ELECTRONICS & WIRELESS WORLD

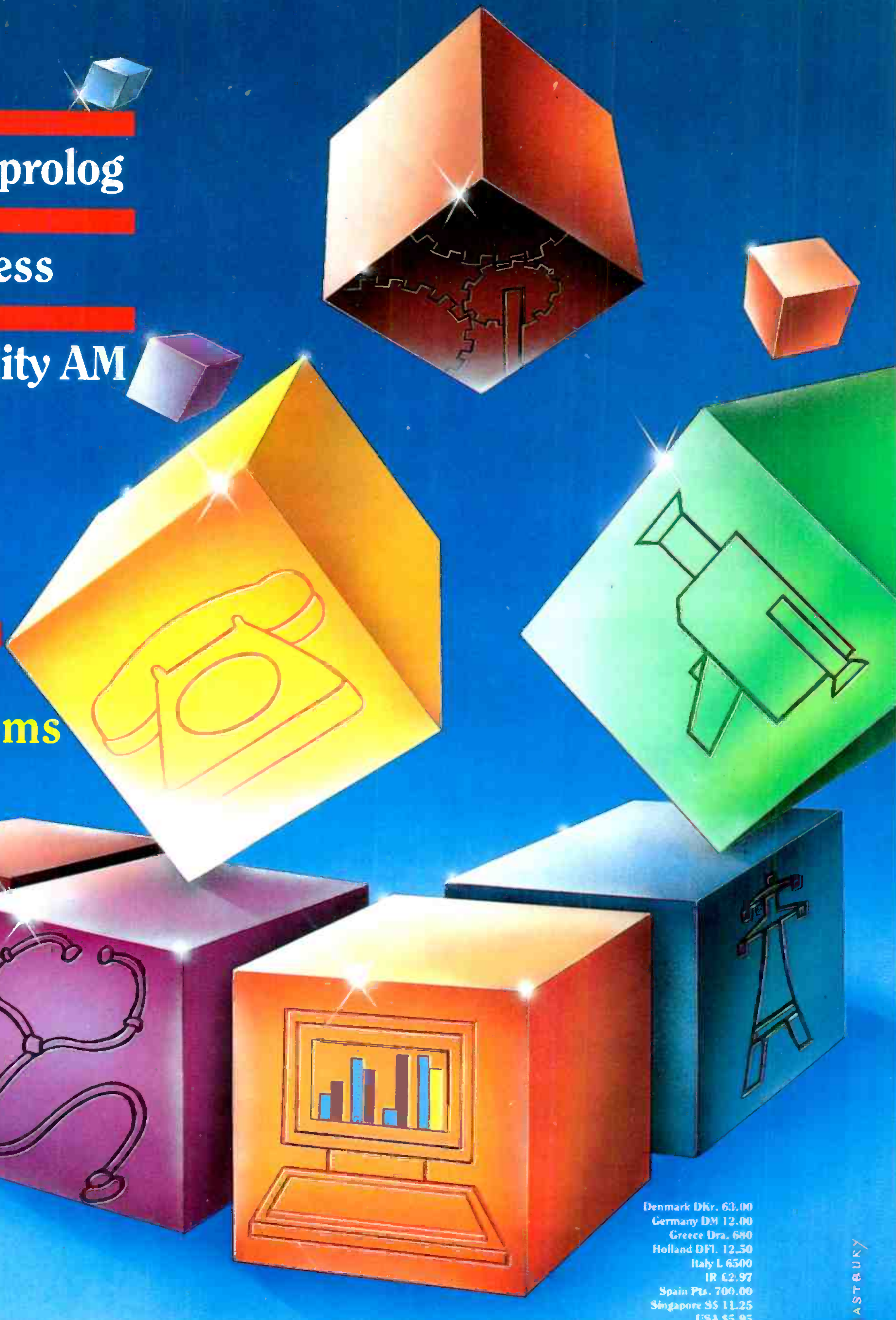
SEPTEMBER 1989 £1.95

Experts speak prolog

The risc business

Broadcast quality AM demodulator

IN DEPTH
PC based systems



9 770266 324004 09

Denmark DKr. 63.00
Germany DM 12.00
Greece Dra. 680
Holland DFl. 12.50
Italy L 6500
IR £2.97
Spain Pts. 700.00
Singapore S$ 11.25
USA $5.95

EASTBURY

ENTER 1 ON REPLY CARD

CONTENTS

SEPTEMBER 1989 VOLUME 95 NUMBER 1643

850 **Who needs electronic circuit analysis?** "Digital circuits are only overdriven analogue ones." Adrian Espin discusses computer-aided modelling.

858 **AM synchronous demodulator.** Synchronous demodulation can improve signal to noise ratios and reduce distortion in AM signal detection.

866 **The risc business.** Conventional micros are more complex than they need to be for most jobs. We examine the alternative.

879 **Experts speak Prolog.** The artificial intelligence language Prolog gives computers a touch of humanity.

912 **Gauss for concern.** The confusion over electromagnetic units started with Faraday and Ampère. It has remained a mess ever since.

920 **Sound in the picture.** The concluding part of Paul Gardiner's article on NICAM TV stereo sound looks at the transmitting end of the system.

924 **Analogue Action.** 1GHz op-amps, high power op-amps and high speed power mosfets.

927 **The what and how of CRCs.** Cyclic redundancy checks are an extension of parity bit error detection into copy protection and program errors.

869 **PC controlled instrumentation.** Business computers provide a virtual front panel for instruments without knobs.

IN DEPTH

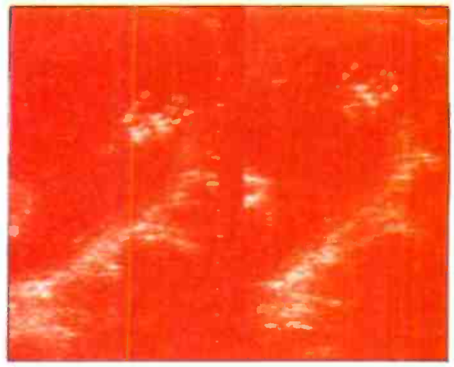
PC-based systems

884 **SCSI and desktop computing.** The small computer system interface, originally designed for intelligent disks, now finds itself in external peripherals.

890 **RS-232 for instrument control.** Less complicated than GPIB and cheaper: instruments can use the standard PC serial port.

892 **NPL's ultrasound beam calibrator.** An application story with a happy ending features a PC at the heart.

898 **Inside the IBM PC.** Technical applications of the PC require users to have some knowledge of the internal workings.



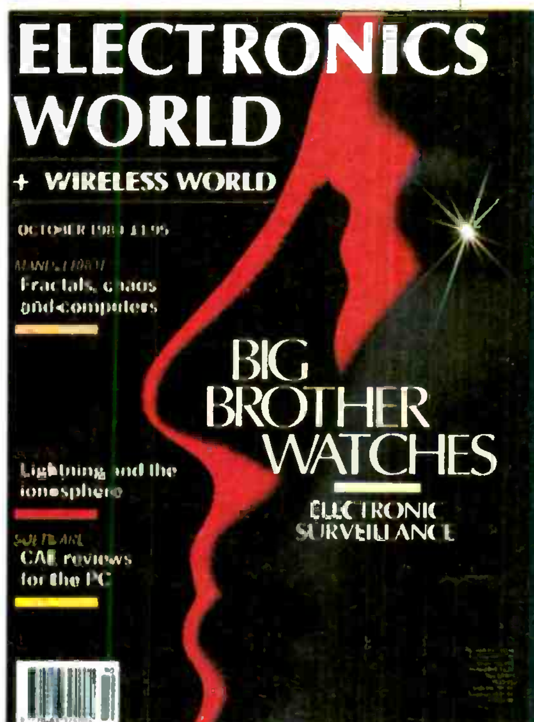
In the early days, technology limited the power of medical ultrasound beams but now there is a growing need for controls on beam power. Two companies and the NPL each describe their part in the design of a PC-based ultrasound calibrator, page 892.

REGULARS

843 Comment. A nation of hairdressers.
845 Research Notes. Diamond transistors, cosmic illiteracy and bloodless surgery.
854 Applications. Class D stereo amplifier, FM stereo decoder with a linear, blending multiplexer and inductors for DC-to-DC conversion.
856 Research profile. The Welding Institute. The UK's leader in microchip bonding and packaging techniques.
862 Update. News from around the industry.
871 New products classified. The monthly at-a-glance round-up.
874 Letters. Microwave mirrors in the sky, cross field antennas, ball bearing motors, photo zeners, circuit symbols and mosfet audio are among the topics you have written about.
903 On the House. Our round-up of parliamentary affairs as they affect the electronics industry.
906 Pioneers. Joseph Henry, an actor turned engineer and scientist, gave his name to both the unit of inductance and an American town.
916 Broadcasting and RF Connections. Our regular column concerned with RF engineering and the broadcast world.
932 Classified.

Readers in the USA facing difficulties in obtaining this magazine are invited to call Worldwide Media Services Inc. toll free on (800) 345-6478.

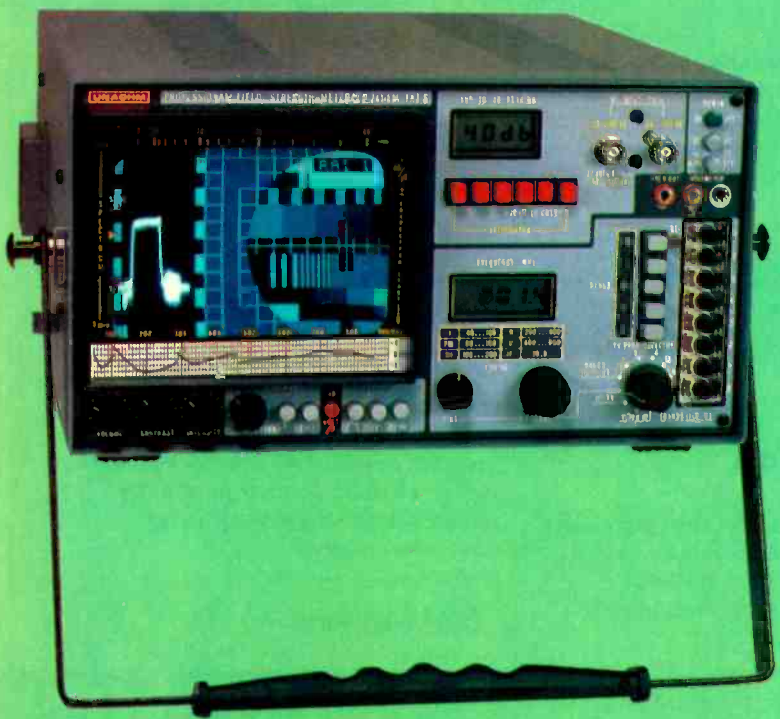
next issue



In next month's issue. Notice the difference? We hope so. Our name changes to *Electronics World + Wireless World*, only the fourth title change in our 76 year history. We feel that the new name reflects our empathy with the rapidly changing electronics industry. But rest assured. We retain completely our commitment to represent the widest range of reader interest from mainstream technology to fringe science. We underline this commitment by publishing an exclusive feature on electronic surveillance delivered from the horse's mouth. In the October issue.

TAYLOR RF/VIDEO MEASUREMENT INSTRUMENTS

MEASUREMENTS MADE EASY



UNAOHM EP741FMS
FIELD STRENGTH METER/SPECTRUM ANALYZER

Frequency Range:	38.9MHz to 860MHz, continuously adjustable via a geared-down vernier
Frequency Reading:	TV Bands - 4 digit counter with 100KHz resolution FM Band - 5 digit counter with 10KHz resolution Reading Accuracy: reference Xtal +/- 1 digit
Function: TV Monitor	NORMAL: picture only ZOOM : 2 to 1 horizontal magnification of picture picture + line sync pulse (with chromaburst if TV signal is coded for colour
Panorama:	Panoramic display of the frequency spectrum within the selected band and of tuning marker.
Panorama Expansion	Adjustable expansion of a portion of the spectrum around the tuned frequency.
Analogue Measurement:	20 to 40dB. Static measurement of received signal. Scale calibrated in dBuV (at top of picture tube) to rms value of signal level.
DC/AC Voltmeter:	5 to 50V.
Measurement Range:	20 to 130dBuV In ten 10dB attenuation steps for all bands. -60 to 130dBuV in nine 10dB steps for I.F.
Measurement Indication:	ANALOGUE: brightness stripe against calibrated scale superimposed on picture tube. The stripe length is proportional to the sync peak of the video signal.
Video Output:	BNC connector. 1Vpp maximum on 75Ω.
DC Output:	+12V/50mA maximum. Power supply source for boosters and converters.
TV Receiver:	Tunes in and displays CCIR system I TV signals. Other standards upon request.
Additional Features:	(1) Video Input 75Ω. (2) 12V input for external car battery. (3) Output connector for stereo earphones.
PRICE:	**£1344.00** nett, excluding V.A.T. and Carriage

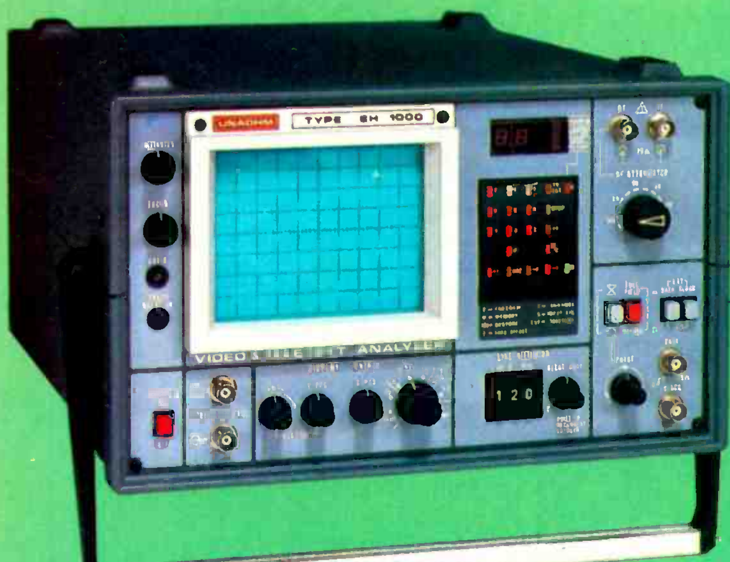
UNAOHM EP742
FIELD STRENGTH METER/SPECTRUM ANALYZER

Specification as EP741 + Synthesized Tuning 99 channels, Programme Storage.
(EP815 Satellite Converter can be added as illustrated)

PRICE **£1498.00** nett, excluding V.A.T. and Carriage

UNAOHM EP815
T.V. SATELLITE CONVERTER

Frequency Range of Input Signal:	950MHz to 1750MHz. Frequency is continuously adjustable through a geared-down control.
Frequency Reading:	Throughout the frequency meter of the associated field strength meter.
Input Signal Level:	From 20 to 100dBuV in two ranges -20 to 70 and 70 to 100.
Power Source:	Available at BNC input connectors as follows: 15V DC/0.5A internal or 25V DC maximum external.
Satus Indication:	Continuity, overload and short circuit conditions of power circuit are all shown by LED lights
Demodulation:	FM for PAL and SECAM coding. Switching to MAC system is provided together with room for an optional MAC decoder.
Audio Subcarrier:	5.5MHz to 7.5MHz continuously adjustable. Provision for an automatic frequency control.
PRICE:	**£536.20** nett, excluding V.A.T. and Carriage



UNAOHM EH 1000
TELETEXT AND VIDEO ANALYZER

Function:	Eye Pattern: display of RF and video-frequency teletext signals by means of eye pattern diagrams both in linear representation and lissajous figures (0 and X). Line selection: display of video signals and line by line selection. Measurement of modulation depth. Teletext: monitoring of teletext pages.
RF Input:	Frequency Range: 45 to 860MHz. Frequency synthesis, 99 channel recall facility, 50KHz resolution, 30 channel digital memory. Level: 40 to 120dBuV; attenuator continuously adjustable. Indication of the minimum level for a correct operation of the instruments. Impedance: 75Ω. Connector type: BNC.
Video Frequency Input:	Minimum Voltage: 1Vpp. Impedance: 75Ω or 10KΩ in case of a through-signal. Connector type: BNC
Teletext Input:	Voltage: 1Vpp/75Ω.
Teletext Clock Input:	Voltage: 1Vpp/75Ω. Measurement: Aperture of eye pattern; linear or Lissajous figures, selectable. Indication: directly on the picture tube. A calibrated scale shows percentage of eye pattern aperture. Error: the instrument introduces an error of less than or equal to 5% with video input and 20% with RF input. Jitter on regen'd clock: less than or equal to 25ns. Line selector: Selection of any TV line between the 2nd and the 625th scanning cycle by means of a 3 digit thumbwheel switch.
Oscilloscope:	VERTICAL CHANNEL: Sensitivity: 0.5 to 2Vpp/cm. Frequency Response: DC to 10MHz. Rise time: pre & overshoot less than or equal to 2%. Input Coupling: AC. Input Impedance: 75Ω/50pF. TIME BASE: Sweep Range: 20 to 10ms (1.1/2 frames); 32; 64/192us (1/2; 1; 3 lines). Linearity: +/-3%. Horizontal Width: 10 divisions; x5 magnification.
PRICE:	**£2030.00** nett, excluding V.A.T. and Carriage

ENTER 50 ON REPLY CARD

TAYLOR BROS (OLDHAM) LTD.
BISLEY STREET WORKS, LEE STREET,
OLDHAM, ENGLAND. OL8 1EE
TEL: 061-652-3221 TELEX: 669911 FAX: 061 626 1736

VISA

REED BUSINESS PUBLISHING

Electronics & Wireless World is published monthly USPS687540. By post, current issue £2.25, back issues (if available) £2.50. Order and payments to 301 *Electronics and Wireless World*, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Cheques should be payable to Reed Business Publishing Ltd. **Editorial & Advertising offices: EWW** Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. **Telephones:** Editorial 01-661 3614. Advertising 01-661 3130. 01-661 8469. **Telex:** 892084 REED BP G (EEP) **Facsimile:** 01-661 8939 (Groups II & III) **Beeline:** 01-661 8978 or 01-661 8986. 300 baud, 7 data bits, even parity, one stop bit. Send ctrl-Q, then EWW to start, NNNN to sign off. **Newstrade:** Quadrant Publishing Services No. 01-661 3240. **Subscription rates:** 1 year (normal rate) £30 UK and £35 outside UK. **Subscriptions:** Quadrant Subscription Services, Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 0444 441212. Please notify a change of address. **USA:** $116.00 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:** Jay Lemman, Reed Business Publishing Ltd, 205 East 42nd Street, New York, NY 10017. Telephone (212) 867-2080. Telex 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 to the above.

A nation of hairdressers

The survey on popular scientific understanding published recently in *Nature* should be cause for concern. In a random sample of 2000 Britons aged 18 and over, around a third believed that the Sun revolves around the Earth; 46 per cent didn't link DNA to genetic study; fewer than a third knew that table salt wasn't calcium carbonate; only 31 per cent could state that electrons were smaller than atoms; under half of the sample could state definitely that the earliest humans weren't around at the time of the dinosaurs and incredibly, given the recent level of public debate, almost half the sample thought that nuclear power stations caused acid rain.

Few people would have cast the former Secretary of State for the Environment, the Rt Hon. Nicholas Ridley, in the role of Jolly Green Giant. However, in the light of the survey's findings, his vituperous outburst on the nation's Greens – "a bunch of politico lefties manipulating public opinion for their own ends" – deserves consideration. The macrobiotic, coarse-wove underlay to the centre stage of British politics exhibits some comprehensively stupid ideas laced with a small thread of immense value to us all. Unfortunately, we appear to be too ignorant to recognize the difference and, for this, the blame must be laid at the door of the outgoing Secretary of State for Education, the Rt Hon. Kenneth Baker.

Consider something else. According to the Association of Graduate Recruiters, one in thirteen job vacancies for new graduates won't be filled. The universities can't meet the employers' demand for all sorts of reasons, some of them good ones.

It is more than a question of cash. Some centres of higher education have up to 30 per cent of their course vacancies unfilled and, even more regrettably, the vacancies occur mostly in the science and engineering departments.

Education ministers can't hide behind the demographic changes: these can be predicted with a degree of certainty. Although the numbers are falling, there are currently 3 844 900 children in primary education, of whom, statistically, some 400 000 will be suitable for university education. This compares with a total university output of 160 000 for 1989 (source: AGR). Given that the primary roll which produced this output was substantially higher than today's, the facts suggest a criminal wastage of talent and a blighting of young lives.

The Government would argue that all is changing with the introduction of the much-vaunted National Curriculum with its emphasis on maths, English and science. One hopes that this is so; but the same disenchanted, occasionally ignorant teachers who made the old system tick along will have to make it work.

The universities have continually made an eloquent case for a sustained level of resources and status. The time is surely right to elevate the rest of the education system. Society should be ready to accord all teachers the status (and money) due to the guardians of knowledge. However, teachers, in return, should be ready to demonstrate that they are fit to hold this great responsibility by the sort of tests which are applied to other professional people.

Primary school teachers represent the difference between mass enlightenment and a nation of hairdressers.

First parallel processor in space

The transputer, one of Britain's many clever ideas that may not remain British, is being used in what's believed to be the first attempt at parallel processing in space. Smith Associates undertook a feasibility study on behalf of the European Space Agency (ESA) which negotiated the £100 000 transputer project with the University of Surrey. ESA now plans to launch the experiment via Ariane this autumn.

What's interesting is that this highly advanced research will be carried on a cheap £250 000 satellite, UOSAT-E. Cheap, in this instance, is not meant as a pejorative expression since Dr Martin Sweeting and his team at Guildford are already world-famous for their succession of highly successful spacecraft, two of which are currently in orbit. These missions have performed a variety of different functions including educational demonstrations, CCD camera surveys, ionospheric and magnetospheric monitoring.

Because of the success of the UOSAT programme and because of the potential attraction of space research at low cost, numerous firms and organizations have continued to provide financial backing and technical resources.

This autumn's launch involves a total of seven payloads: SPOT-2, the primary payload, UOSAT-D, UOSAT-E and four AMSAT-NA MicroSats. UOSAT-D and UOSAT-E will take over the mission objectives of UOSAT-C which was to have flown last year. UOSATs D and E have had to be smaller than UOSAT-C to fit the European rocket; but according to Martin Sweeting, many of the mechanical and electrical subsystems of UOSAT-C were simply taken apart and re-assembled like Meccano, to make the new satellites!

