltmeter AC/DC/Ohms/Auto £400
SOLARTRON 7045 4½ digit Multimeter Volts/Amps/Ohms £80
THANDAR 1504 4¾ digit True RMS Multimer with Adaptor £100
THANDAR 1503 4¾ digit Multimer with Adaptor £75
H.P. 3310A Func Gen 0.0005Hz–5MHz Sine/Sq/Tri/Pulse/Ramp/DC £200
WAVETEK 182A Func Gen 0.004Hz–4MHz Sine/Sq/Tri/DC/TTL Pulse etc £225
THANDAR TG501 Func Gen 0.0005Hz–5MHz Sine/Sq/Tri/Ramp/Pulse/etc £175
GOULD J3B Sine/Square Oscillator 10Hz–100KHz £150
FEEDBACK FG600 Sine/Sq/Tri 0.01Hz–100KHz £60
H.R. SMITH ANTENNA TEST SET type 12-602-4 .... £2000
UNAOHM EP501 Audio Analyser £350
PHILIPS PM5565 Waveform Monitor £300
PHILIPS PM8917 Video Line Selector £200
FERROGRAPH RTS2 Recorder Test Set £250
KEMO Dual Variable Filter VBF/3 0.1Hz–10KHz £200
RACAL Instrumentation Recorder Type Store 4DN £350
RACAL Instrumentation Recorder Type Store 7DS £500
NAGRA IV-SJ Tape Recorder £350
AWA Distortion and Noise Meter F242A £400
LEADER LSG216 Signal Generator £450
MARCONI TF2700 Universal Bridge Battery Operated from £150
MARCONI TF1313A Universal LCR Bridge 0.1% £125
WAYNE KERR B424 Digital Component Meter LCR £200
HEALTHKIT IB RLC Bridge £60
SORENSEN DCR600–4.5B 0–600 Volts 0–4.5Amps. £700
H.P. 6268 0–40 Volts; 0–30 Amps £500
FARNELL H30/100 0–30 Volts; 0–100 Amps, Metered £800
FARNELL B30/10 30 Volts; 10 Amps Variable £150
FARNELL L30–5 0–30 Volts; 0–5 Amps. 2 Meters £150
FARNELL L30E 0–30 Volts; 0–5 Amps. Metered £100
FARNELL L30–2 0–30 Volts, 0–2 Amp. Metered £80
FARNELL LT30–1 0–30 Volts; 0–1 Amp. Twice £130
FARNELL L30–1 0–30 Volts, 0–1 Amp. Metered £65
THURLBY-THANDAR TSP3222 Programmable 32V; 2Amp Twice GPIB Digital £500
THURLBY PL320QMD 0-30V; 0-2A Twice Digital £225
BRANDENBURG Alpha Series 2 Models 2702 15KV £300
BRANDENBURG Model 472R +/– 2KV Metered £200
MANY OTHER POWER SUPPLIES AVAILABLE

NEW EQUIPMENT

HAMEG OSCILLOSCOPE HM1005 Triple Trace 100MHz Delay Timebase £847
HAMEG OSCILLOSCOPE HM604 Dual Trace 60MHz Delay Sweep £653
HAMEG OSCILLOSCOPE HM303. Dual Trace 30MHz Component Tester £422
HAMEG 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 Timer Ratio/Period/Time interval etc £234
APOLLO 100-100MHz (As above with more functions) £332
METEOR 100 FREQUENCY COUNTER 100MHz £119
METEOR 600 FREQUENCY COUNTER 600MHz £145
METEOR 1000 FREQUENCY COUNTER 1GHz £189
JUPITOR 500 FUNCTION GEN 0.1Hz-500kHz Sine/Sq/Tri £125
ORION COLOUR BAR GENERATOR Pal/TV/Video £243
All other Black Star Equipment available

OSCILLOSCOPE PROBES Switchable ×1 ×10 (P&P £3) £13

Used Equipment—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
VISA
110 WYKEHAM ROAD, READING, BERKS RG6 1PL
Telephone: (01734) 268041. Fax: (01734) 351696
Callers Welcome 9am-5.30pm Monday to Friday (until 8pm Thursday)

CIRCLE NO. 153 ON REPLY CARD

CLASSIFIED

TEL 0181 652 3620 FAX 0181 652 8956

CLASSIFIED

TEL 0181 652 3620 FAX 0181 652 8956

ARTICLES FOR SALE

INDEX TO ADVERTISERS

	PAGE		PAGE		PAGE
Ampat	865	ILP	865, 867, 869	Pico Technology	822
Bull Electrical	860, 861	Intech	851	Quickroute Systems	810
Cirkit	893	Interconnections	900	Ralfe Electronics	903
CMS	869, 887	Iosis	810	Research Communications	818
Cricklewood Electronics	867	Johns Radio	862	Robinson Marshall	834
Crossware Products	882	JPG Electronics	893	Seetrax Ltd	821
Crownhill Associates	869	Kestrel Electronic Components	901	Smart Communications	865
Dataman	OBC	Keytronics	882	Sowter	882
Devantech Ltd	853	Lab Center	819, 893	Stag	810
Display Electronics Ltd	891	M&B Radio (Leeds)	872	Stewart of Reading	901
Equinox	IFC	Millford	867	Surrey Electronics	853
Field Electric Ltd	894	MQP	887	System Enclosures	886
Grandata	843	Number One Systems	851	Technology Sources Ltd	825
Halcyon Electronics	851	Oema	821	Telford	900
Hart	885	Olson Electronics Ltd	855	Telnet	901
Hitex (UK) Ltd	882	Perry Bee	894	Those Engineers Ltd	853
ICE Technology Ltd	815			Tsien Ltd	822
				Ultimate Technology	IBC

ELECTRONIC UPDATE

Contact Malcolm Wells on 0181-652 3620

A regular advertising feature enabling readers to obtain more information on companies' products or services.