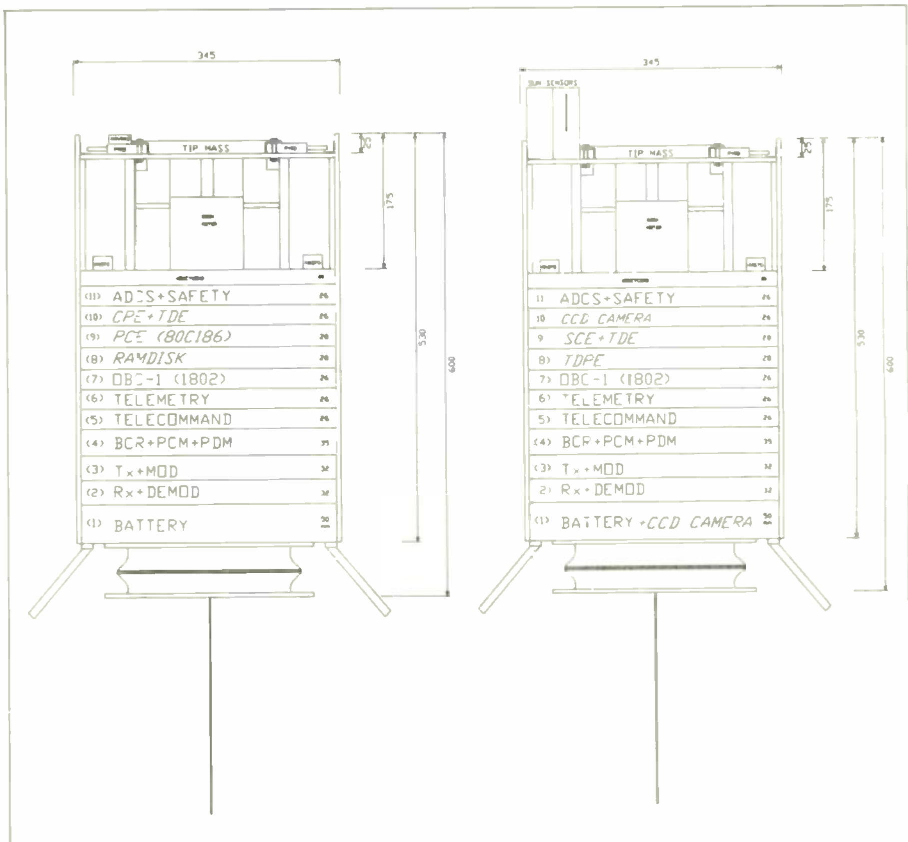
On board UOSAT-E will be CCD imaging systems carrying on the work of earlier UOSATS. There'll also be an array of advanced solar cells made from gallium arsenide, indium phosphide and silicon. These will be mounted in various experimental covers to reduce degradation and improve efficiency.

The transputer experiment is perhaps the most interesting, however. Three Inmos transputers will be used in a variety of modes, varying from conventional high-speed parallel processing to monitoring one another and watching for erratic behaviour arising from radiation-induced Single Events Upsets (SEUs). Results from this study will be of special value in devising high-performance data handling systems for future satellites.

UOSAT D will also monitor SEUs, using cosmic particle detectors, and will carry an advanced store-and-forward communications transponder.

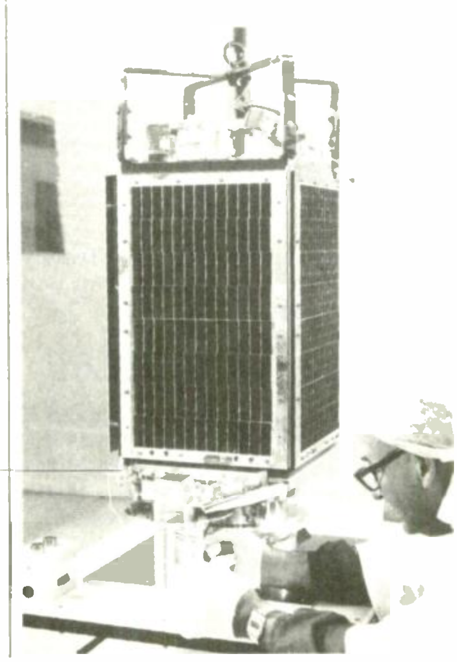
During its feasibility studies, Smith Associates discovered that transputers are inherently about three times more radiation-resistant than conventional microprocessors, especially in terms of 'hard' (i.e. permanent) failures. As for SEUs, the very architecture of parallel processing systems should help to ensure that massive system crashes due to the corruption of a few bits of data become things of the past.

Once again, all being well, it seems that the UOSAT team has found a winning formula that should help to disabuse people of the notion that 'low cost' equals 'shoddy'. As Sweeting observes, the reality is that radio amateurs have once again demonstrated their ability to respond imaginatively to short-notice launch opportunities and to continue the all-important transfer of information between the amateur and professional engineering communities. Long may it continue.



UOSAT D (left) and UOSAT E, from the engineering drawings.

Below: the earlier UOSAT-2, during its final preparations for launch.



V-525 Cursor measurement 50 MHz real time oscilloscope

NEW PRICES FROM **£639·00**

- 2 Channel
- CRT Readout of Key Parameters
- Cursor Measurement of ΔV, Δt and $1/\Delta t$
- 1 mV/div Sensitivity
- Max Sweep 20ns/div
- Alternate Magnification
- DC Offset Function
- Signal Delay Line and TV Sync.

Expect more from Hitachi

HITACHI

In a word, reliability

13 Garrick Industrial Centre,
Irving Way, London NW9 6AQ
Telephone: 01-202 4311. Telex: 27449

ENTER 40 ON REPLY CARD

TDS9090 Problem Solver...

This computer card from Triangle Digital Services Ltd is for building into products. Put software for the application into PROM and it starts to run as soon as power is applied. Some existing uses are:

- ★ Water Control
- ★ Conveyor Weighers
- ★ PABX telephone exchange
- ★ Diesel engine testing
- ★ Mass Spectrometry
- ★ Intelligent Keyboard
- ★ Tide measurement
- ★ Crane control
- ★ Paging systems
- ★ Sports timer
- ★ Colour analysis
- ★ Public address switching
- ★ Data Buffering
- ★ Agricultural machinery
- ★ Machine-tool control
- ★ Remote robot handling
- ★ Heart rate data collection
- ★ Hand-held data input
- ★ Geological instrumentation
- ★ Electron microscopes
- ★ Security validation
- ★ Surveying instrument
- ★ Swimming pool control
- ★ Effluent monitoring
- ★ Bar code readers
- ★ Further education projects

Many of these use the low power of the TDS9090, its direct connection to matrix keyboards, and ouput via character or graphic Liquid Crystal Displays.

Control Computer

The TDS9090 is a powerful control computer based on the high level language Forth. Although small, it is packed with important features which make it easy to use in solving your control problems.

The computer uses the HD63A03Y microprocessor and has on card 16K bytes of Forth as well as full symbolic assembler. You write programs in high level lanugage. Mix it with assembler if required. There is 30K of data RAM and 16K for your program (TDS9092 has 8K and 30K respectively).

The board has 35 parallel I/Os and two RS232 serial ports. A 256 bytes EEPROM keeps data while the card is not working. Additional features include the Watchdog Timer, Time-of-day Clock and Multitasking. The single power supply draws 15mA, with only 3mA in a low power operational mode.

The TDS9090 measures just 100 × 72mm. One version has a DIN connector making it a shortened Eurocard. The other has pin headers for connection by ribbon cable, or use it as a component inserted on a larger board.

Development System Requirements

TDS9090-IBMSOFT gives you a development environment on an IBM-PC or clone. It stores your source code on disk, although your program is still compiled and debugged on-line in the TDS9090. Your Forth is written with any standard word-processor.

When the program is written you'll need a prom programmer. Either buy the TDS961 card and attach it to the TDS9090, or transport the finished code to your existing programmer in the non-volatile RAM supplied with the TDS9090.

The software support disk also has a library of sub-programs in Forth and assembler which help in your TDS9090 applications. For instance interrupt driven serial I/O, paged memory for data collection, clock support, graphics LCD drivers, inverse trigonometry, frequency measurement, solid-state speech and interrupt driven stepper motor control.

Triangle Digital Services Ltd, 100a Wood Street, London E17 3HX. Tel: 01-520 0442. Fax: 01-509 3263.

ENTER 29 ON REPLY CARD

R.I.P. cold fusion

Scarcely three months after the scientific community and indeed the world at large had been rocked by the claims of Fleischmann and Pons there came what most observers had been expecting – the effective death knell of cold fusion.

After spending £320 000 and using £4 million worth of equipment, the UKAEA Harwell Laboratory finally decided to put an end to the search for limitless energy from a test tube. Dr Ron Bullough FRS, chief scientist of the AEA, said, "The potential benefit and scientific interest in cold fusion, together with the Government's need for information and advice meant that the subject had to be investigated. However, results to date have been disappointing and we can no longer justify devoting further resources in this area." So although Fleischmann and Pons are still struggling on, most other cold fusion research has been abandoned.

My justification for resurrecting this corpse is not the fusion debate itself, but what has now been revealed of the experiments undertaken at Harwell. This research, it emerges, continued unabated for three months, throughout weekends and public holidays, with a team of six electrochemists and four nuclear physicists often working 80-hour weeks. The programme is believed to have been the most comprehensive mounted anywhere in the world, with 30 "fusion" cells under observation at a time.

Many of the experiments were designed to detect emissions of neutrons and gamma rays, typical of known fusion reactions, from a variety of electrochemical "cold fusion" cells. When it became apparent that these emissions were not in the range of hundreds of events per second, more sensitive detector systems were used, capable of seeing as few as 0.01 neutrons per second.

Considerable care was taken to eliminate the effects of cosmic rays and other background sources such as electronic noise. Background signals from unpowered cells were compared with those observed from powered cells. Computer-controlled data logging eliminated human errors and by these methods any long term background variations were eliminated. Multiple banks of gamma and neutron detectors were used to identify spurious events due to electronic malfunction in any individual detector.

Dozens of cells were examined, varying the size, geometry and metallurgical properties of the electrode systems in a systematic way. In many others electrode materials were changed to include palladium, gold, titanium and uranium/cerium compounds. The chemical constitution of electrolytic solutions was changed to observe the effects of using heavy water and light water mixtures; various salts of lithium, sodium and palladium; and different "cocktails" of deuterated acids. The use of controls (e.g. using light water in place of heavy water) further reduced the possibility of signals being mistaken for genuine fusion events.

As well as altering the size, shape and thickness of electrodes, the research team fabricated others from palladium that had eight different metallurgical histories. Electrodes were made from wires, rods, tubes, foils and granules and were used in a number of different geometries. Cells were subjected to a regime of varying current densities, cycling currents and to steep rises in current following various periods at low current densities.

In none of these experiments was there statistically significant evidence of a fusion reaction taking place under electrochemical conditions. Need we say more?

Infra-red waveguide for bloodless surgery

ERA Technology, in conjunction with the technology transfer organization Cogent, has developed a novel hollow glass waveguide for directing infra-red energy from CO_2 lasers. Several prototypes based on a non-toxic oxide glass have recently been fabricated at ERA's laboratories in Leatherhead and are currently being evaluated for surgical applications.

Carbon dioxide lasers, operating at mid-infra-red wavelengths of around 10μm are particularly useful for tissue cutting and cauterizing; they permit virtually bloodless surgery and thus reduce the immediate trauma and after-effects for the patient.

For a CO_2 laser to be used to the maximum effect, its energy needs to be transferred from the rather bulky laser itself to the precise point at which it's needed. The only problem is that radiation as long as 10μm cannot be transmitted along conventional optical fibres because of the extremely high attenuation due to molecular vibration or rotation.

ERA Technology has therefore adopted a different technique, replacing optical fibres with hollow glass optical waveguides. The air-cored waveguide, with an internal diameter of 1mm, uses a glass cladding whose optical properties have been tuned to ensure maximum internal reflection (i.e. minimum attenuation) of a wavelength near 10.6μm. Laboratory prototypes transmit about 80% of the incident energy through a straight waveguide one metre long, but this reduces to 40% when the waveguide is bent to a 50cm radius. It's not marvellous compared to the performance of optical fibres at shorter wavelengths, but it should permit a whole new degree of freedom for surgeons using CO_2 lasers. What's more, ERA Technology and Cogent are already predicting considerably improved performance when the waveguide is manufactured using precision machine-drawn fibres. They are at present looking for suitable partners to develop the technology further.

Ultimately the development of disposable high-efficiency optical waveguides should make possible a whole range of virtually non-invasive surgical procedures. ERA believes that there is now a very real prospect that major heart surgery such as coronary bypass operations could be conducted on an out-patient basis. All a surgeon would need to do would be to feed the waveguide and an optical fibre viewing device into a major blood vessel through a small hole in the skin, and then direct it to the site of action. The rest could be done with little more than a screen, a mouse and a button marked 'zap'! ■

Diamond chips will soon be forever

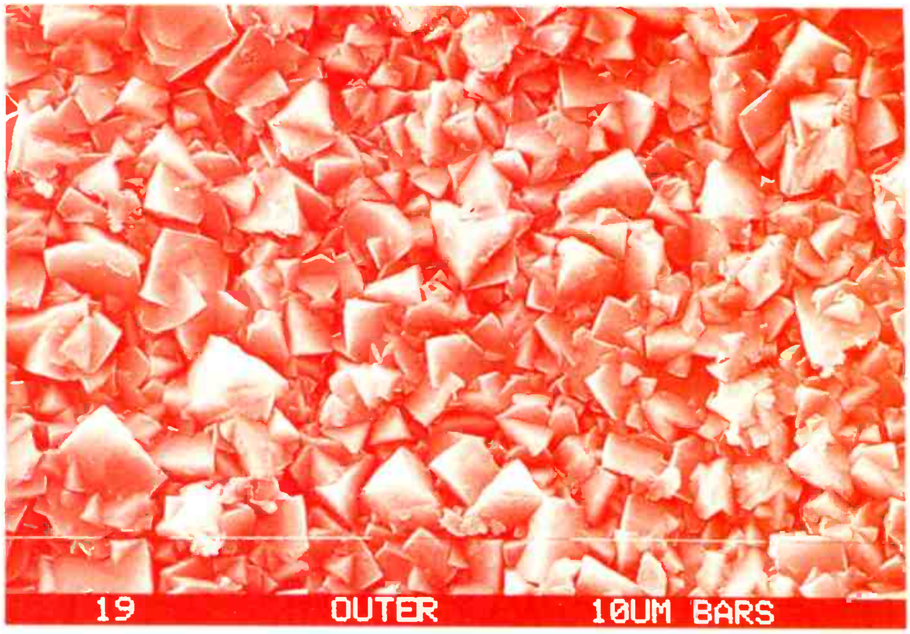
Looking down Group IV of the Periodic Table of the elements, many of us must have wondered at some time or other why germanium and silicon make useful semiconductors, but why no carbon chips have yet existed – except perhaps, at the local take-away. The reason, of course, is that virtually all practical active devices are made from crystalline materials that share the same crystal lattice structure as silicon. In the case of carbon, that – unfortunately – means diamond.

Some time ago, Michael Geis of MIT's Lincoln Labs in Lexington showed that is was possible to fabricate active devices from diamond, but not on any useful scale. Problem one was the difficulty of doping diamond with the necessary Group III or V elements: problem two was the need for natural high quality gems. Wafer-scale integration, had it been possible, would have needed the Koh-i-Noor!

The attraction of diamond chips is not just the intellectual satisfaction of plugging a gap in the Periodic Table: diamond has the highest breakdown voltage, highest saturated electron velocity, lowest dielectric constant and highest thermal conductivity of all known semiconductor materials. Taken together those qualities are a recipe for high-speed, high frequency, high power, high temperature and high radiation resistance. This last quality has led to various Star Wars projects spending a total of $13M on diamond research.

Obviously the important step forward will be the successful production of synthetic diamond monocrystals that can be deposited on a silicon substrate. The two problems to be overcome are the incompatibility of the two atomic lattices and the tendency for vapour-phase carbon to deposit itself as graphite rather than diamond.

Here in Britain, Pilkington Electro-optic Materials (PEO) has combined high-energy plasmas and chemical vapour deposition (CVD) to coat a variety of surfaces with polycrystalline diamond. Hydrogen introduced into the vapour phase effectively mops up any graphite that might otherwise be formed. This process, though not designed to create a large monocrystal, does make materials ideally suited for insulators, heat-sinks and optical components. Wayne Rabalais and Yeshayahu Lifshitz of the University of Houston and Sorq Nuclear Research Centre in Israel report (*Phys. Rev. Letters* vol. 62 p.1290) a way of extending that process to create a diamond monocrystal that fits perfectly on to a silicon substrate. Their approach is to combine CVD with an ion accelerator to punch carbon atoms into the substrate. This appears to overcome the incompatibility between the respective lattice dimensions and ensures that the diamond crystal stays firmly in place.



Elsewhere, other workers are trying different approaches such as searching for substrate materials that are a better match to the natural dimensions of the diamond lattice. Substances like lithium fluoride look promising contenders; but because of their relatively low melting point they defeat some of the advantages of using diamond.

Obviously all this work will add to the little that's currently known about diamond crystals and will undoubtedly lead to better method of fabrication. It will also, we may hope, provide material with which to study appropriate doping techniques – especially difficult with diamond. Then, and only then, will we have chips capable of operating at 600°C in the core of a nuclear reactor or on board a radiation-hard spy satellite. Diamonds may be hard to win but the prizes are truly glittering.

Are you cosmically illiterate?

A nationwide survey has recently revealed that many American adults suffer from cosmic illiteracy. For example, 45% are unaware that the Sun is a star. Only 37% believe that the Sun has a finite life and only 24% know that the Universe is expanding.

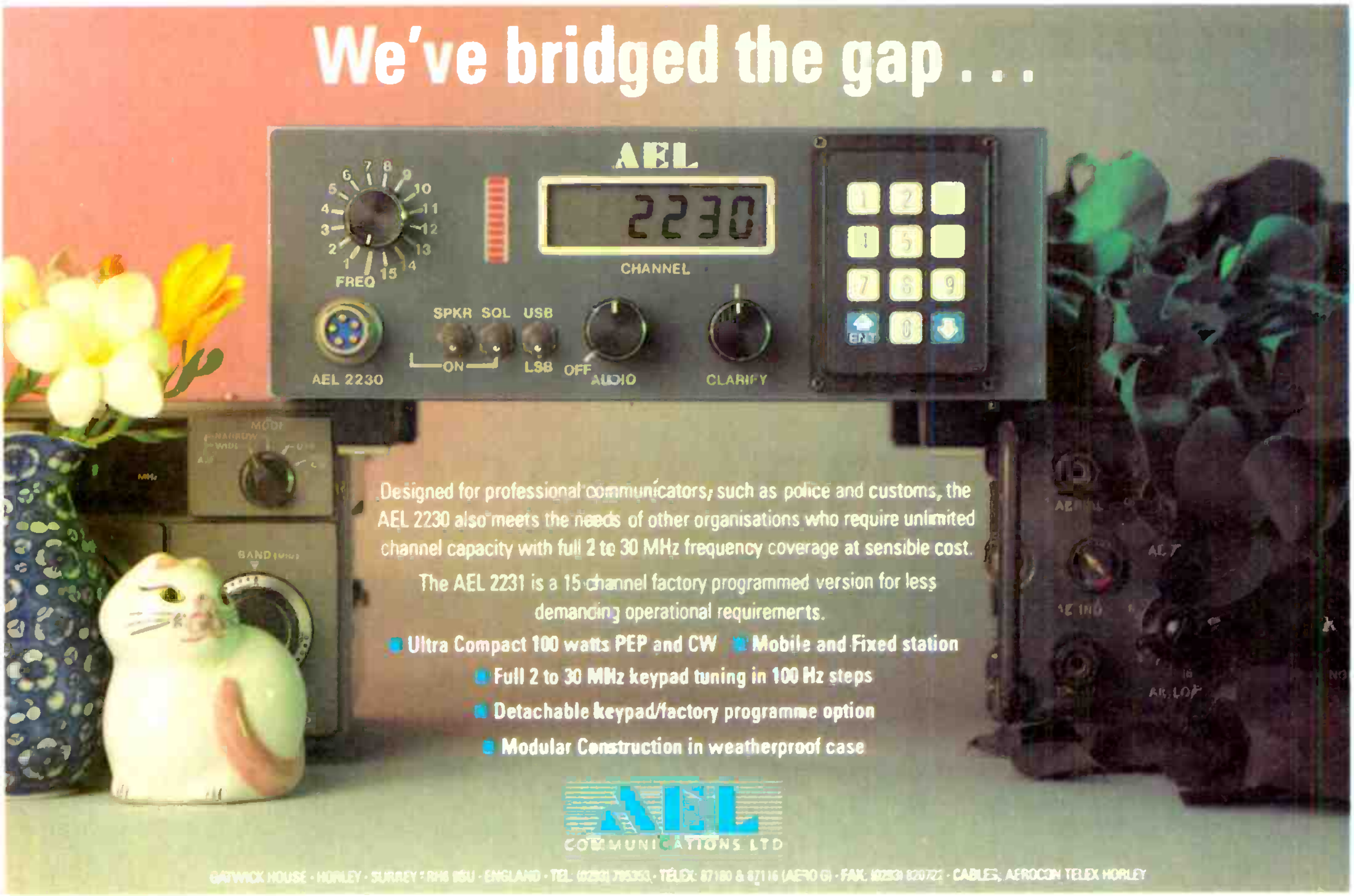
Professor Alan Lightman of the Massachusetts Institute of Technology who co-authored the study is not too surprised by some of the findings, except the belief, held by 25% of respondents, that the Sun is a planet. More pleasing is the finding that 62% of the great American public believes that the Universe is full of planets like our own on which life could have developed.

One curiosity with which Galileo would have felt some sympathy is the finding that astronomical knowledge bears an inverse relationship to church attendance! This appears especially true in areas of cosmology such as the expansion of the Universe. But even allowing for factors like religion, age, sex and education, Lightman found a marked preference for belief in a Universe that is static and unchanging.

Change, he believes, is psychologically hard to cope with – even if it's on a time-scale of ten billion years!

• *See also Comment, page 843.*

Research Notes are by John Wilson of the BBC World Service science unit.



ENTER 39 ON REPLY CARD

TELECOMMUNICATION TRAINING EQUIPMENT

Full range of Training Equipment including:

- ANALOGUE & DIGITAL COMMUNICATION CIRCUIT & SYSTEMS
- FIBRE OPTICS
- MICROWAVE
- TELEPHONY
- RADAR **NEW**

For more information contact:

LAB-VOLT (UK) LTD.

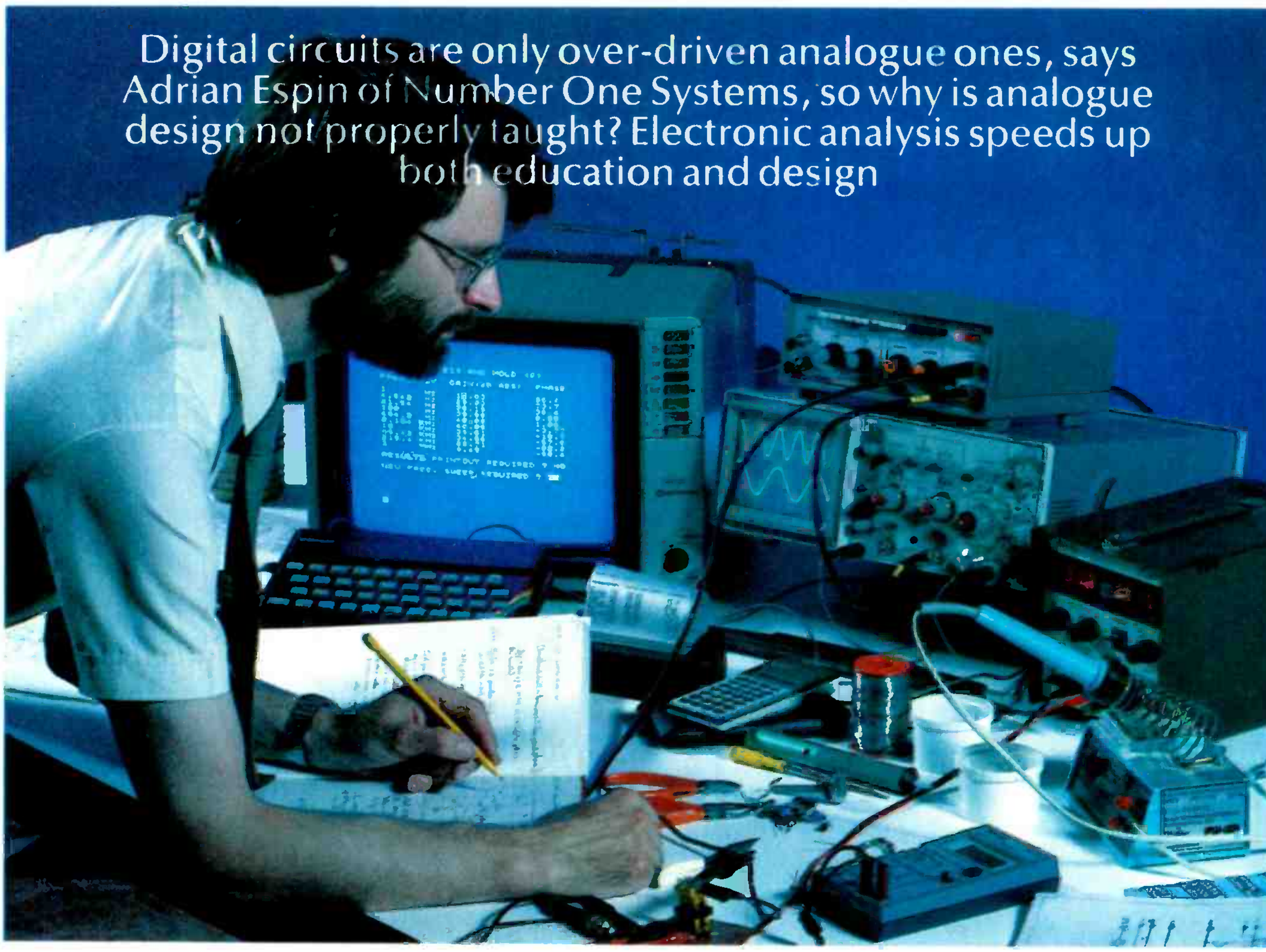
4A Harding Way,
St. Ives Industrial Estate
Huntingdon,
Cambridgeshire
PE17 4WR
Tel: (0480) 300695. Fax: 0480 61654

Lab-Volt®

ENTER 47 ON REPLY CARD

Who needs electronic circuit analysis?

Digital circuits are only over-driven analogue ones, says Adrian Espin of Number One Systems, so why is analogue design not properly taught? Electronic analysis speeds up both education and design



This article gives an insight in to what facilities are available from analogue cad simulation systems for circuit design. It also highlights an apparent deficiency in the education system governing many of our major colleges and universities regarding electronics circuit design using discrete components and suggests that the use of analogue circuit simulation on low-cost microcomputers can aid the teaching of the subject.

Around a year ago I was invited to give a short talk to a group of university and college lecturers about Number One Systems' range of electronics cad programs. I leapt at the chance of addressing these revered gentlemen, because over the years I was becoming more and more convinced that they were failing to educate our young hopefuls in the ways of the real electronics world. I must admit that I was also convinced that greater use of our range of software in colleges and universities would ease these problems!

Educating engineers

Perhaps I should explain how I came to my unfortunate conclusions. My company is an electronics design consultancy which originally specialised in analogue circuit design. Over recent years we have branched out into microprocessor and computer control and we now also produce computer-controlled machine-vision systems for inspection and measurement applications. We have also had considerable success in developing a niche market in affordable computer-aided design software.

As a small but expanding company, finding additional, versatile, high-quality staff has always been a problem. We have been interviewing engineers for design and consultancy work over recent years and, to our dismay, only around five percent of graduate electronics engineers who get as far as the interview are capable of "analysing" a single-transistor audio amplifier stage. We are therefore left with the conclusion that colleges and universities have almost completely failed to educate "electronics engineers" with the basic understanding required to design circuits down to discrete-component level. Indeed, when talking to the previously mentioned group of lecturers and confronting them with the exercise described below, it became apparent that by no means all of them were capable of performing the same task.

At the risk of giving away one of our standard interview tests, the diagram in **Fig. 1** shows the circuit presented to interviewees with the request that they should talk about it for as long as they can, giving as much information as they can.

Fortunately, most applicants recognized that it is an amplifier of some sort. About 50% of applicants suggested that it may be a relatively low-frequency AC amplifier. Only 30% were capable of estimating the DC voltage at the emitter of the transistor. Only 20% managed to calculate the collector voltage without being reminded that $I_e = I_c + I_b$! About 20% got warm on the input impedance, realising that the transistor had an effect but being quite incapable of estimating it. About 10% could provide a figure for output impedance and, amazingly, less than 10% offered, without any prompting, any kind of gain figure for what must be one of the simplest of circuits. Only the same 10% were capable of modifying the gain to X4 without upsetting the DC conditions and only the same 10% had a glimmer of understanding of the relevance of r_e and the hybrid-pi equivalent circuit.

It is only fair to point out that a good proportion of applicants were able to work out the gain of simple operational amplifier circuits and indeed did much better when grilled on digital systems, microprocessors and software engineering.

What this points to is that the bulk of our current educational establishments are producing engineers who can design using building blocks but cannot design the blocks used.

This is surely equivalent to an architect who can only draw street plans or a master builder who can only build prefabs!

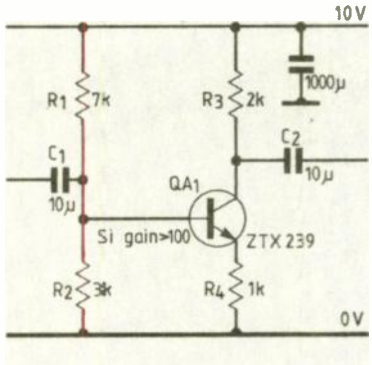


Fig. 1. Simple amplifier circuit presented to interviewees

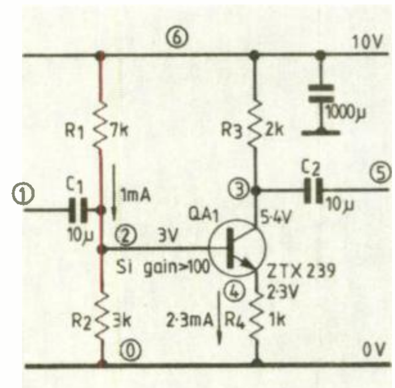


Fig. 2. Circuit of Fig. 1 with DC conditions

The reason behind this is almost certainly that the syllabus setters or heads of department in our colleges and universities believe that it is easier to teach digital and microprocessor design and programming languages and that the nitty gritty of analogue circuit design using discrete components is unimportant in the modern world.

This could not be further from the truth. The whole purpose of our modern digital systems is to make our world easier to live in and our world is an analogue one. In the majority of cases, where computer systems interface with the real world it is via an analogue interface.

Apparatus to measure temperature, pressure, acceleration, and many other quantities all rely upon analogue interfaces. Radio, television, tape recorders, patient-monitoring systems and the like all have heavy analogue content and many of them rely heavily on discrete components in their manufacture. Surely, it is essential to ensure that our engineers of the future understand the basics of discrete component designs.

It must also be remembered that digital circuits are only analogue circuits that have been over-driven. With a good understanding of discrete analogue circuit design you are well placed to design or analyse individual logic elements and, arguably more important, analogue/digital interface circuits.

The beauty of our simple interview test circuit is that if you understand it then you are in a position to work out for yourself the operation of, and even design, many other analogue circuits and logic elements.

Circuit simulation

Let's take another look at the circuit. In **Fig. 2**, I have added the bias voltages and currents.

The art of good circuit design, both analogue and digital, is made much easier if you remember the words "If you can't work it out, make it negligible". A good circuit will always be designed on this basis, so that changes in performance of the circuit due to normal spreads in component parameters such as gain and F_t in bipolar transistors will have minimal effect on final circuit performance. This will also be the case for the DC conditions or bias point. The approach taken to analyse this circuit could be as follows.

We know that the maximum possible collector current (if the transistor were a short circuit from emitter to collector) would be 10V/(2k + 1k) ~ 3.3mA. As the gain of the transistor used is quoted as 100 minimum, we know that if the transistor were not saturated, the highest the base current could be is 3.3mA/100 ~ 33µA. This can be regarded as negligible compared to the 1mA flowing down the base bias chain and we can therefore also assume that the base voltage is about 3V. With this knowledge, we know that, as it is a silicon transistor, the emitter voltage is approximately 0.7V below the base, giving us an emitter voltage of around 2.3V. We therefore have an emitter current of 2.3mA (2.3V/1kΩ). The majority of this comes directly from the collector of the transistor if the base current is as low as we have assumed and therefore the collector current is also approximately 2.3 mA. The voltage across the collector load resistor is therefore 4.6V (2.3mA × 2kΩ) and the voltage across the transistor (collector/emitter) is 3.1V. The transistor gain figure tells us that the base current is only a maximum of 23µA and therefore our original assumptions were correct. (Had our calculations shown that the transistor had been saturated, V_{ce} ~ 0.2V or less, than the assumptions would not have been correct and we would have to re-analyse the circuit.

Building the circuit and carrying out a few tests with a voltmeter would quickly confirm the DC conditions. Note that, on high-impedance circuits, care should be taken to minimise the loading effect of the test instrument.

Let's now get down to the interesting bits of the circuit – what it was designed for – the AC parameters, i.e. gain, input impedance and output impedance.

In this circuit we can say very simply that if the capacitors can be regarded as AC short circuits, and ignoring second-order effects, then the gain will be approximately R_I/R_E or $2k\Omega/1\Omega = 2$ (strictly -2, as the stage is an inverter). This becomes obvious, as we have already established that the emitter voltage follows the base voltage and that the collector current is virtually the same as the emitter current. It follows then that the gain is approximately the ratio of these two resistors.

Analysis of the circuit for gain using a circuit simulator confirms this. To produce the results shown in **Fig. 3** on an IBM PC or clone takes less than a couple of minutes, including entering the circuit – far quicker than building up the circuit, connecting the necessary test equipment and then carrying out the measurements.

To be able to carry out this analysis, the circuit must first be entered into the simulator in the form of what is called a "nodal connectivity list" or "netlist". The netlist for this circuit is shown in **Fig. 4**.

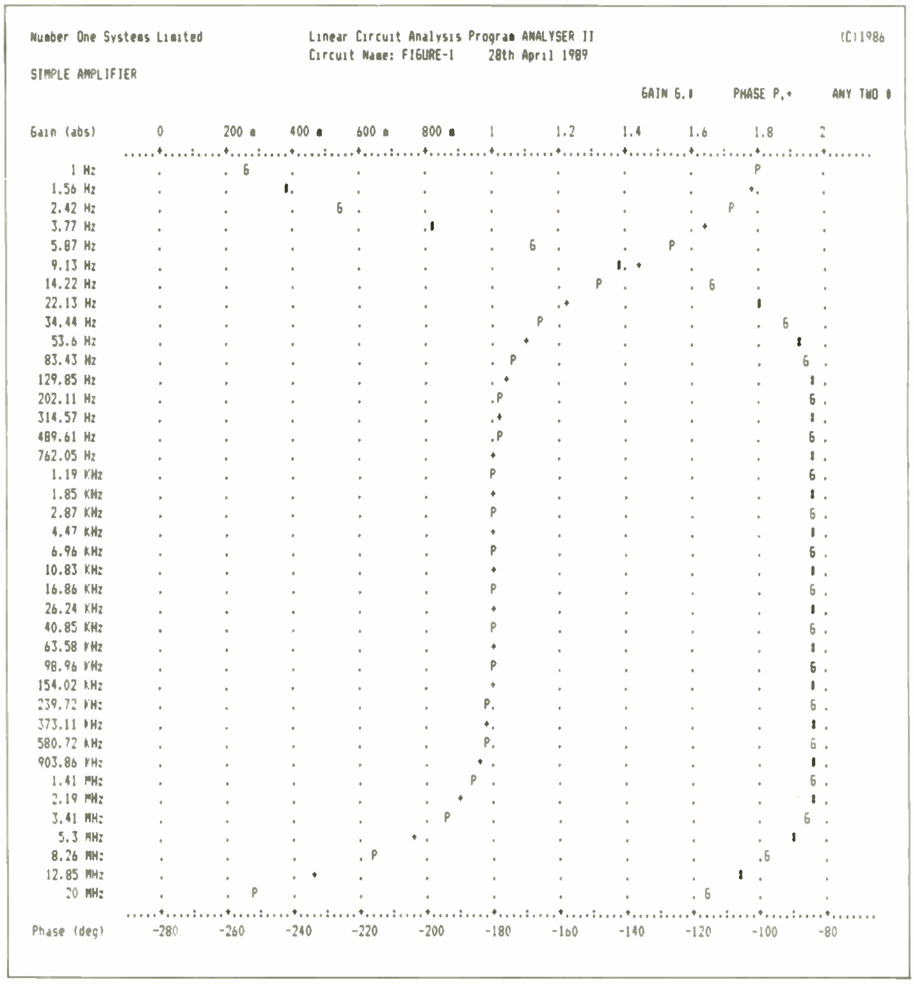


Fig. 3. Result of analysing Fig. 1 circuit for gain and phase

Only two applicants that we have ever interviewed were capable of estimating the gain from a circuit where the emitter of the transistor is completely de-coupled to ground, as shown in **Fig. 5**. In this case, the voltage gain is still given by the collector resistance divided by the emitter resistance, but the effect of the internal emitter resistance r_e now takes over, since our original gain equation (R_I/R_E) should really have been $(R_I/R_E) + r_e$); r_e is obviously no longer insignificant compared with the external emitter resistance as in Fig. 1, because the external emitter resistance has effectively been short circuited by C_4. The internal emitter resistance r_e is dependent upon the emitter current of the transistor and (unknown to most applicants) is predictable and is approximately equal to $25/I_e$ ohms (I_e expressed in mA). If the transistor is running at 1 mA, then the internal emitter resistance will be approximately 25 ohms. In our case, the emitter current is reduced to approximately 0.5mA and therefore r_e is about 50 ohms and, with a collector load of 500 ohms, we get a ratio of R_I/r_e and therefore voltage gain of 10. It should be noted that, at high currents, the internal bulk resistance of the emitter region of the transistor can start to become significant and that accuracy in voltage-gain predictions using this technique will decrease. The same circuit analysed using Analyser II gives the results predicted.

Input impedance

It should be noted when designing circuits of this form that, if very high voltage gains are aimed for, second-order effects will decrease accuracy and the overall gain attainable. For instance, one important pitfall to watch out for is the dramatic decrease in input impedance of an amplifier stage if the emitter of the transistor is de-coupled. This can be checked very quickly using a simulator. Analyser's results for the above circuit show that the input impedance drops to 1.149kΩ, compared wth 2.06kΩ for the circuit of Fig. 1. This would have been even lower if the circuit had been run at the original current of 2.3mA.

Fortunately, the input impedance of such a stage is also calculable. In the circuit shown, at low frequencies, the input in parallel with the combined resistance of the base-bias chain. In the circuit of Fig. 5, with r_e at approximately 50Ω and a transistor gain of around 100, the input impedance of the transistor can be predicted as approximately 5kΩ.

The 5kΩ in parallel with 7kΩ and 3kΩ gives a combined input resistance of 1.47kΩ, which agrees quite closely with the value 1.49kΩ predicted using Analyser II. However, it is worth mentioning that very few development laboratories have the facilities to measure accurately the impedances presented by active device networks and it is obviously much quicker, and normally cheaper, to use a simulator to predict these impedances before bread-boarding such circuits.

The input impedance also greatly reduces at high frequencies due to the effect of the emitter/base capacitance, and also due to the collector/base capacitance of the transistor – especially if the voltage gain of the stage is high (Miller effect). The output impedance of the circuit at low and medium frequencies is almost completely due to the collector load resistor, as the output impedance of the transistor is normally very high.

The reality that output impedance is

often much higher than expected and that input impedance is often much lower than expected is the downfall of many analogue designs. The use of a simulator can give almost instantaneous predictions of the input and output impedances, greatly easing the checking and fine tuning of designs for multi-stage and complex systems well before getting the soldering iron and test equipment out. In the classroom, the use of a circuit simulator will enable the students to experiment with circuit parameters and observe the results far more quickly than hardware experiments can be carried out.

The diagram in **Fig. 6** shows a TV IF amplifier, before the days of acoustic wave filters, and its resultant analysis, which took only 30 seconds on an IBM PC/AT clone running at 12 MHz.

There is a large selection of circuit simulators available running on a wide variety of computing equipment – from the Sinclair Spectrum through PCs and clones right up to main-frames. Prices start from as low as £20 and go up into the tens of thousands of pounds. They cover an enormous range of simulation applications from DC through to microwaves and may include analysis of noise performance, thermal effects, distortion, transient response and other parameters.

Complex logic simulators exist which are capable of predicting the shortest of glitches caused by race conditions in the most complex of circuits. The majority of large-scale integrated circuits are checked completely using circuit simulators and their test programs automatically created, well before masks are made or diffusion processes started.

C_1	capacitor	1	2	10u
C_2	capacitor	3	5	10u
R_1	resistor	6	2	7k
R_2	resistor	2	0	3k
R_3	resistor	3	6	2k
R_4	resistor	4	0	1k
QA_1	ZTX239	2	3	4
C_3	capacitor	6	0	1m
P	ports	1	5	0

Fig. 4. Netlist of simple amplifier.

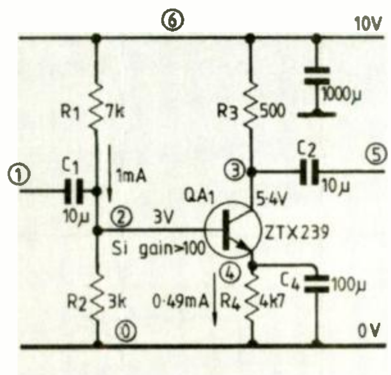


Fig. 5. Modified simple amplifier with decoupled emitter.

Some simulators work directly from the cad circuit diagram or schematic – especially useful for very large simulations. Others use a netlist editor similar to a basic word processor and require the netlist and processing instructions to be saved as a file for batch processing. This is ideal for processing large simulations overnight but not if you wish to check out a simple circuit quickly. Others, like Analyser II, provide a menu-driven environment, allowing you to create and modify netlists, library components and frequency sweep instructions interactively.

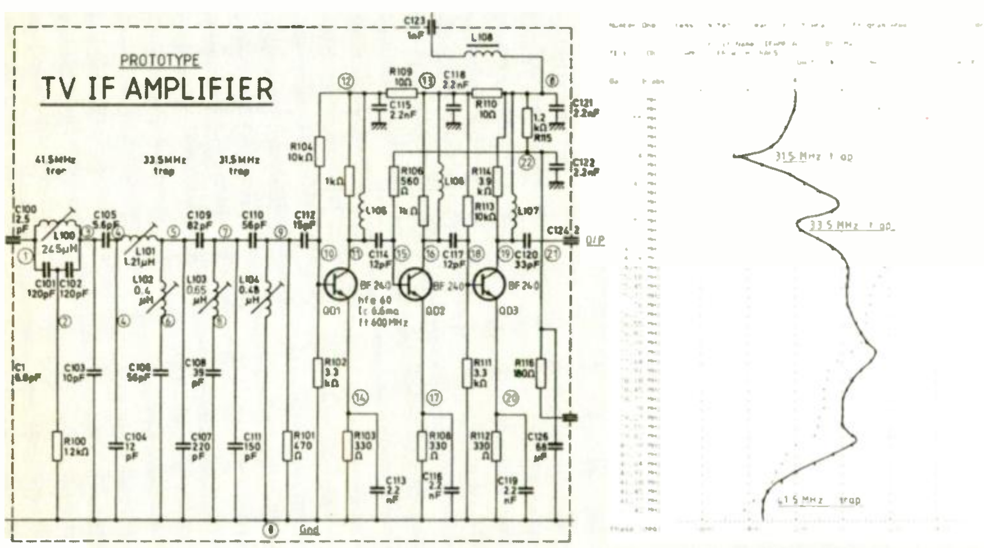
As with so many things, you get what you pay for. It is very easy to pay for more facilities than you need. The range of components covered and the simulation facilities offered by one program may only be a small fraction of those covered by another. The component library facilities, if any, may be too limited for your requirements, or may not be easily extendable to include the devices which you wish to use. The user interface may be ideal for some applications but not for yours. The support and help given by the supplier is also very important: some suppliers charge up to 20% of the purchase price of a piece of software per annum for telephone support and updates, while others will give you support at no charge for years, especially if they are hoping that you will buy other products from their range!

College cad

The use of analogue circuit simulators is now becoming common in industry but is, as yet, less common in training courses for our future engineers. There are colleges which have spent small fortunes on cad which would make engineers in many small firms green with envy, but the software bought can be so complex that it has no place in the classroom, where students have perhaps only an hour or two a week to become familiar with it.

The use of circuit simulation can greatly ease and speed up the design process and the education process. It allows simple and complex ideas to be evaluated with the minimum of fuss and expense, often in much greater detail than can be achieved using breadboards and test equipment. Any company which could use it and ignores it is risking losing out to its competitors. Any electronics college which ignores it is only doing half a job. Any electronics college that does not give an understanding of circuit design down to component level is producing master chefs who can only re-heat TV dinners. ■

Fig. 6. TV amplifier and results obtained by Analyser II.

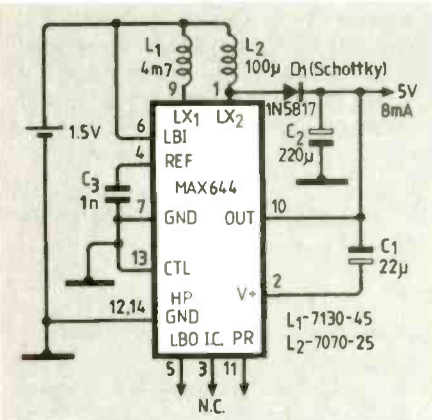


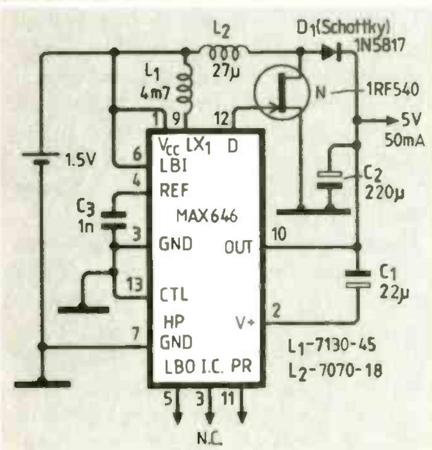
Analyser II
Number One Systems Ltd
Harding Way
Somersham Road
St Ives, Huntingdon
Cambridgeshire PE17 4WR
0480 61778

Inductor induction

Accompanying data on new low-input-voltage DC-to-DC converters from Maxim is a note for UK designers on availability of inductors specified in the data sheet.

By its existence, the note hints that designers working from Maxim data sheets have had problems when using inductors other than those specified. The note reports that common problems with using incorrect coils are excessive resistance and inadequate pre-saturation current handling.





Inductors specified in the data sheet for the MAX644 series DC-to-DC converters (and no doubt many specified in earlier data sheets) are made by Caddell-Burns and cannot be obtained in the UK; suitable equivalents from Dale ACI in Berkhamstead and Bonex in Slough, however, can.

Also in the note is a brief discussion on efficiency loss through poor Schottky diode choice. In the data sheet, there are no applications circuits other than the two shown here, but there are sufficient design equations. The 644 series will start up from a 1.15V supply and will operate from an even lower voltage.

Maxim, 21C Horseshoe Park, Pangbourne, Reading, Berkshire RG8 7JW. Tel. 07357 3863.

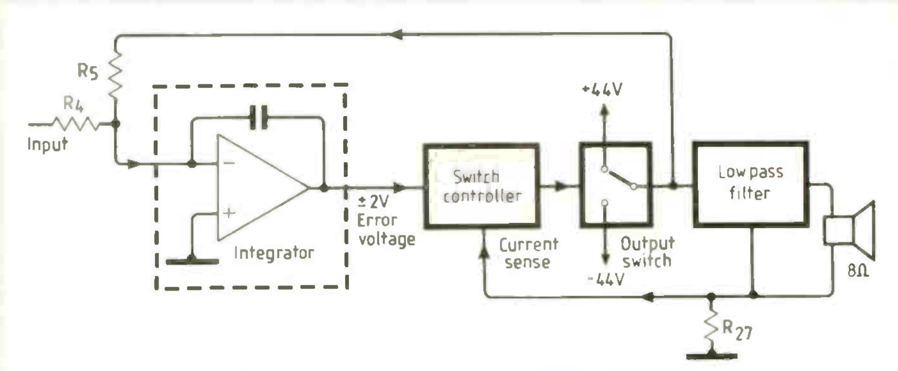
Switching audio power amplifier with low distortion

For a class-D power amplifier, this one from Motorola's AN1042 application note has quite low distortion, ranging from 0.08% at 10Hz to 0.31% at 10kHz with a ±30V output into 8Ω. Although low, these distortion figures are still higher than the better analogue counterparts; in terms of efficiency though, this switching design is significantly better, as you would expect, with a figure of 92% at 72W.

Detailed design information is given in the note, including a potted history of class D audio amplification. There is also a discussion of supply-bus runaway on the drive-circuit lines, and a novel solution for it (the right-hand drive circuit on the diagram).

Other relevant specifications are 0.24% intermodulation, 100dB signal-to-noise ratio, 0 to 20kHz power bandwidth and a damping factor of 80.

Motorola, Macro Marketing, Burnham Lane, Slough SL1 6LN. Tel. 0628 604422.



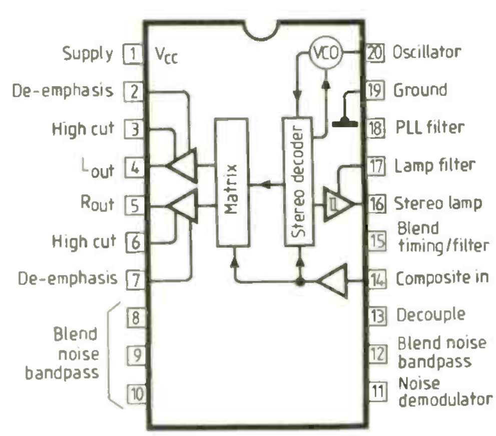
Improved FM stereo under adverse conditions

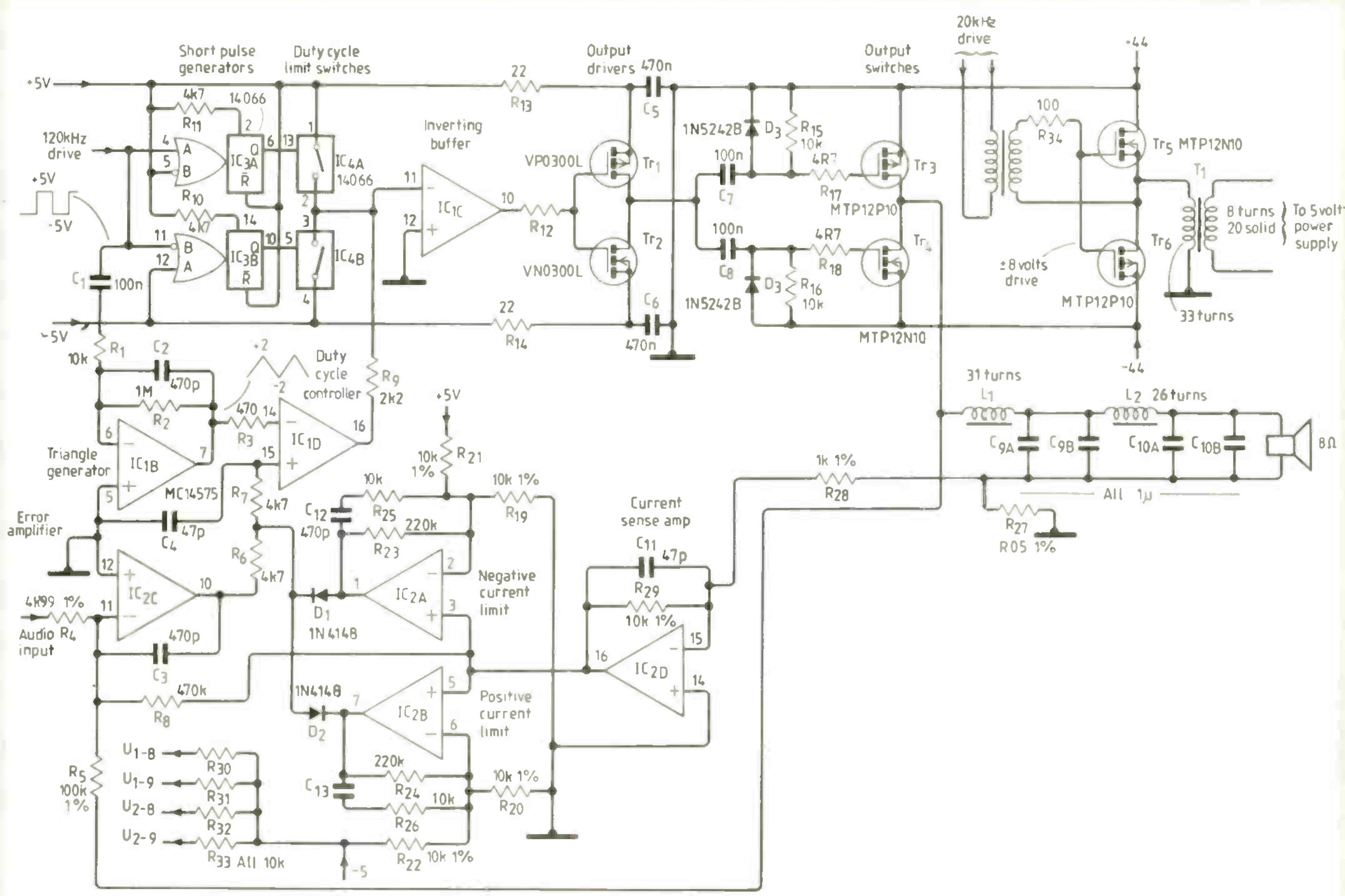
Data on two new stereo decoders giving better reception under adverse reception conditions has arrived from Sprague. One of these decoders, the ULN3800A, handles FMX transmissions for 'almost noise-free' stereo reception in weak signal areas. But for UK readers, this device is only of technical interest since as yet there are no fast plans to introduce FMX transmissions for VHF broadcasts in the UK.

Of more immediate commercial interest in the UK is the second device, the ULN3827, which is designed to improve weak-signal reception on normal stereo transmissions. It is a blending stereo decoder IC that varies the stereo/mono mixture depending on signal strength, in order to reduce noise at the expense of image width.

Most benefit from a blending stereo decoder will be obtained in automotive receivers since signal-strength and multi-path effects vary continuously.

Two main improvements of the 3827 are a dual-bandwidth PLL and a Walsh-function carrier regenerator. Under noisy conditions, the dual-bandwidth PLL switches to a very narrow bandwidth to ensure optimal phase stability. Noise-actuated blending adjusts stereo separation as a function of signal-to-noise ratio to reduce background noise at low signal levels and eliminate prob-

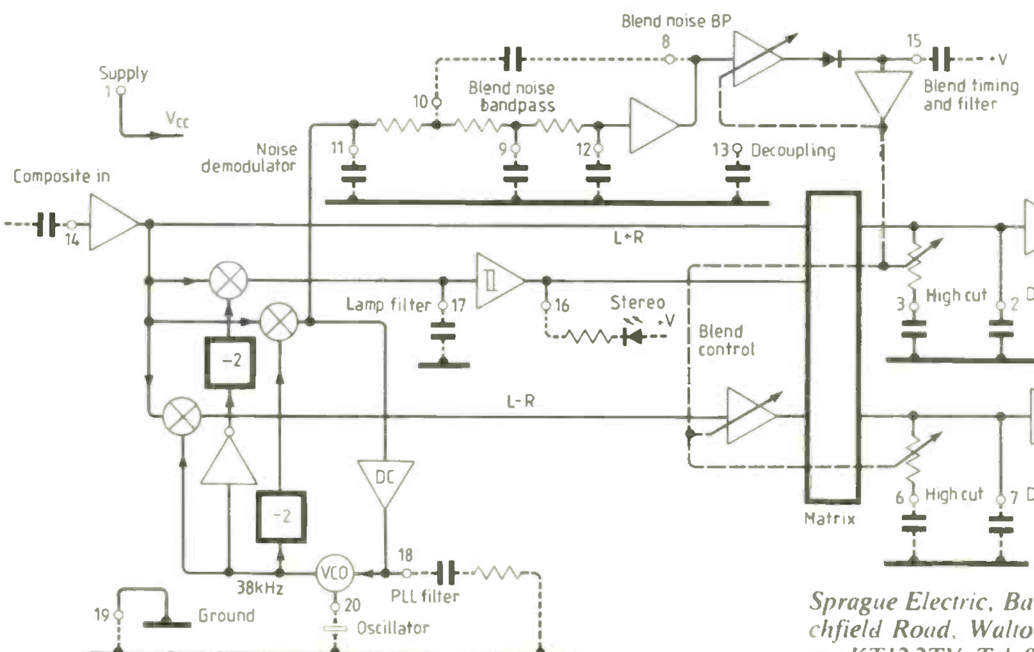




lems associated with stereo/mono switching.

Both the 19kHz reference and the 38kHz carrier are free from third and fifth harmonics, which improves adjacent-channel rejection and Radio Data System rejection as well as signal-to-noise ratio. Third-harmonic distortion of the 3827 is 0.1%.

Full details on the 3827 decoder, the FMX decoder and FMX encoding are included in various application notes and data sheets from Sprague. An overview of these devices – a new double-balanced mixer, a multi-voltage regulator, a dual-conversion radio i.c. and the FM noise blanker mentioned in RF Connections on page 918 – is given in Ed Baker's Technical Newsletter, 23 June 1989.

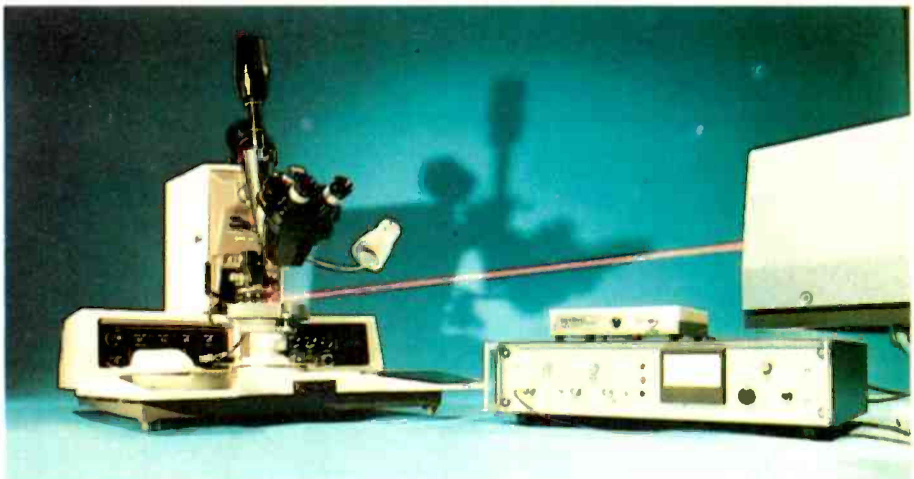


Sprague Electric, Balfour House, Churchfield Road, Walton-on-Thames, Surrey KT12 2TY. Tel. 0932 253355.

Research profile – the Welding Institute

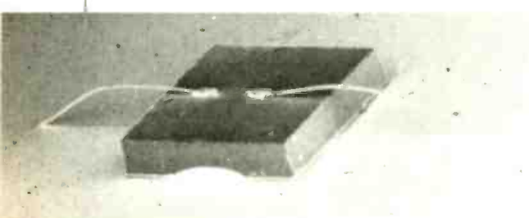
Welding might seem an unlikely subject for an electronics magazine. In general it is, but the Welding Institute's Microjoining Division is an exception.

Microjoining at the Welding Institute in Cambridge includes methods used in the fabrication and assembly of microelectronic circuits, and extends to cover the joining of sheet and wire components up to 1mm thick. Materials involved are often exotic, and range beyond metals to ceramics, glasses and plastics. Among the diverse processes available are laser and arc welding, diffusion and electrostatic bonding, resistance, friction and ultrasonic welding, brazing and soldering.



Quality control for wire bonding

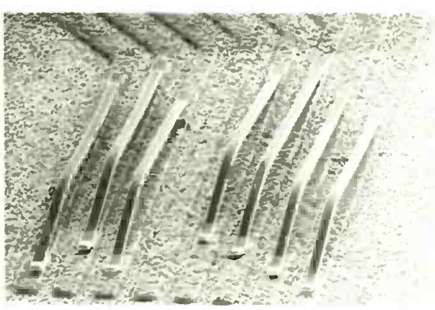
All wire bonds have to meet stringent quality requirements, and the small size of components and the increased speed of automated equipment place increasing demands on quality control systems. In-process monitoring of wire bonding parameters is being pursued using a high-speed transient recorder, laser interferometer (shown), and other transducers and analysis software. These measure vibration amplitude, load, wire deformation, driving current and voltage to monitor ball and wedge bonding operations. The object of this work is the development of an in-process multiparameter monitoring system for use with production equipment.



Connections to small bond pads

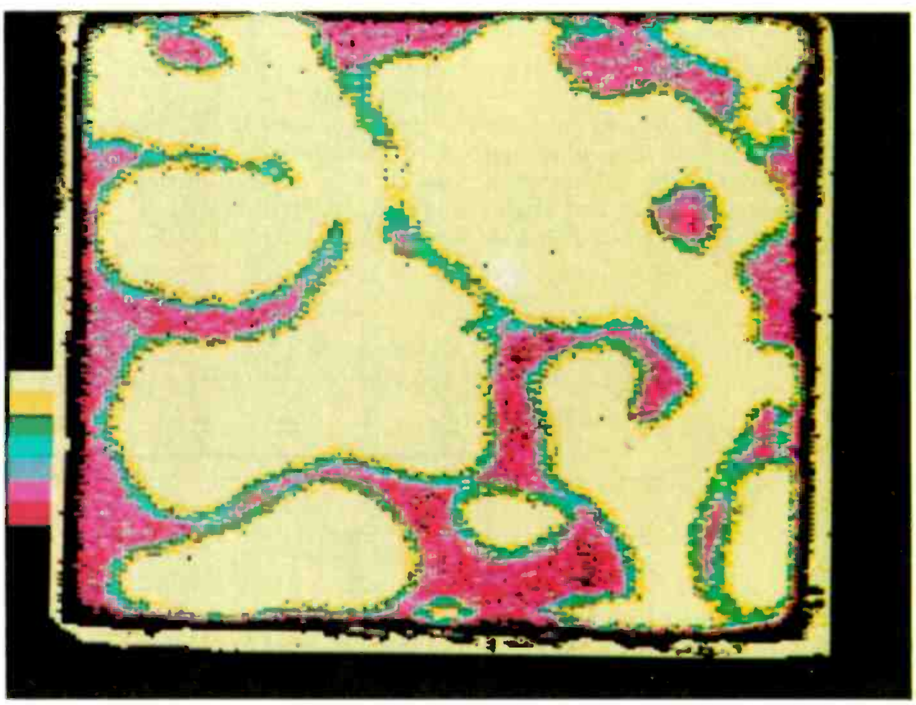
Continuing integrated circuit development, and the introduction of high-frequency microwave devices (>10GHz) have led to demands for connections to closely spaced bond pads as small as 12.5μm diameter.

Work is underway to develop ultrasonic, thermosonic, thermocompression wedge/wedge bonding techniques to enable them to be used on pads of this size. The existing lower limit on wire diameter for this programme is 7μm, with gold and aluminium wires being studied. Shown here is a 7μm diameter gold wire thermocompression wedge bond.



Al 1% Si ribbon

Ribbon bonding is a technique which has potential for interconnection of high lead count, small pad size (<50μm) devices, especially for small batch production. Shown here are 30×12μm ribbon bonds to aluminium (with 1% silicon) copper tracks on PCB. The technique can combine the flexibility of wire bonding with the electrical characteristics and fine feature sizes of lead frames. There are potential benefits for the interconnection of high lead count, small feature size VLSI devices and for the intra- and inter-connection of high-speed, high-frequency microwave type devices.



Large area die bonding

Several methods of attaching large area (10×10mm) circuit dice to a range of substrates are under investigation, including adhesive and thermoplastic bonding, AuSi eutectic bonding, soft soldering and glass bonding (silver glass). Joint quality is being assessed using microfocus X-ray, infrared thermography and high-frequency ultrasonics, and performance tests including thermal shock, thermal cycling and mechanical testing are scheduled. This photograph shows a high frequency ultrasonic image of an epoxy die-attach joint, illustrating a large number of voids.

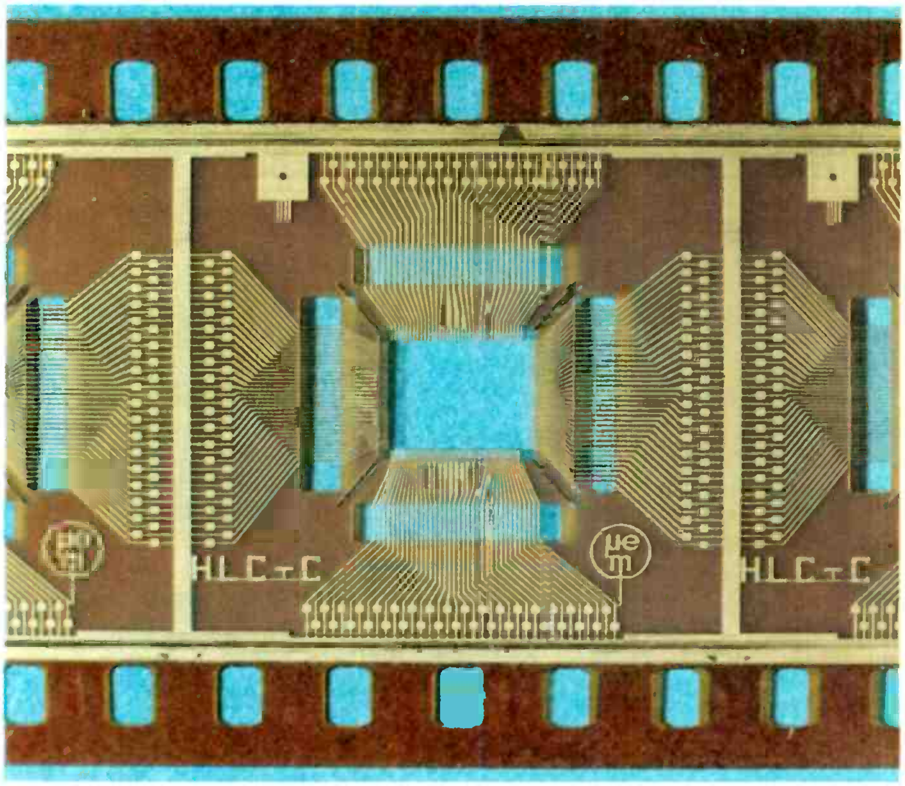
Tape-automated bonding

For the interconnection of high-performance, high-pin-count packages, tape-automated bonding, TAB, offers a higher density of interconnect with improved performance characteristics over wire-bonding techniques.

Interconnection techniques chosen for inner and outer lead bonding depend on a number of factors such as speed and reliability of production, reworkability etc. For inner-lead bonding, the available techniques include solder reflow thermocompression, ultrasonic and thermosonic bonding (for solid-phase bonds).

For outer lead bonding, where the predominant method of forming a joint is through reflow of solder, the other techniques available include vapour phase, infra-red, hot bar, thermocompression, laser, resistance and ultrasonic bonding.

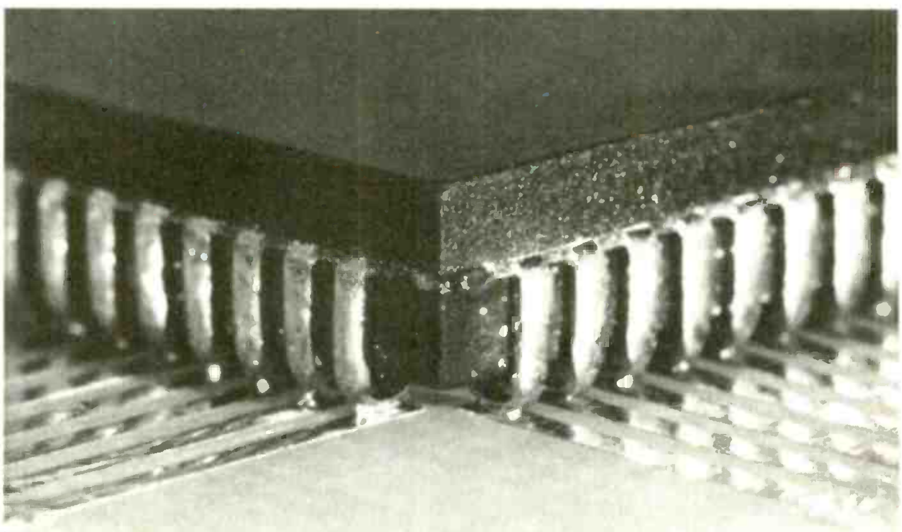
All these techniques are currently under study at the Institute. Shown here is a high lead count TAB leadframe which is being used for the outer lead bonding trials.



Laser reflow soldering

Laser melting of pre-placed soldering pastes or pads is an alternative to the 'whole-board' soldering methods in common production use. Laser soldering may be advantageous where circuits are complex, sensitive to the thermal cycles of the wave and vapour phase process, or where dismounting and re-attachment of circuits is required.

A range of equipment is being used for this project, including a silk-screen printer for depositing solder paste and pulsed and continuous wave Nd-YAG and CO_2 lasers, work manipulation tables and a four-way beam sputter and optical fibre delivery system for multitrack Nd-YAG operations. Both plastic and ceramic substrates and a wide range of solder pastes and preforms are being studied.

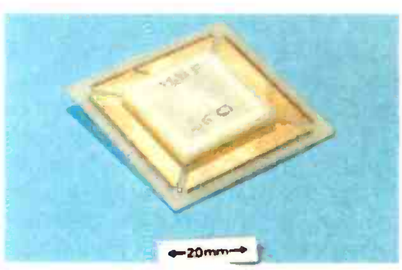


Plastics packaging

Continuing increase in silicon chip size and reduction in package thicknesses have caused problems with transfer injection moulding and liquid encapsulation due to stresses being imposed on the device and interconnection system by contact with the organic encapsulants.

The development of thermoplastic lidded enclosures where there is no contact with the chip or interconnect system could result in an improvement in device reliability and the cost-effectiveness of the packaging system especially for asic type devices.

Shown here is a thermoplastic lid which has been joined onto a fine-line glass-epoxy PCB.



And more...

In addition to the research topics mentioned here, the microjoining section carries out large numbers of confidential projects for industrial sponsors or groups of sponsors. These projects cover an even wider range of topics than the basic research programme, making use of the extensive range of microjoining equipment available in the section and the facilities in other areas of the Institute.

AM synchronous demodulator

Used with an existing short-wave AM receiver, this demodulator by Trevor Brook of Surrey Electronics provides SSB, ISB, envelope, DSB and quadrature detection to reduce the effects of poor S:N ratios

Synchronous detection of AM signals has long been known to provide several benefits but, although the technique has been applied to the demodulation of vestigial sideband television for many years, practical systems for radio reception have often proved disappointing. Several of the problems for synchronous radio reception, particularly in the case of short wave, arise from the need to cater for very poor signal-to-noise or interference ratios.

Requirements for regenerated carrier

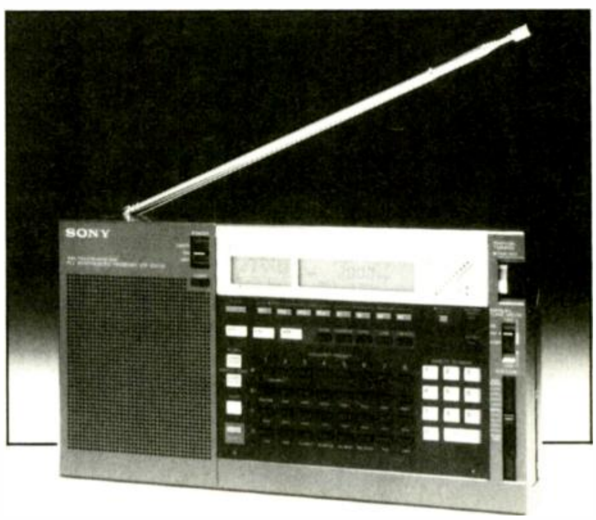
To avoid the generation of objectionable heterodynes, the phase-lock loop used to produce the synchronous carrier for demodulation must maintain lock down to negative signal-to-noise ratios and not suffer phase modulation in the presence of the following:

- reduced carrier operation, as proposed for future HF broadcasting;
- fading of signal and sidebands;
- selective fading of carrier and sidebands;
- reception of transmissions using either type of dynamic carrier control – increasing or decreasing with audio level;

and

- interfering signals of any description and any strength more than about 30Hz from the wanted carrier.

Conversely, the loop may need to follow phase modulation accurately on the received signal in the presence of various phase-modulated radio data systems on LF and MF broadcasts; spurious hum, synthesizer noise or poor frequency stability on transmissions; and spurious phase modulation by the wanted audio.



Synchronous demodulators are beginning to be included in a number of commercial receiver designs. An example is this general-coverage AM/FM model by Sony (type ICF2001D): its synchronous demodulator can be switched in to give reduced distortion and fading on AM transmissions, and to enable the user to listen to whichever sideband is less subject to whistles and interference. Another broadcast receiver fitted with a synchronous demodulator (though a much more elaborate one) is the Liniplex monitoring receiver made by the British company Phase Track (tel. 0734 752666).

These latter characteristics are technically equivalent to unfiltered, exalted-carrier, or 'synchrodyne' reception, where the received signal is limited to provide a carrier which is itself used directly for synchronous demodulation. Finally, if the transmission ceases, the loop should remain very close to its last frequency for an indefinite period and milli-seconds of the signal reappearing.

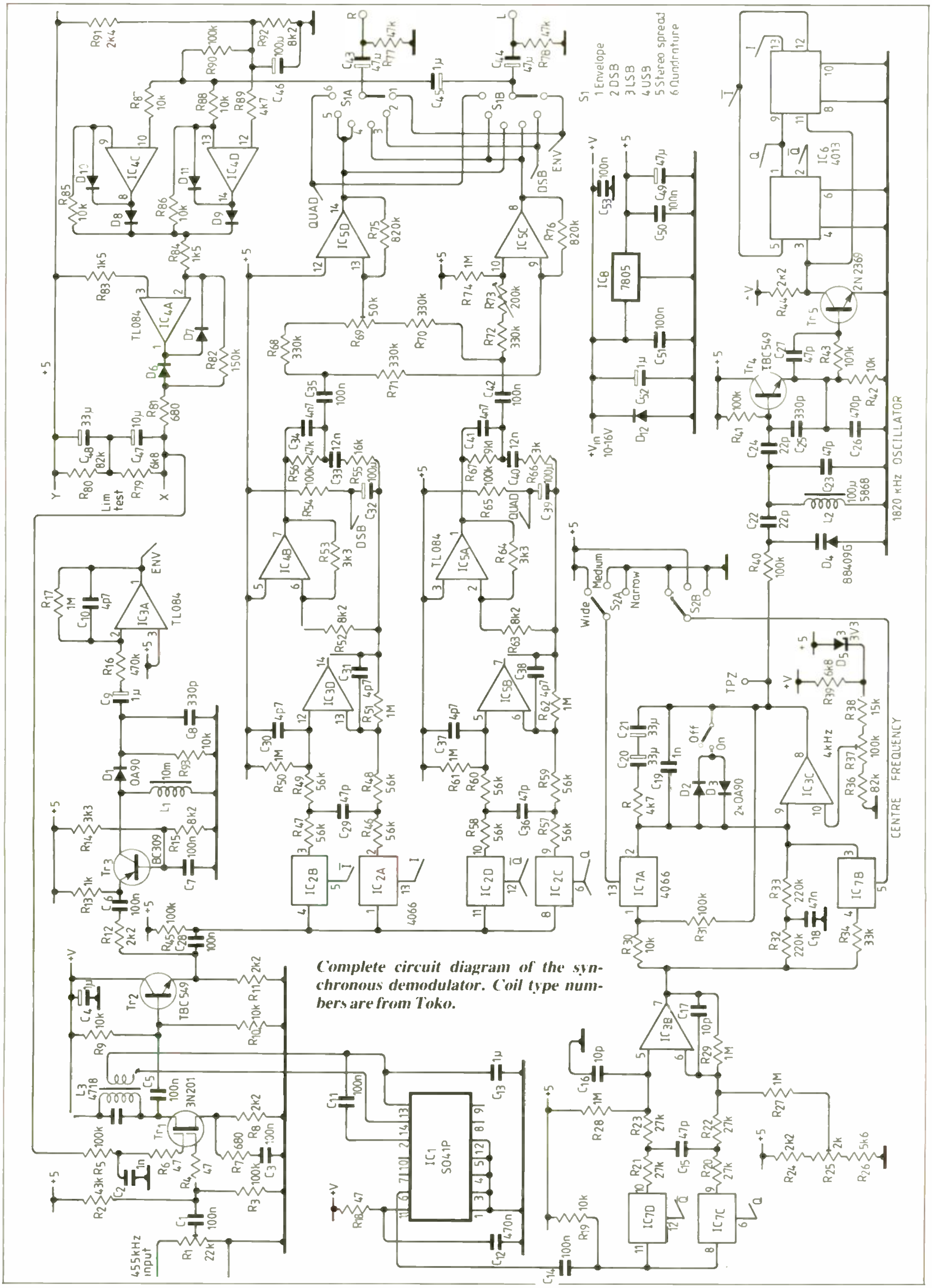
Where there is selective fading, or where single sideband reception is selected, the need for the demodulating carrier to be accurately in phase with the received carrier can be abandoned, since wanted sideband energy exists both in phase and in quadrature with any demodulating carrier. It would be undesirable to attempt to follow the rapid polarity inversion of a carrier which has experienced a selective fade, so the flywheeling action of frequency lock only is required.

Subjective audio level

Apart from the gross distortion which arises in an envelope detector during a selective fade of the carrier, which is overcome by synchronous detection, there is also an objectionable surging in audio level caused by the receiver automatic gain control system unnecessarily increasing the gain. This effect can be ameliorated by an audio gain-control system which senses the peak level of the selected audio output and reduces the gain appropriately.

Circuit and operation

Intermediate frequency of 455kHz enters via the input control, R_1, which allows the gain to be set to suit the level coming from the receiver so that a 100% modulated signal with full carrier does not quite activate the audio limiter. Transistor Tr_1 provides buffering and amplification, an output tuned circuit rejecting harmonics of 455kHz. The SO41P high-performance limiter possesses low AM-to-PM conversion and good limiting action down to very low input levels, its squared output feeding the balanced modulator formed by



Complete circuit diagram of the synchronous demodulator. Coil type numbers are from Toko.

$IC_{7C,D}$ and IC_{3B}. A preset, R_{25}, allows offsets to be cancelled so that the regenerated carrier is accurately in phase.

The op-amp IC_{3C}, with IC_{7A} and IC_{7B}, forms the main loop filter which can be switched between three different bandwidth characteristics. "Wide" allows the loop to lock quickly over a range of ±6kHz and can be used for general tuning around. "Medium" restricts the rapid locking range to ±1kHz, which is about as narrow as one can go when receiving PM data systems carried on certain broadcast stations: France 162kHz, East Germany 177kHz, UK 198kHz, West Germany 1017kHz. Whatever kind of demodulator is used, the presence of such phase modulation on an AM signal does unavoidably lead to some further degradation of reception in the presence of selective fading or co-channel interference. "Narrow" brings the bandwidth down to ±30Hz, which is low enough to avoid disruption by audio components and still allow some margin for drift and microphony of the receiver local oscillator. This position gives a flywheeling effect, so that the regenerated carrier will not attempt to follow the rapid phase changes and polarity inversions of a signal suffering selective fading or cancellation fading, where two stations are nearly on the same frequency.

The "Window" selector switch restricts the voltage swing fed to the varicap, D_4, and thus prevents the loop being captured by signals away from the desired frequency set by the centre frequency control. This facility means that the receiver IF filters can be exploited to the maximum advantage, in addition to the sideband selection on the unit. For instance, the receiver IF filter could be positioned entirely over one sideband of an AM signal, the appropriate sideband selected on the unit and centre frequency offset to where the carrier now lies. The window facility allows the loop to hold lock tenaciously even when the wanted carrier is down the slope of the IF filter or buried beneath noise and interference. In the absence of any steady carrier within 30Hz, the loop will generate a carrier stable enough to permit reception of CW, FSK or suppressed-carrier SSB signals.

The output from the loop amplifier is fed to the varicap, D_4, which controls the frequency of the Colpitts oscillator formed by Tr_4 at 1820kHz. Transistor Tr_5 is a high slew-rate amplifier feeding the divide-by-four circuit, IC_6, which produces in-phase and quadrature feeds of both polarities at 455kHz to drive the balanced modulator and demodulators.

From Tr_1, the 455kHz IF passes through an emitter-follower buffer, Tr_2, and then to the in-phase demodulator, $IC_{2A,B}$ and IC_{3D}, the quadrature demodulator, $IC_{2C,D}$ and IC_{5B} and the low-distortion envelope detector, Tr_3 driving D_1 with constant current. Op-amp IC_{3A} amplifies the output from the envelope detector, while IC_{4B} and IC_{5A} respectively invert and reduce the amplitude of the in-phase and quadrature demodulator outputs and provide drive for the broadband audio phase-shift networks. The outputs from these networks are summed by IC_{5D} for USB and differenced by IC_{5C} for LSB.

Switch S_1 selects the outputs desired. Op-amps $IC_{4C,D}$ form a full-wave peak rectifier which senses the peak audio output level beyond a threshold of +0.5dBμ, giving a small guard band beyond the 0dBμ output for a full-carrier, 100% modulated signal. The output is amplified by IC_{4A}, which drives the storage capacitors through R_{81}, chosen to give an attack time of a few milliseconds. The double time-constant arrangement allows a short burst of audio beyond the threshold to reduce the gain for only a short time, while longer-lasting high levels will cause a slower release time. These characteristics avoid impulsive interference or programme material causing unpleasant pumping effects. The DC output from the time constants is fed to Tr_1, where it controls the 455kHz input-amplifier gain.

The unit requires a positive supply between 10V and 16V at 50mA and IC_8 generates an internal 5V regulated line; a suitable supply can often be obtained from the associated receiver. Audio outputs may be fed into any stereo system, or just the left output used with a mono amplifier or fed back into the receiver's own amplifier and loudspeaker.

Audio outputs

"Envelope" can be convenient for general tuning, to exploit the receiver filters fully when a signal is suffering interference, before going into a synchronous mode. "DSB" gives reduced distortion on heavily modulated and on over-modulated signals arising from selective fading of the carrier. Next come "LSB" and "USB", which provides good results where one sideband of the signal is suffering interference and for the proposed future broadcasts at HF using single-sideband with reduced carrier. "ISB/Stereo spread" gives LSB on the left and USB on the right, which gives interesting effects on fading signals and when the two sidebands are suffering different interference. An unexpected observation has been that propagation effects cause distant lightning static at LF and MF to sound quite different in the two sidebands. Finally, "Quadrature" gives a null on the audio from the strongest station on the channel, thus improving the audibility of any background station. This position can also be used to receive narrow-band frequency modulation, or any other phase modulation.

Lower noise levels occur in the DSB synchronous mode, since noise in quadrature is rejected, while the noise spectrum extends up to half the IF bandwidth. With an envelope detector, noise at one edge of the IF passband demodulates against noise at the other edge, thus producing audio noise extending up to the full IF bandwidth and no rejection of noise in quadrature occurs. The envelope detector and synchronous modes all yield total harmonic distortion below –44dB (0.6%) at 100% modulation at any frequency and the response is 20Hz – 7kHz ±0.5dB. ■

References

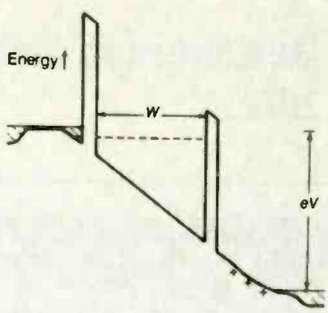
1. Wright, D.T., 'L.F. Radio-data: Specification of BBC phase-modulated transmissions on long wave', BBC Research Department, RD1984/19, December 1984.
2. Macario, R.C.V., Craine, J.F. and Walters, D.S., 'A practical receiver design for SSB, ISB and AM medium-frequency broadcasts', *EBU Technical Review*, 145, pp101-108, June 1974.
3. Eckersley, P.P., 'Asymmetric-sideband broadcasting', *Proc. Inst. Radio Engineers*, 1938, 26, p1041.
4. Tucker, D.G., 'The history of the homodyne and synchrodyne', *J. Brit. Inst. Radio Engineers*, 1954, 14, p143.
5. Macario, R.C.V., Heng, Y-C, Dargahi, A., 'Implications of the proposal to employ SSB with partially suppressed carrier for HF sound broadcast transmissions', IEE Conference Publication, 'HF Communication Systems and Techniques', London 1982.
6. CCIR doc. no. 10/106 to 10/155, 'Decisions of the Interim Meeting of CCIR Study Group 10 on subjects related to HF planning', EBU doc. GT/R1 164, 30 October 1980.
7. Thiessen, P., 'Assessment of the deterioration in quality of single-sideband transmissions caused by frequency error and harmonic distortion', *EBU Technical Review*, 140, August 1973, p3.
8. Langecker, K., and Tropper, H., 'A design for a receiver for amplitude-modulated, single and double sideband broadcasting', *EBU Review*, No. 139, June 1973, pp116-123.

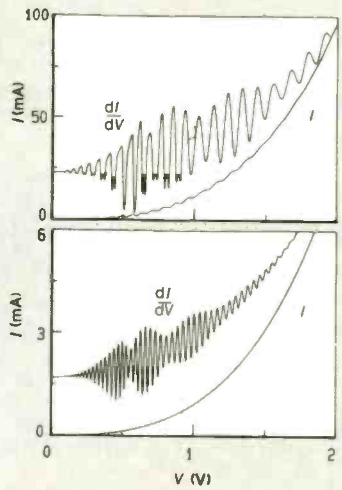
Electron tennis and semiconductors

When a voltage is applied across a double-barrier semiconductor device, the resulting current is not ohmic and exhibits some remarkable effects.

M. Henini *et al.*, in an article in *J. Phys: Condens. Matter* vol. 1, 3025-3030; 1989, reported in *Nature* vol. 339, 581; 1989, describe their work in which a gallium arsenide device is provided with two narrow aluminium gallium arsenide barriers, through which electrons tunnel under the influence of an applied voltage.

In the current/voltage plots for two different barrier spacings of 60nm and 120nm, the current increases in steps, those at low voltage being negative-going. The differential conductance, dI/dV, therefore exhibits spectacular oscillations.





What seems to be happening is that the electrons, wearing their "wave" hats and not behaving like billiard balls at all, find that they can tunnel through the 6nm barriers. The gallium arsenide is in an extremely pure state, having been prepared by the molecular-beam epitaxy technique, the high degree of purity being necessary to ensure that the electrons do not bounce off the usual imperfections found in semiconductors and cross the barriers with their phase coherence intact.

Variation of dI/dV is explained by considering the wave-like properties of electrons. An electron having negotiated the first barrier on the left of the diagram may not be energetic enough to get through the right-hand one first time round. It will bounce backwards and forwards between the barriers like a tennis ball but, if its backward-going wave interferes constructively with itself, it stands a better chance of making it the second time, transmission thereby increasing.

Since it will only interfere with itself constructively if its phase changes by a multiple of 2π radians during the round trip, and since its wavelength and therefore phase depend on, among other parameters, its energy derived from the applied voltage, as the applied voltage varies so does the transmission.

But that is not all. The dI/dV plots show that the rapid variations are amplitude-modulated by slower changes. These are the result of electrons with a voltage of more than about 0.5V possessing more energy than the right-hand barrier height. Although, as a particle, the electron would promptly fly straight over it and away, as a wave it sets up another set of resonances within the barrier. Since the barrier width is a great deal less than that of the well in which the first interaction took place, and since the voltage spacing of the peaks in dI/dV is inversely proportional to the width, the resulting oscillations are more widely spaced.

As regards application of the effect, the negative differential resistance and resonant tunnelling effects of the type shown in the graphs lend themselves to such devices as microwave oscillators and rapid switches. There is also talk of a three-terminal device to act as an And gate, with the voltage of the three areas being varied to enhance or destroy the current-carrying properties of the device. One such device would replace several other components.

DBS for Poles?

Political changes in the communist world are occurring at a rate that would scarcely have seemed possible a year ago; and one of the latest lies behind a request by Poland to join the Eutelsat organization. As with most of the rest of eastern Europe, Poland's telecommunications and broadcasting policies have until now been guided more by Soviet influence.

Eutelsat, a body representing 26 European member states, operates four Eutelsat 1 satellites for communications within Europe, including telephony, television, radio and business services. Next year it will introduce a second series of satellites which, among other possibilities, will offer multi-channel DBS TV reception on small dishes.

Views wanted

More complex methods of managing and allocating the radio spectrum must soon be introduced, or the UK could run out of space by the turn of the century.

According to a report published by the DTI, civil spectrum in the range 470-3400MHz is already fully allocated and is virtually all used – mostly in a satisfactory way. But because of international commitments and the large assignment to television broadcasting, the scope for making major alterations is limited. So finding space for new services such as advanced personal communicators, public telephones on airliners and digital sound broadcasting from satellites will mean moving many existing fixed link services to higher frequencies or to alternative means of communication.

The DTI's Radiocommunications Division could also play a part, says the report, by tightening up its administrative procedure, improving the accuracy of its records and pressing for higher efficiency in the use of the spectrum.

A feature of the report is a set of annexes which set out in tables and charts, and some detail, the present UK civil frequency allocations, together with a good deal of supplementary information on topics such as the industrial applications of RF equipment,

NICAM stereo from Thames

Independent Television's first test of true stereo programme sound took place on July 10, with a recorded opera relay from the Royal Opera House, Covent Garden, one of a number of special programmes to mark Thames Television's 21st birthday (see also NICAM digital stereo, page 920).

Sound from the production, the first two acts of *The Marriage of Figaro*, was balanced by Ron Ferris, Thames's head of sound. It was replayed from an analogue Dolby A recording on a C-format VTR and fed by wires run along a corridor to the sound-in-syncs equipment which feeds the transmission network. "It took a lot of hard work by a lot of people", said Ferris.

Stereo sound was heard only by NICAM-equipped viewers in the London area; although Yorkshire Television's transmitters are also radiating NICAM tests, the necessary programme links were not in place. Other ITV viewers heard a mono reduction of the sound.

A few spits and crackles marred the transmission, which was made using Thames's Mark I sound-in-sync equipment. Because of the complex four-level digital coding needed to cram the digital signal into its narrow time-window in the vision waveform, the equipment sometimes randomly changed the flags which denote stereo or dual-language mode, causing a momentary loss of signal at the receiver. This could happen in response to a minor sync disturbance. According to Ron Ferris, some manufacturers' TV sets respond to this condition more gracefully than others.

However, by July 11, when Thames transmitted the concluding acts of the work, Mark II SIS equipment had been installed and the problem seemed to have been largely solved.

Thames hopes eventually to achieve an all-digital audio chain. Its present Panasonic MII cartridge video machines will be returned to Japan to be replaced by models with digital audio. This will enable broadcasters to keep their sound in the digital domain all the way from the studio or outside-broadcast site to the viewer's home.

Olympus TV/ comms satellite on its way

Ariane 3 lifted off successfully with the Olympus 1 communications satellite on July 11.

One of Olympus's functions will be a direct satellite TV service by the BBC for northern Europe and by RAI for the Italian audience. During off-peak hours, the northern beam service will be carrying out distance learning experiments.

Olympus will also be used for business applications involving small Earth stations.

on UK civil spectrum review

Findings of the civil spectrum review will be the basis of Britain's preparations for the next ITU allocation conference, possibly in 1992. A further spectrum review would then be needed in the mid-1990s (ITU picture).

and an extensive list of possible future demands on the part of the spectrum under review. There is also a useful glossary and a list of abbreviations – some of them otherwise obscure.

Among the principal findings of the review are the following –

- Frequency planning should maintain a long-term perspective. Civil and military apportionments should be aligned where possible.
- In accommodating new services, priority should be given to applications such as mobile radio which cannot reasonably use higher frequencies.
- A review of the needs of the emergency services is required. This should take into account the harmonization of their requirements with commercial standards and specifications; greater sharing of resources between police, fire and ambulance services and with other users, on a pre-emptive basis; better co-operation between the Home Office and the DTI in matters of planning, monitoring and sharing.
- The requirements of broadcasting ancillary services (such as outside broadcast links) should be re-examined to take account of the needs of new broadcasters; demand for spectrum will be especially high in the London area. Sharing with Defence users might be possible. Fixed broadcast links in the 1500MHz band should be moved to above 3400MHz, releasing space for transportable links.
- Technical evaluations should be conducted of the possibilities of increased sharing between different services, both between civil users and between civil and defence users. Sharing could be on a geographical, time or common-carrier basis.

Copies of the 105-page document, "Report of the Civil Spectrum Review Committee, Stage 1: 470-3400MHz", are obtainable from the DTI (24-hour ordering service on 01-215 2072) and comments on it should be submitted by the end of August.

Cellular for the 1990s

Three further cellular radiotelephone networks could be operating in Britain by 1992-1993, if the industry responds to a call from Lord Young, the Secretary of State for Trade and Industry.

Frequencies for the systems will be in the 1.7-2.3GHz region, much higher than the 900MHz channels used by the existing cellular networks.

One operator, said Lord Young, will be Mercury or its parent Cable and Wireless. Although Mercury operates a fixed telecommunications service, it has been excluded from the existing highly lucrative cellular market. Other prospective operators of the new network(s) will be identified by the end of this year.

The new systems, described as personal communications networks (PCNs), will allow users to make two-way telephone calls using a large number of small radio cells. These will be based on one of two technologies already under development – either the pan-European digital cellular system (GSM) or the digital European cordless telephone (DECT). Applicants for the licences, who must lodge their submissions with the DTI by September 14, can base their proposals on either or both systems.

One company which has already announced plans for PCNs is Racal – which, though ineligible to operate a 1.7-2.3GHz network, could run one on 900MHz in tandem with its 900MHz GSM system now being planned. Racal intends to integrate its PCN with GSM by basing the PCN on a simplified version of its GSM handset.

With the lightweight handset, costing £150-200, users could receive or make local calls (costing 8p-12.5p per minute, with a monthly charge of £12.50); or they could slot the handset into a car adapter which would provide the additional power output and signal processing necessary for access to GSM. The handset would provide a talk-time of 90 minutes on a single battery charge and would allow hand-off between microcells. Conversely, GSM users could take advantage of the PCN microcells to make cheap local calls.

One of the main omissions from the handset is the digital equalizer, which must – among other duties – cope with the worst-case Doppler shift when a 400km/h high-speed train roars past a cell-site. PCN users would be restricted to a maximum speed of 40km/h.

Racal's plans include a large number of microcells, some 7000 of them each 2km across, covering all centres of population from modest-sized towns upward. Racal envisages reassigning the existing TACS channels to PCNs while maintaining its present analogue cellular service in the ETACS channels during its declining years.

Racal believes it could have a PCN in operation quickly because it already has distribution networks in place.

Racal's Orbitel GSM demonstrator.

A case of sour Apples!

That well-known creature from another planet, Apple Computer, has realised that there is a world out there, and that it won't go away. So it is opening diplomatic relations with the natives.

Apple has always been isolationist by nature, which is sad. The Mac is arguably a much better computer than some I could mention, but it has always been out there on the periphery of every-day life.

Now, however, the company has opted for a closer relationship with everyone else and produced a range of communications products that help users link the Mac to PCs. In particular, the idea seems to be to provide ways of linking the Mac into PC network systems.

This is because Apple has at last recognized that the big personal computer market, and the largest quantities of brass margarets, are to be had in the corporate business – and that means accepting the reality of IBM.

It also means the appearance of more 'corporate-oriented' applications software for the Mac. Symantec, for example, has produced More II, an outliner package similar to one it already produces for the PC (called Grandview). More II, however, makes use of the Mac's capabilities by adding presentation graphics as a feature – arguably one of the world's less useful applications.

Talking of graphics, here's a word for the future. Uncle Sir Clive Sinclair is about to do it again, so they say. The 'it' in question is come out with a mind-bending new product, in this case a 250 MIPS (Millions of Instructions Per Second) graphics computer than emulates an IBM PC/AT and costs around £2000. Don't hold your breath – it won't be available for a year. The industry cynics have already dubbed the project "PC5".

Fax cards are apparently becoming something of a flavour of the month. Companies such as Philips, Computafax and comms specialist, Hayes, are all in on the act now and it is a growing market. A proper fax machine I can understand, but for the life of me I can't see a point to Fax cards in PCs, especially when compared to 'proper' comms systems such as Telecom Gold.

Lastly, it will be a rare month when there is nothing to report on dear old IBM, and this isn't it. Anyone wanting to be first on the block with the latest gizmo now has the chance, for Big Blue has come out with an upgrade board for the Model 70 PS/2 machine that uses the latest Intel 486 processor.

This was announced last month, but (naturally) won't be available for a while yet – after all, Intel won't have it in volume production until the end of the year. The add-in should make the Model 70 go quite fast, however.

And by that time there might be a reasonable number of OS/2 applications which make proper use of Presentation Manager. That will make the new machine look pretty, but won't actually improve it a great deal.

The reason, of course, is that the OS/2 operating system will still strap the 486 processor down as a pretend 286. The real advantage won't appear until the 386-version of the operating system appears in 19XX (fill in your guess for the great sweepstake).

– Martin Banks

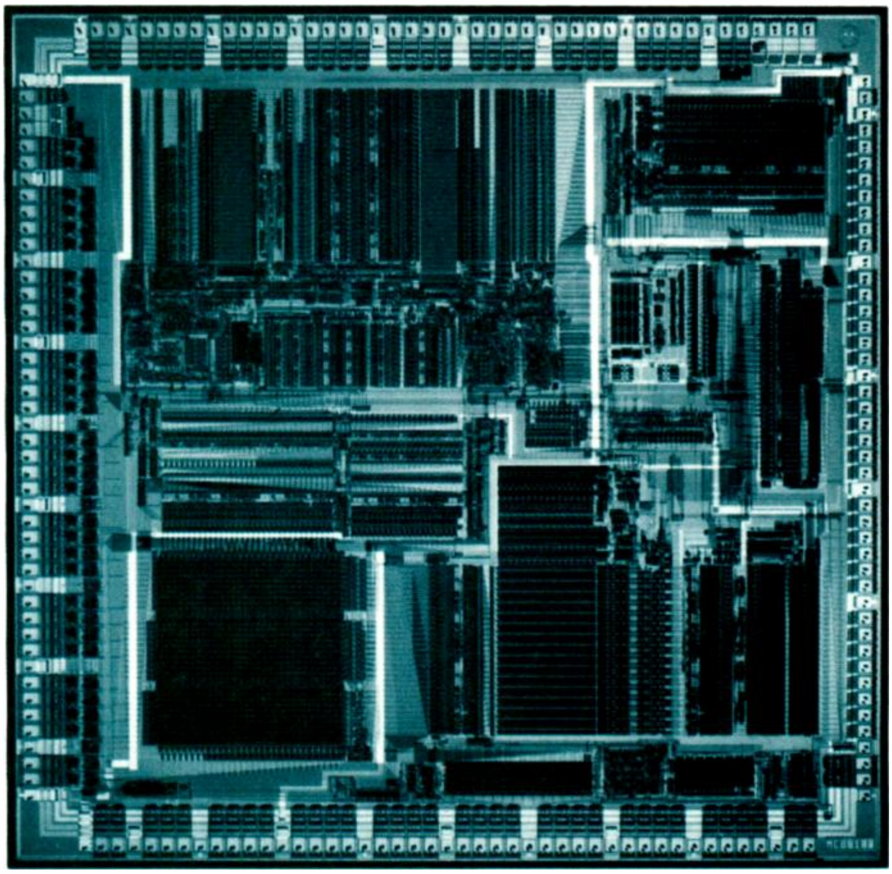
THE RISC BUSINESS

Risc microprocessors, built for speed rather than complexity, are not just a passing fad. Rupert Baines shows how they achieve their astonishing performance.

I think it was Mae West who said that the simplest things in life were the best. Admittedly she was talking about *really* simple things, like men and diamonds, but it's a belief that suddenly seems very relevant to computing. I'm talking about high-tech high-fashion: reduced instruction set computers, or risc devices as they're known. Risc is arousing interest because the resulting chips are very, very fast indeed.

Conventional processors such as the 68000 or the 80386 are complex instruction set computers (cisc devices). They gain their power from a rich architecture with a large number of addressing modes and plenty of versatile instructions (perhaps as many as 20 distinct modes and 300 different op-codes). These allow a programmer working directly in machine code a lot of flexibility in choosing precisely the neatest instruction (though unfortunately compilers are rarely as clever, tending to use standard codes throughout).

Cisc processors have a microcoded instruction set. A machine code instruction is not directly executed, but is decoded and used as an entry into a subroutine stored in the processor's internal rom. This sub-program is written in microcode, a very low level language hidden away privately inside the chip, which reduces the machine code instructions down to the fine level of detail needed by the internal hardware of the CPU (enabling registers, switching signals, controlling gates etc.). The more involved an instruction becomes, the more decoding, processing and analysis are required, and the longer it will take to execute. This is the major problem with cisc devices. Their vast instruction set doesn't come for free: every additional op-code needs to be checked for, each new instruction needs a little bit more logic, and it all slows things down. Even the simplest instructions suffer, because the decoding process still has the complex task of deciding that they *are* simple instructions.



Motorola's MC88100 risc microprocessor: running at 20MHz, it can execute 17 million instructions per second.

The whole point of risc is that this process is unnecessary. The essence of the idea is this: very few of the available instructions are actually used. If the processor were designed to run *only* these instructions we would lose virtually nothing in terms of power or efficiency. However, because we now have fewer instructions we can design our processor to suit them, making decoding very simple and very fast. In fact, the op-codes are hard-wired to control the risc processor's innards directly, which gets rid of an entire layer of logic (the microcode and its control circuitry) and all its associated delays.

Stripping out seven-eighths of the instruction set is one part of the design process. The flexibility of the remaining instructions is pared down too, for the same reasons: complex options are not needed or used but their existence ruins the performance of the options that are.

Addressing modes are reduced in number too. Most conventional processors allow instructions to have different lengths, depending upon the number and type of operands. This imposes a significant overhead in decoding

("Should I fetch the next op-code?", "Is this a short or a long jump?", etc). Because every byte needs to be fully deciphered before chip knows what to do with its successor, this slows everything down. One way to avoid making these decisions is to give all instructions a fixed length and a fixed structure.

For example, every op-code could be 32 bits long, with a one-byte instruction field, a one-byte target register and a 16-bit data field (having a large word length helps!). Some operations (e.g. Complement Registers) would not need to use the data field at all, while others might have fetch it in two gulps (e.g. Long Jump). Since all instructions have the same format they can be treated identically, so the fetch cycle can be simplified and a whole section of control logic eliminated – taking with it another set of delays. This system is used in all risc devices, in one form or another. There is a further bonus: everything will always be neatly aligned on 32-bit boundaries, which makes pipelining much easier and gives more scope for increasing the chip's performance.

A good analogy of risc in the racing car – strip down to the essentials, pare off every ounce...

Another design idea that all risc chips share is that of a load/store architecture. The only instructions that can access main memory are those that load a register or store a register, which restricts all the arithmetic and logical operations to being register-to-register only. The advantage of this is, as always, speed: the on-chip registers are made out of very fast logic and can be accessed easily, while the system's main memory even with a cache is much slower and access to it is more complex. Consequently only the simplest load and save instructions are needed.

Compiling for speed

A good analogy of risc is the racing car – strip it down to the essentials, pare off every ounce and design everything for raw speed. But a powerful engine requires exceptional fuel (Formula One cars don't run on four-star) – for risc, tightly written code from a powerful optimising compiler.

The importance of the compiler cannot be over-stressed. The two are often developed together, working as a partnership to get the best out of a chip. A compiler will drastically alter how a program is implemented to wring the maximum advantage from the processor's clever hardware: instructions will be rearranged to make optimum use of the pipeline and avoid bubbles or breaks, registers will be reassigned to benefit from the scoreboard and routines will be merged or split to suit the requirements of the cache memory. (Some of these techniques are men-

Table 1: speed ratings of some modern microprocessors, both cisc and risc.

	Clock (MHz)	Dhrystones (integer)	Whetstones (double precision)	VAX Mips
VAX 11/780		1757	0.8	1.00
68020	25	6649	2.6	2.3
80386	25	8775	1.7	3.5
Acorn ARM	10			5
Sparc	14	29 230	3.3	8
AMD 29000	25	32 000		8
88100	25	34 000	3	
MIPS R3000	25	45 000	13	20
i860	33		20	70
IBM 3090/180		110 000	25	

THE RISC SUCCESS STORY

Just three or so years ago, risc was very much a low-key idea. No-one in the mainstream of processor design was selling or designing any devices based on this philosophy. A few academics were discussing the implications and some small companies were quietly developing products, but risc was an idea whose time had not yet come. That has now all changed: processors are coming thick and fast from a variety of manufacturers, small start-ups as well industry giants, with amazing performance claims and tumbling prices.

The whole story started in 1976, with a team of IBM engineers who were developing the 801 minicomputer. Before launching in on the design they did some research on how efficiently existing computers worked; and they came up with some surprising results. Regardless of their instruction set, most computers spent the vast majority of their time executing only small proportion of the available op-codes. In fact more than 80% of the processor's time was spent executing the very simplest instructions – load from memory, copy register, add immediate etc. Even more intriguingly, the team found that same 80:20 ratio in a different context. Three-quarters of the design effort and circuit complexity had gone into implementing just one quarter of the instruction set. Unfortunately that was the quarter embodying the most complex and least used op-codes!

The lessons were obvious, and so the IBM engineers designed their risc processor's instruction set. Apparently the prototype ran at an impressive 10Mips (10 million instructions per second). I have heard that IBM became so frightened at the damage this achievement might do to other sales that it promptly killed the project! Whatever the truth of this story, even without being released the 801 started something big. Ten years later, the design philosophy that it inspired lives on at the heart of all the reduced instruction set computers now being produced.

The next developments in the risc story were at Stanford University in 1980, where a student project developed two new chips. The second of these (imaginatively named Risc 2), with an 8MHz clock, could run integer C programs faster than a 12MHz 68000. It says a lot of about the power of the idea that a student research project could so trounce a state-of-the-art processor. This research was sponsored by Sun Microsystems, and in 1983 development work was started on what became the Sparc microprocessor, the first risc chip to make it to the market-place.

ENHANCING PERFORMANCE

Since risc chip designers do not have to worry about compatibility with earlier products (a major headache for the team working on the 83086) or about providing sophisticated instructions, they can concentrate on optimising the device's performance for those few codes that do exist. With fewer codes, there can be more flexibility in how they are organized to give the best results, there is more silicon area to play with and more design time to implement other performance-enhancing features. None of the manufacturers has missed these opportunities.

The idea of pipelining is that the processor shouldn't have to wait for the next instruction and is kept working as fast as the silicon will allow. It's hard work to implement on a conventional cisc processor because instructions can be of different lengths and it takes complex logic to handle this. Risc processors with their fixed-size instructions make the most of it. The idea is simple: instructions are stacked up inside the processor in a queue. While one is being executed its successor is being decoded; as soon as the ALU is free the next instruction and is ready and waiting.

A difficulty comes with jumps and branches: you cannot decode the instruction because you won't know where it is until the actual jump has been evaluated. This takes some time. It is also wasteful because the instructions in the pipe will need to be thrown out (this is called a "bubble"). There are ways round it though; for example, Acorn's ingenious conditional op-codes.

tioned in the panel "Enhancing performance"). MIPS Ltd estimates that optimisation doubles the speed of execution, turning 10Mips (10 million instructions per second) into 20Mips.

For historical reasons, most of the

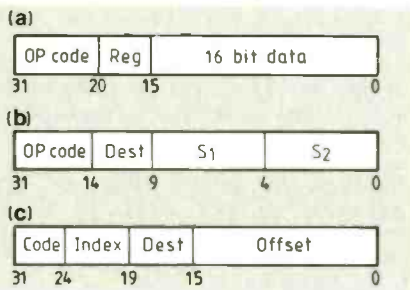


Fig. 1. Some examples of how a hypothetical risc processor's instructions might be arranged. All instructions fit into one word and conform to the same format.
(a) an immediate load – R_n = #data. Usually 16bit data is all that is required. A Load High instruction would allow 32 bits to be loaded in two goes.
(b) this arrangement allows a general register-to-register operation, with one destination and two source registers specified in the instruction.
(c) different addressing modes all fit the same format: this allows register indirect access with an offset word.

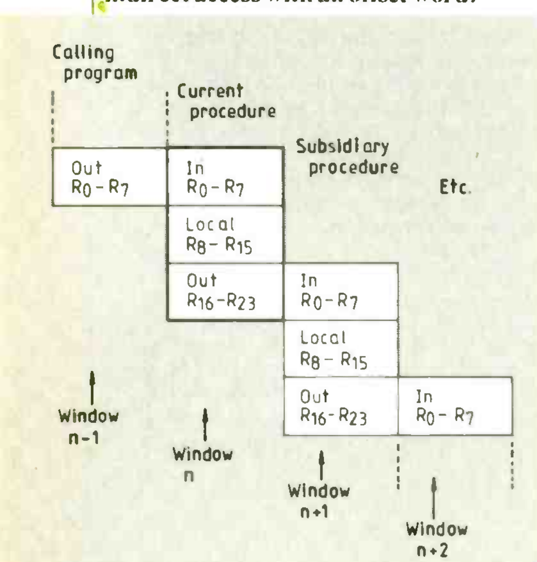


Fig. 2. The Sparc processor has 192 registers, arranged as a succession of partially-overlapping windows. By merely shifting window, a new procedure can be started instantly. It can access the calling parameters (through the out/in shared registers), use local variables (R8-R15) or pass parameters to a subsidiary procedure (out/in registers R16-R23). This fast and elegant method of implementing procedures makes languages like C and Unix very efficient.

experience with optimising compilers is in Fortran, so this is the language that offers the best performance at the moment. However, the popularity of C and Unix has ensured these are well supported too (indeed the Sun Sparc processor has been explicitly designed to run procedural languages like C very efficiently).

Even without the need for optimisation it would be difficult to program a risc chip at the machine code level: the few instructions that exist are not very powerful and so an incredible number of very simple operations is necessary to achieve anything worthwhile. Compilers are there to protect the programme from the harsh reality of an instruction set – it makes no difference to the user what op-codes exist in the CPU, since the high-level language is compiled down regardless. The system program can happily use the simpler risc codes to construct any more complex functions when (if) they're needed. This substitution does mean that there is a slight size/speed trade off, with cisc-coded programs being somewhat shorter than the risc equivalent. With memory capacities on the increase, this is usually less important than the gain in speed. For example, a Pascal program which compiled to 700 lines of 68020 code produced about 1000 lines of instructions for the AMD 29000 – a 40% size penalty. However, since the risc device handles each instruction six times faster than the Motorola part, the eventual speed gain was still an impressive 4:1.

Be warned – the trade-off between code size and speed is different for each chip and each program. Very rarely is it tidy or easy to calculate. This is why raw Mips ratings are such an unsatisfactory way of comparing the performances of different chips.

Lower costs, higher tech

Manufacturers have other reasons for pursuing risc ideas. Processors following this philosophy can be simpler than their cisc competitors, which means that they need less silicon. If a chip doubles in complexity then it takes four times as much design time and effort to develop, and that is very expensive. But with a simple architecture, you can make more chips simply because you can fit them on to the wafer.

Yield (the percentage of working devices) will increase too. Contamination by a single speck of dust is enough to make a chip useless: by having more, smaller chips on the wafer you can significantly increase the chances that some of them will survive to be sold.

REGISTER SCOREBOARDING

Scoreboarding is a technique developed for supercomputers like the Cray but now being applied to the latest risc chips (e.g. the 88100 and the 80860).

If a register is in use it is "tagged" on a scoreboard. The processor then goes on to start the next instruction, while still executing the earlier one. If the new code doesn't involve a tagged register then it can be completed concurrently with all the other operations. This means that several things can be happening simultaneously, stopping only when the result of a calculation is needed (i.e. the new instruction wants to access a register which has been tagged). It's particularly useful when accessing external memory (which is slow); the rest of CPU can still be working away. Otherwise the system would need *very* fast memory if it weren't to suffer crippling delays (who wants to have a fast processor and then run it with wait states?).

Finally, because risc processors are smaller than their cisc cousins, they can take advantage of new process technology sooner.

These very important considerations for the processor manufacturer also benefit the customer: the easier a chip is to make, the lower are the producer's overheads. And that means cheaper chips for us. Already prices are tumbling: MIPS now offers its R3000 at less than $200 – which may sound a lot until you realise that it comes to les than $10 per Mips! (For comparison, the 25MHz 68030 comes in at about $64 per Mips).

Here to stay

Last year people were still debating whether risc was a nine days' wonder or a technology that was here to stay. Others were arguing about the eventual winner of a risc/cisc war and which was the better approach. The arrival of chips like the R3000 and the entry of industry giants such as Intel with its hugely powerful 80860 have silenced all the squabbling.

It is obvious that not only is risc here and here to stay, it is going to become the dominant design philosophy. Manufacturers will still develop cisc chips, to retain the compatibility market (Intel has just released the complex 80486, a triumph of baroque architecture, and is probably now working on an 80586; the release of Motorola's 68040 is imminent) but their heart isn't in it any more. If there ever was a battle of the designs, then risc has very definitely won. The next battle is the bloodthirsty one to decide which of the manufacturers will survive. ■

PCs control instruments for simplicity and reliability

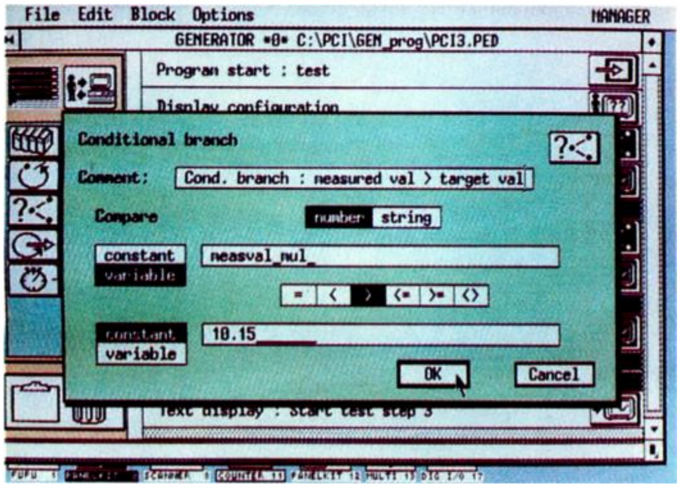
Demands for user-friendliness and increased reliability in measurements have led to the development of PC-based instruments. Klaus Metzger and Johannes P. Schwemmer of Siemens explain the philosophy.

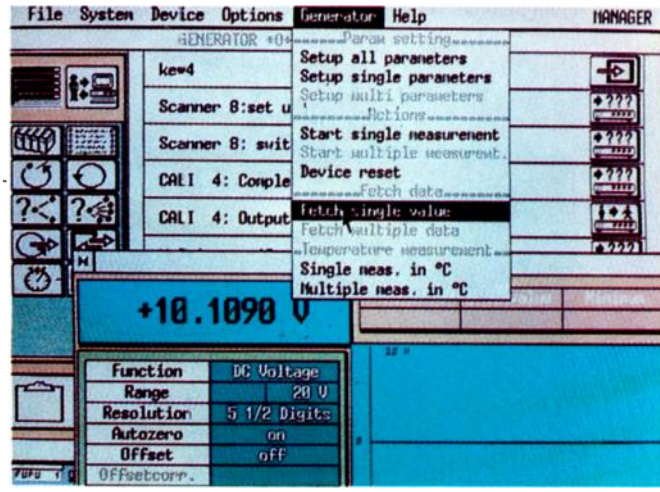
Four generations of devices in the development of electronic instrumentation have existed over the last thirty years. The "classical" form of instrument, with its pointer and rotary knobs, was soon followed by the second generation: instruments with digital displays, albeit still operated by knobs or push-buttons.

The third generation – fully digital devices, whose functions were controlled by microcomputer – came with the introduction of microprocessors. Users continued to operate these by traditional front-panel controls and were provided with additional information by leds beside the controls; complicated systems would have CRT screens and a large number of control buttons. Furthermore, these devices could usually be assigned parameters from a computer through the IEC bus (IEC 625 or IEEE 488), although possibly not covering all the functions set up on the front panel itself.

Electronic instruments of the fourth generation are represented by computer-dependent test instruments (CDTIs). They no longer have dedicated operator controls, but are controlled, using a screen and keyboard, by a computer via an external or internal bus.

Improved computer control and reduced operator and display requirements make these devices particularly suitable for automated test sequences.





Moreover, they can, by using the appropriate software, provide simpler and more unified interactive control by the operator.

New operator philosophy

Operator input to computer systems has undergone a rapid change in the last few years, from using commands which were difficult to grasp, through plain-English commands, to icon-based systems, which help to confer transparency on the system and allow the user to concentrate on the task in hand.

Measurement technology can profit in two ways from developments in and experience of personal computers. On one hand, the task of measurement is simplified by the user's new ability to operate instruments using PC software based on icons (Apple Macintosh, the Smalltalk language or the GEM graphics system). On the other hand, PC software has a familiar appearance to those who are already acquainted with such systems and helps to overcome any anxiety at working with instruments which do not have physical operator controls.

The concepts of this kind of advanced instrumentation system are similar to those of many Macintosh and GEM programs in that all the important control and display functions are presented simultaneously and alongside each other, providing an overview of the proceedings; less commonly used functions are easily accessible from a menu. Functions are selected directly from icons, using a mouse or graphics tablet. Even complex relationships can clearly be seen; functions not being used are visible, but labelled as disabled. Window techniques allow the user to divide the screen as he likes.

These developments mean that the time is past when it was necessary to have multiple nesting of menu trees, which were so difficult to trace through in the case of complex devices that

Fig.1 (left). All the important control and display functions are presented to the user simultaneously, alongside each other. Along the lower margin, the instruments which are connected are shown as icons and can be selected by mouse.

Fig.2 (above, right). If the range of functions available on an instrument is so large that they cannot all be displayed, a selection box appears showing, for example, the choice of ranges on a multimeter. The box disappears after the mouse has made its choice.

manufacturers provided abbreviated commands for frequently used paths, inevitably making the over-all structure appear even more confusing.

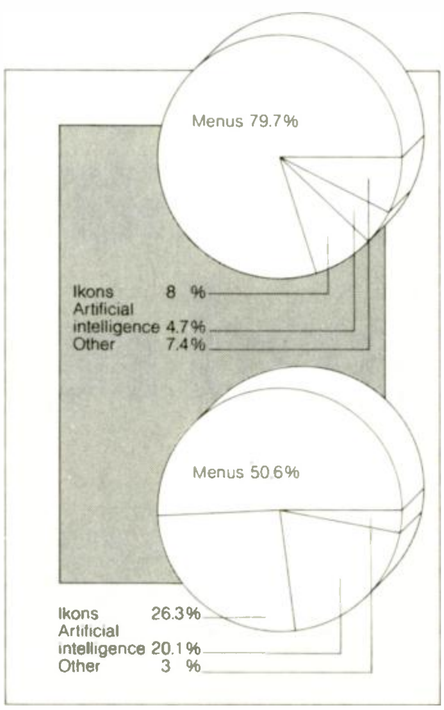


Fig.3. The trend towards icons at the expense of menus is seen in the chart, compiled by Prime Data. The top chart is the current position, while customers' preferences are seen below.

Neither is it necessary to hunt for the constantly changing legend on soft keys that were all too soft. By simple clicking with a mouse against an icon or a box representing a function, action or parameter, the software is asked to think. If the user's intention is unambiguous, the computer will react immediately; otherwise, a small box appears to show the alternatives, whereupon a further click makes a selection (Fig.2).

The keyboard is only needed for typing in exact numeric values or names; for example, of a file in which the measurement parameters are to be stored. Using a mouse also has the advantage that the operator's eyes remain on the screen, since all controls are accessible from it.

Icons on the increase

This approach, using icons, possesses considerable advantages over a menu-based method of working, as users of CDTI in the USA have already recognised.

At present, around 80% of this equipment is still using menus. A survey by Prime Data has shown that CDTI users would like simpler methods of control and the use of artificial intelligence, which is indicated by nearly half the users, shows the direction in which future instrumentation should go. It is possible that those users who intend to continue with menus are not yet familiar with icons; it is necessary to work with icons before it becomes possible to reach a judgement between the two methods of control.

This article is based on "Simpler, more rapid and more reliable measurement using PC-based instruments", published in Energy and Automation, vol.X, April 1988, the journal of the Energy and Automation Group of Siemens AG.

ACTIVE

ASIC

C-mos standard cells. High-performance c-mos standard cell asic devices with on-board analogue functions provide an average cell propagation delay of 1.4 ns/gate. The EBB/AT AV family consists of four types of cells: unit cell, i/o cell, rom/ram/PLA cells, and analogue cells. The analogue function options available with EBB/AT include operational amplifies, comparators, transmission-type analogue switches, amplifiers, comparators, transmission-type analogue switches, fixed on-resistance-type analogue switches, digital-to-analogue converters, and analogue-to-digital converters. Fujitsu Microelectronics, 0628 76100.

A-to-D and D-to-A converters

6-bit analogue-to-digital converters. The AD9006 and the AD9016 6-bit analogue-to-digital converters encode at 500Msample/s. The AD9016 combines the performance and features of the AD9006 with an integral output data multiplexer, to switch the output word to two 6-bit data banks, each of which includes a Data Ready signal and overflow bit. These two new devices also exhibit signal-to-noise ratio of 39dB at 200MHz. Analog Devices, 0932 253320.

Sampling 12-bit ADC. The AD1678 12-bit sampling analogue-to-digital converter uses recursive subranging to deliver a 5μs total conversion time for a 200 kilosamples per second throughput rate. A sample/hold amplifier, ADC, reference, clock and processor interface are combined on the single BiMOS chip. AC specifications include a 72dB minimum signal-to-noise and distortion ration (S/N + D), –80 dB maximum (intermodulation distortion). Analog Devices, 0932 253320.

14 bit converters. The ADC-914 is a high-speed A-to-D converter which accomplishes a 14-bit conversion in 2.4μs, whilst dissipating only 925mW. The conversion process is based on a digitally corrected subranging architecture. The ADS-924 combines a high-speed 14-bit converter and a fast sample-and-hold amplifier. Datel, 0256 469085.

General microprocessors

Single-board microcomputer. The Gespak GESBDS-6 multi-user computer system has nearly 512K of rom-resident software and allows two users to program directly in C or 68000 assembly language under its OS-9 real-time operating system. It is self-contained and needs no additional hardware, such as external disc drives, for its operation. It provides users with an on-board, battery maintained 128K non-volatile c-mos ram disc for storing source and object files and it can be expanded as the user's needs change. Altek Microcomponents, 06285 582637.

Risc processor. The UT1750AR from United Technologies is a monolithic, c-mos 32-bit microprocessor that supports the complete MIL-STD-1750A instruction set architecture (ISA). Underlying the MIL-STD-1750A support is a high-performance reduced instruction set computer (RISC) that provides the MIL-STD-1750A emulation capability. Micrologic, 04862 29551.

Interfaces

Industrial control card. This multi-function industrial control card is said to work in any IBM compatible PC/XT or AT system. The four-layer PCB includes eight opto-isolated outputs with 100mA Darlington drivers, eight opto-isolated inputs, SPST reed relay outputs, TTL i/o lines, 12-bit analogue jinputs and 12-bit analogue output. The opto-isolators provide protection to the PC up to 2500V AC and allow a data throughput of 10kHz. Fairchild, 042121 6527.

Linear integrated circuits

High-speed op-amp. OP-260 is a dual, high-speed operational amplifier that uses current feedback to provide wideband operation regardless of gain. It combines a bandwidth of 40MHz at a voltage gain of 10 with a slew rate of 550V/μs and needs only 4.5mA supply per amplifier. Bourns Electronic, 0276 692392.

Accurate operational amplifier. The AD707 operational amplifier is claimed to feature the lowest ever offset-voltage in a DC precision op-amp, together with the highest open-loop gain and stability over all working temperature ranges. The offset voltage of less than 15μV is the best available in a bipolar op-amp, while the maximum input offset current is 1.0nA. The top-grade 883B version is the first monolithic bipolar device of this type to offer a maximum offset voltage drift of 0.1μV per degree Celsius. Analog Devices, 0932 253320.

Memory chips

Video d-ram. The μPD42274 1Mbit dual-port graphics buffer represents the largest video d-ram to be made by NEC. The device has a ram port for the input or output of a 256K × 4bit memory cell and a serial port which can output a 512 × 4bit data register at a clock rate of 33MHz. 2001 Electronic Components, 0438 742001.

Radiation-hard static rams. Two low-operating power, 16K × 1 static rams feature operating power of 30mW maximum (1MHz) and a worst case access time of 70ns. MA9167 is manufactured on silicon-on sapphire. Current performance figures are: total dose – parametrics guaranteed to 300KRad (Si); transient (upset) – a × 10^{11} errors/bitday (geostationary orbit); and neutrons –> 10^{15} N/cm_2. For systems that require less performance, but the same low operating power, Marconi offers the MA9067. Marconi Electronic Devices, 0522 500500.

128K eprom. The Fujitsu MB71C46 16K × 8bit high-speed Bi-CMOS prom offers three-state outputs, high programmability, single voltage operation and typical access times of 30ns. Maximum access times are quoted at 35 and 45ns for the MB71C46-35 and MB71C46-45, respectively. The memory is fabricated with all logic set to zero. Logic 'ones' can be programmed using the diffused eutectic aluminium process. Pronto Electronic Systems, 01-554 6222.

Oscillators

Crystals. Professional-grade crystals and oscillators from Euroquartz cover frequencies from 40 to 200kHz, 100 to 300kHz, 250 to 800kHz, and 800kHz to 25MHz in fundamental mode. Extended ranges from 25 to 180MHz (seventh overtone) and 180 to 280MHz (ninth overtone) are also available. Crystal cut variations include +5°C X-cut, DT-cut, CT-cut, and AT-cut depending on frequency range. Euroquartz, 0460 76477.

5-50MHz crystal oscillators. Vectron series CO-253 temperature-compensated crystal oscillators are compact units offering a wide variety of temperature range-/frequency stability options from ± 2 × 10^{-7} over 0°C to +50°C, to ±1 × 10^{-5} over 855°C to +125°C. Available at any specified frequency in the 5MHz to 50MHz range, they provide HCMOS/TTL compatible output from supplies of 12-24V and 5V, with a single 5V supply optional, in a 24-pin dual-in-line package. Lyons Instruments, 0992 467161.

Task-oriented processors

Real-time controller. RTC31 uses an 8031 processor and is intended for OEM use. The entire module is 3.5 in × 3.5 in. It has provision for 64Kbyte of memory using ram/eprom, 12 bits of TTL parallel i/o and one serial port, which supports both RS232 and RS485, and the entire board runs from a single power supply. In RS485 mode, this controller can be connected in a network configuration to an IBM PC using Micromint MC-net control networking software. J. B. Designs, 0285 658122.

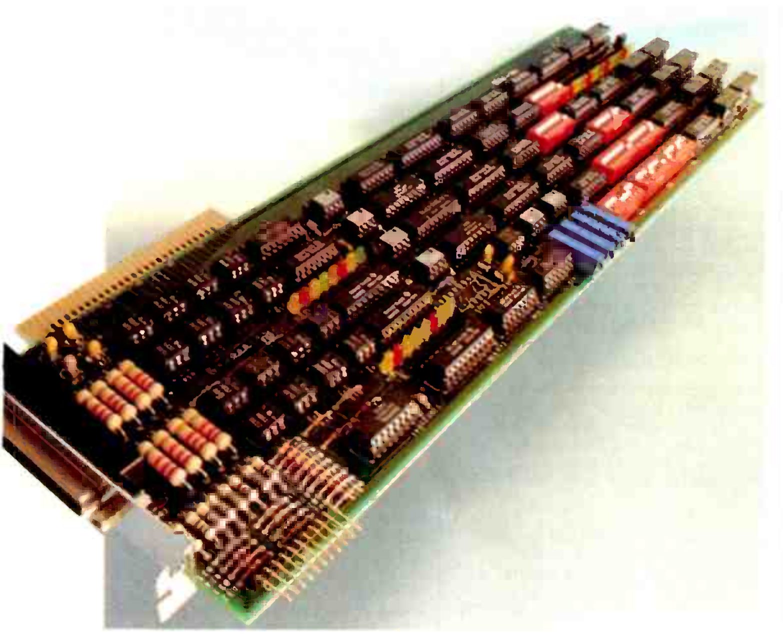
Encryption processor. The DVS 200 is a VLSI chip which implements a time-division-multiplexing (TDM) encryption algorithm and can be used to protect vulnerable speech communications channels. This device features high security by the use of a complex on-chip key generator and an algorithm that checks the "randomness" of the encrypted output. This device can be used to encrypt data streams of up to 4.8kbit-sec. Marconi Electronic Devices, 0522 500500.

VGA-compatible controller. The UM587 is a single-chip, high integration, high-resolution graphics controller for use in IBM PS/2 model 30-compatible systems as well as PC/AT and PC/XT – compatible systems. It provides graphics of 800 × 600 elements with 16 colours and is fully compatible with IBM VGA, EGA, CGA, MDA and Hercules graphics plus IBM BIOS. Manhattan Skyline, 0628 75851.

DC motor controller. The National Semiconductors LM628/9 precision motor controller simplifies the control of DC and brushless motors by performing real-time computational tasks. A closed-loop servo can be built using only a DC motor, an optical Incremental encoder, a D-to-A converter and a power amplifier. Thame Components, 0844 214561.

Television chips

Video dot clock. RF Monolithic's HC1198 video dot clock generator offers less than 50ps jitter over any 15 μs period. Running at 357MHz with a basic tolerance of ±0.025%, it is aimed at manufacturers of high-resolution imaging and graphics equipment such as that used in cad and meteorological applications. This high degree of accuracy derives from the use of saw (surface-acoustic wave) technology. The clock's differential output stage is ECL-compatible, i.e. matched to a 100kΩ load. Quantelec, 0993 776488.



PASSIVE EQUIPMENT

Connectors and cabling

Patch cords. The Pro patch cord range of high-performance patch cords is designed for use in broadcast and professional audio and video applications. The range features corrosion-proof nickel-plated plugs which ensure quiet contact with the jacks and reduce contact resistance. Pro patch cords can be supplied in Longframe (¼in) and Bantam sizes, in both dual and single configurations. ADC Europe, 0734 441955.

Angled display sockets. Vertisockets can be made to bring a display (led, incandescent, etc) to a precise angle and height, so the display can be seen from any window in the system chassis. The angle can be in the vertical or horizontal plane. The 0.025in (0.64mm) square pins mount securely into PCB holes prior to soldering. Aries Electronics, 0908 260007.

High-density connector. The 3629 connector is derived form the Din 41612 (Eurocard) range of connectors. It is used for interconnection of printed boards requiring large number of I/Os, having four rows of contacts from 120 to 684 contact arrangements and a pitch of 2.54mm. The male receptacle used on backplanes is available in press-fit with provision for wire wrapping or rear plug-up. Souriau (UK), 06285 24981.

Circuit protection

Gas tube arresters. The SR series of gas tube arresters offers faster response times than conventional arresters to protect communications equipment from electrical surges. The arresters respond as soon as the surge begins, rapidly reaching a constant discharge rate, which they maintain even if the current continues to rise. Protectors are available for ICs in networked computers and terminals, for equipment that uses AC power, for coaxial cable transmission systems, for PBXs and for telephones and terminal equipment. ECC Electronics, 0628 810727.

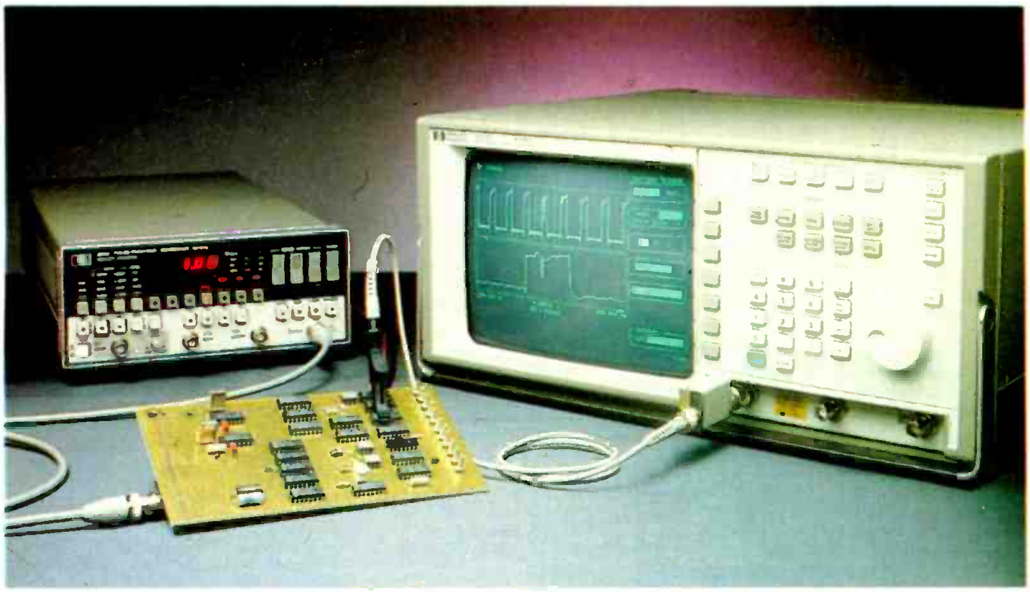
Displays

LCD module. Led-backlit alphanumeric LCD modules offer a significant increase in operational life compared with traditional electroluminescent types. The units combine dot-matrix LCDs with low-power c-mos circuitry and include on-board character generators. Options include a choice of viewing angles and led backlighting choice of green, red or amber. Anders Electronics, 01-388 7171.

Back-lit LCDs. A range of dot-matrix LCD modules which possess led backlighting is made by Stanley. Current consumption is 160mA for a 16-led module up to 380mA for a 38-chip unit. Luminous intensities in cd/m^2 ar 42 (red), 39 (orange), 39 or 80 (yellow) and 27 (green). Rom and ram character generation and microprocessor bus interface are provided. STC Mercator, 0493 844911.

Filters

Interference filters. Two choke-based filters with integral BS4491/IEC320 appliance inlets are available. The range



Hewlett-Packard's 500MHz digitizing oscilloscope, 54503A

offers improved attenuation over standard choke filters and is supplied in 1A, 3A, 6A, and 10A ratings with a choice of 2.8 series tabs/solder tags or 6.3 series tabs. A. F. Bulgin, 01-594 5588.

Hardware

Pin-grid-array heatsinks. Three heat sinks by Thermalloy for cooling PGAs are available. Where the air flow is directed straight on to the pins, the heat transfer coefficient achieved is up to 20% greater than with extruded heat sinks of similar area. The 2328, 2329 and 2334 series are designed for use with 121, 196 and 441 PGA packages. Suvicon, 021-643 6999.

Instruments

High-resolution chart recorder. The MT-95000 chart recorder possesses a resolution of 300 d.p.i. on the amplitude axis and more than 300 d.p.i. on the time axis, permitting even minute waveform changes to be interpreted. The recorder also features a real-time frequency response of 20kHz. All-electronic and operating without pens, styli or other moving parts, the MT-95000 records 8, 12 or 16 separate or overlapping channels, printing the waveform data and the chart grid simultaneously. Astro-Med, 0628 668836.

Multimeters. The 200 series of professional digital multimeters features a self-setting fuse for protecting the electronics and the user, the 223 also incorporating an audible bargraph. The instruments measure alternating and direct voltage and current and resistance. Beckman Industrial, 021-643 8899.

Light meter. The HD 8366 is a digital light meter used for measuring lighting levels outside and inside buildings. HD 8366 uses a silicon sensor, with no memory, and the spectral response has been adapted to that of the human eye by means of a filter fitted onto the sensor, with an integral error of less than 4%. The linearity of the sensor is better than ± 1.4% in the field from 100.000 to 200.00 lux. Delta Ohm, 0903 214335.

Storage-oscilloscope battery pack. A rechargeable battery pack which gives independence from mains power supplies is made by Gould for its 400 digital storage oscilloscope. The pack is 1.5 in deep and fits underneath the instrument, providing up to two hours of continuous operation. Gould Elctronics, 01-500 1000.

Digitizing oscilloscope. The H-P 54503A digitizing oscilloscope offers a 500MHz bandwidth and four channels. Features include autoscale, for single key-stroke set-up, 16 automatic pulse-parameter measurements and an HP-IB (IEEE-488) interface. Hewlett-Packard, 0734 777828.

Compact recorder. The TK0401 dual-deck voice-logging recorder offers up to four channels of simultaneous recording on a standard compact cassette tape, and provides 12-hour continuous recording capability in a low-cost desk or rack-mountable format. Recording may be continuous or triggered by voice operation, and sequencing of the two tape decks means that the second standby deck is automatically activated on completion of the first tape or in the event of a malfunction, and rapid access to recordings is ensured by a time/date log combined with a high speed search and recall facility. Racal Recorders, 0734 782158.

Literature

Single-board PC STEbus. A new six-page brochure details the features and benefits of the first fully compatible single-board PC for the STEbus. The Celeste PC card is based on the V20 processor running at 8MHz which gives it a performance three times that of a standard IBM PC (Norton SI = 3.1). Control Universal, 0223 244447.

Displacement drying. A flyer from ICI describes the single-solvent displacement drying system from ICI, 'Arklone' A-MD. Typical drying applications for the new solvent are printed circuit boards after through-hole plating, plastics after plating, glass lenses after aqueous cleaning and assemblies after aqueous cleaning. ICI Chlor-Chemicals, 0928 513065.

Instrument rental. "The complete guide to instrument rental, 1989" covers a total package of electronic instruments and computer systems available under a variety of rental and leasing schemes. The new catalogue contains details of computers, development systems and marine instrumentation as well as test and measurement equipment. I. R. Group, 0753 580000.

Proximity-switch data. MTE Ltd has published a 40-page manual providing technical specifications and extensive application data for their Turck range of inductive, capacitive and intrinsically safe proximity switches. MTE, 0702 421124.

Materials

Synthetic diamond. Pilkington can now produce true diamond at low pressure and modest temperatures by combining high-energy plasmas and chemical-vapour deposition and can coat small surfaces directly and produce self-supporting films. Application is in electrical components such as insulators and heat sinks as well as windows with special relation to X-rays, electron beams and particle beams. Pilkington Electro-optic Materials, 0389 59021.

Printers and controllers

Thermal graphics printer. a 42-column fixed-head thermal printer, the GPP-42, offers selectable international character sets and graphics capability. As well as printing in blue or black characters on white, the GPP-42 features a software selectable reverse-out printing mode which can be invoked line-by-line. Datel, 0256 469085.

Production equipment

Dry film laminators. Hot-roll laminators manufactured by Western Magnum are designed to laminate dry film photoresist to inner layers, multilayer boards, double-sided plated through-hole boards, chemical milling parts and other specialized substrate materials. Sizes range from 12 to 24 inches. Temperature controllers maintain constant temperatures across the full roll width, while air pressure cylinders provide the necessary panel-wide contact pressure. Astro Technology, 0489 577233.

Plug-in module cases. Cadlow have introduced plug-in module cases, whose base incorporates an 11-pin relay-style plug, the snap-on ABS cover having internal slots for PCBs and a recess on the top for a flush-fitting label. An internal metallic coating against RFI is also available. Overall dimensions are 76×38mm in two heights: 71 and 120mm. Cadlow, 0732 63266.

Monitoring for PCM reflow. The PCB reflow tracker system by Datapaq measures the effectiveness of reflow soldering, helping to minimize IC overheating and dry joints. The system monitors critical temperatures using a thermally protected Flatpaq 'tracker' module which follows a PCB through the reflow process. Connected to the PCB via thermocouples and short PTFE or fibre-glass wires, the tracker unit measures and records temperatures at specific points, downloading the information to the system's computer for interrogation and analysis. Dage (G.B.), 0296 393200.

Aqueous cleaner. An aqueous cleaning system with the capability to efficiently clean and dry densely packed printed circuit boards is less than half the price of an equivalent traditional solvent cleaner, with none of the associated environmental problems. Poly-Clean is compatible with in-line processing systems or can operate in a stand-alone mode. Using water as the cleaning fluid enables the use of a more aggressive flux in the soldering process. The system is 13½ft long with a 20in wide conveyor. Hollis (Europe), 0634 716733.

Power supplies

Power-factor correction IC. The Micro Linear ML4812 is a power-factor correction circuit designed specifically for use in DC power supplies for computer systems. It will supply up to 30% more power from a standard wall outlet. Ambar Cascom, 0296 434141.

Power supply. The S25D series are 25W, triple-output, switched-mode power supplies, usable anywhere in the world without modification. They operate within specification over a mains input range of 90V to 270V AC. They are totally enclosed in moulded, rugged polycarbonate cases, work without derating from 0°C to 50°C and they contain built in RFI suppression filters to meet VDE0871 level B. Standard output configurations are +5V with ±12V, +5 with ±15V, and ±5V with +12V, but other voltage combinations can be provided if required. All outputs are short-circuit protected and the main +5V has overvoltage crowbar protection as standard. Gresham Powerdyne, 0722 413080.

Power modules. A series of high-power, fast turn-off modules in two package sizes offers thyristor-thyristor, thryristor-diode, diode-diode and diode configurations. The thyristor-thyristor and thyristor-diode modules are available in a variety of circuit configurations. The INT-A-PAK series is rated from 200 to 1200V at 70 to 150A with turn-off time (t_q) of 12 to 25μs the MAGN-A-PAK series is rated from 200 to 1200V at 180 to 200A with t_q of 18 to 23μs. Diode-diode and single-diode versions are also available in various configurations. International Rectifier, 0883 713215.

Voltage converter. MAX681 from Maxim is a c-mos dual charge-pump voltage converter that provides a +10V output from a 5V input voltage. The device provides both a positive step-up charge pump to develop +10V and an inverting charge pump for a −10V output. It has charge pump capacitors internal to the package, operating with input voltages from 2.0V to 6.0V to supply simultaneous outputs of $+2 \times V_{in}$ and $-2 \times V_{in}$. Kudos Electronics, 0734 351010.

Radio communications

Rotary joints. Spinner GmbH rotary joints are used wherever it is necessary to transfer RF energy from a static system to a rotating antenna. They are available as single or multi-channel joints, with connections of one or more coaxial channels. Joints are available for nearly every waveguide size and frequency, with slip rings supplied for the transfer of low-frequency signals. All signals are transferred without any change of phase and amplitude. Hayden Laboratories, 0753 888447.

Mass storage

Magnetic disk controller. Samples of AMD's Am 95C95 disk controller are now available. It features a data transfer rate or up to 32-megabits per second (NRZ) and on-chip functions include buffer management, Reed-Solomon error detection and correction, a sophisticated sequencer engine, and a writable control store block that allows the chip to interface to a variety of standard interfaces, including ESDI and the ST506. AMD (UK), 0483 740 440.

Tapeless audio. ESTA products use non-volatile eprom memory as a sound storage medium. They can be used for speech, sound effects and music and, as there are no moving parts, they provide reliable sound with no regular maintenance. There is a choice of bandwidth or quality up to 12kHz, and storage capacity is up to 168 minutes at the lowest 4kHz quality. Electrosonic, 01-854 1414.

Tape autolocator. Studer Revox announce the availability of the Revox Autolocator for the C270, V274 and C278 range of professional tape machines. All 'C'-range versions accept the autolocator via the RS232 port, allowing remote control of all tape deck functions: Z-Loc, A-Loc, loop, programmable rollback (0-59s), locate and search, with channels 1 to 8 individually preselected 'ready'. Additionally, the autolocator has the facility to store 18 locator addresses. F. W. O. Bauch, 01-953 0091.

Software

Optical storage data bridge. Bypass is a software utility that provides data connectivity between hardware platforms via erasable optical discs. Working in tandem with Alphatronix's Inspire erasable optical storage system, users may read and write data between DEC VAX workstations and personal computers by means of an optical disc. Decade Computer, 0635 38008.

LETTERS

Weinstock

Thank you for giving me the opportunity to answer the questions raised in Mr Catt's letter (August).

My statement that GEC has proved a good investment for its shareholders is proved when we look at the purchase price of the shares ten years ago and the price they can be sold for now.

With regard to the smaller companies taken into the GEC Group, since these mergers and take-overs were carried out with the approval of the majority of the shareholders and, in most cases, the executives, we must assume that they felt the companies could not continue satisfactorily without such actions.

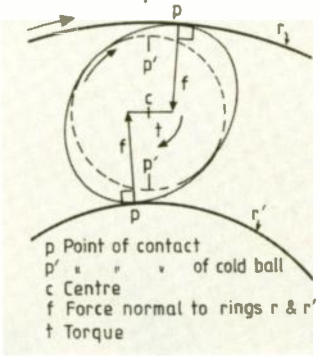
The rest of Mr Catt's letter does not refer to mine.

T. Jeffrey Burton
T.J.B. Associates
Tunbridge Wells
Kent

Ball-bearing motor

Concerning Stephan Marinov's ball bearing motor in the April, 1989 issue, F. Donachie is on the right lines in his letter in the June issue, but fails to hit the nail on the head. His idea of a delay between heating and expansion is spurious.

In an idealised ball race in motion, any point on the surface of one of the balls is in contact with the rings for zero time and hence experiences zero electrical heating. This is not true of the great-circle arc of contact of the moving ball. Hence, all the relevant heating has occurred around the small arc immediately in front of the point of contact (p) which itself is heated by thermal conduction only. The expansion caused by this heating has two effects: firstly, a force (f) perpendicular to the tangent at p is created (i.e. along a radius of the race) – so much Stephan Marinov got right; secondly, the ball is deformed as shown with the bulge mainly in front of the point of contact. This shifts the point of contact with respect to its position on a cold ball outwards (stressing the metal and producing f) and forwards. Hence, f is not along a radius of the ball and so exerts a torque on it and it dutifully rotates. So f does, in fact, do work, making this just another heat engine. I cannot comment on Mr Marinov's calorific



experiments but would be surprised if his results prove to be repeatable.

P. Mitchell
Southend Hospital
Essex

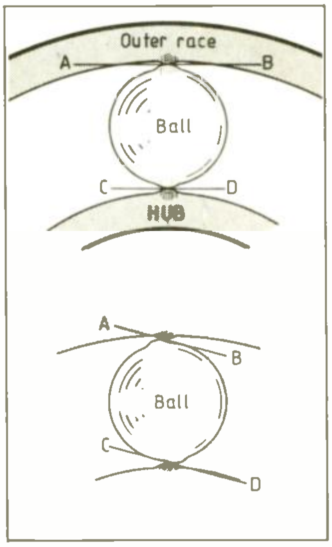
I would like to thank Dr Marinov (*EWW*, April 1989) for introducing me to the ball bearing motor. However, it was not clear from the article whether he understands the nature of the motor he is championing. For example he speaks of the "bulge" moving from one race to the other (top left p.357) but I doubt if this is so.

Consider **Fig.1**. This represents a stalled condition and no matter how much current passes through the contact planes AB, CD it's unlikely to become unbalanced. Give it a nudge, however, and the ball no longer occupies the balanced condition and rotates a little, thereby re-arranging the points of contact as in **Fig.2**. Current flow through these new points creates bulges growing out of the sides of the old bulges and pressure builds up at the new pressure points. This time the contact planes AB, CD are not at right angles to the hub and to each other and the pressures can now show themselves. This translates as the side of one bulge pushing the side of the other bulge that it's in contact with around the perimeter of the race.

The "energy from nothing" claim (bottom left p.357) got my attention, but I do not see what the problem is. The thermal energies stored within the motor will show up on the calorimeter test, but what will not show up is the potential energy stored at the contact planes. In the balanced condition these planes are under *compression* and this qualifies as potential energy. It will not be released until the motor is made to turn and this is where the "energy from nothing" comes from. It was there all the time but was invisible to the testing method! I have built a couple of these over the last week but unfortunately deadlines preclude a full assessment; however, they did work. Efficiency is low, probably around the 10%. Dr Marinov claims. There is a huge thermal problem – 10% efficiency demands the generation of approximately 7.5kW of heat within a 1h.p. ball bearing motor and providing it doesn't melt it should at least solve a few heating problems. It is a lot of heat to get rid of and might prove hard to surmount. The high-current low-voltage transformer makes the motor much larger and heavier than is useful. The poor self starting can be avoided.

The motor provides the basis for a cheap, small, light power unit capable of powers out of all proportion to its size, but only if it can be developed and be arranged in a more useful format to overcome the criticisms levelled at it.

B.G. Cave
Leyton
London E15



Microwave television distribution

Your correspondent Mr Lewis (Letters, June 1989), writing about microwave television distribution, referred to the Touche Ross Report for the DTI. He described us as concluding that, in the UK, the 2.5GHz band was already fully loaded and stated that, without further investigation, we ruled this out for further investigation for the use of microwave distribution of domestic services. He went on to argue that tropospheric scatter applications in the 2.5GHz band were making bad use of the spectrum.

We were puzzled by this as our report is in the public domain, having been published in October 1988 by HMSO. Our terms of reference did not include a study of the optimal use of the 2.5GHz band but instead required a technical and commercial evaluation of the attractions of MVDS in this and other bands. We therefore provided a full investigation of MVDS at 2.5GHz but did not make any comment whatsoever on the loading of this or any other band. Mr Lewis may be confusing the Touche Ross report with a consultation paper issued recently by the DTI which dismisses the scope of MVDS in this band.

Your correspondent's comments on the troposcatter systems seem, on the face of it, to be valid. However, decisions about optimal use of the spectrum cannot properly be taken until we move towards a system where assignments are charged at their opportunity cost.

L.D.C. Rees
Touche Ross Management Consultants
London, EC4

Crossed-field antenna

For once I am on the side of the unconventional. The design of antenna proposed by Kabarry *et al* in the March, 1989 issue conflicts with the technology of the 20th century but it does not appear to conflict with theory: Maxwell's equations for a plane wave state that if there exist oscillating fields of E and B (or H) then a plane wave will propagate. (The weakness of this form of the statement is that it ignores boundary conditions and the fact that the wave launched from an antenna is initially circular rather than plane but this does not seem to change things to a major extent.) The second piece of basic theory is that if there exist fields E and H then there is a power flow E×H, whether or not the fields are oscillatory or plane. I did not study the *E&WW* article because I had already been aware of the scheme for a year and had checked the author's calculation of the equatorial magnetic field, both within and outside the E plates; and the authors had also shown how this field could be measured with a screened pick-up coil. Instead of an intemperate attack, a quantitative analysis of the effect of current in the feed wires would have been more helpful than a casual comment by William G. Chambers about what *might* happen.

Qualitatively it seems to be that the only reason for making a resonant antenna large (e.g. the half-wave dipole) is that the E and H fields close to the conductor are in quadrature and the phase of the contributions from various parts will differ at a distant point, depending on the distance travelled, so that a component appears in which the two fields are in phase. This factor is evident in the directional pattern in the radiation from long non-resonant wire (e.g. one limb of a rhombic antenna). If there is a defect in the present proposal it should be exposed analytically, so that one could consider whether it could be overcome. There is nothing basically impossible about an antenna smaller than a wavelength in dimension, provided that it is not resonant.

D.A. Bell
Beverley
North Humberside

Light current

Recently I was carrying out tests on an electronic circuit which employed two glass-cased zener diodes in series to develop a 57V reference. The interesting phenomenon I observed was that when light was shone on the zeners the voltage reference was reduced to as low as 47V, depending on the intensity of the light. The phenomenon has no ill effects on the application at hand because the printed-circuit board is housed in an opaque plastic mould, but I would be very interested in hearing whether this effect or similar effects have ever been observed by any of your other readers.

Joseph McClean
Theo Benning Ireland GmbH
Wexford
Ireland

Circuit symbols

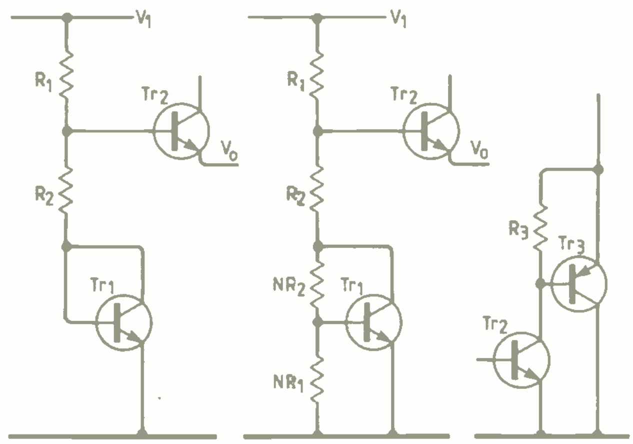
Isn't it a little late in the day for Mr McLoughlin (May, 1989) to beat the BSI with the 'rectangular resistor'? BS3939 'Guide for graphical symbols...' was first introduced in 1966 and even then was in conformity with many IEC symbols. The BSI may have thrown caution to the wind 23 years ago but it can hardly be accused of having imposed its will on a cowed industry as the circuit diagrams in this journal and many others demonstrate every month.

It was presumably in the interest of a "truly international language" that BSI and IEC symbols were made to conform and I do not believe that the 'wiggly resistor' was in common use in continental Europe prior to 1966.

I do not have any connection with the BSI, but I was under the impression that circuit symbols, and indeed all other standards were the result of the deliberations of committees of experienced people from the industries concerned. We have all heard about camels and committees but why is it that the 'rectangular resistor' raises such ire? Is it so much more difficult to appreciate its ohmic qualities rather than those of a wiggle? Even today the rectangle is easier to draw using the average computer drawing program which was, I understand, one of the original criteria for its choice all those years ago. All the "intelligently chosen" symbols were, after all, the work of the same committee.

The use of different circuit symbols depends to a large extent upon the market place. Firms doing work for UK government agencies and continental Europe may use one set and those doing work for the USA and Japan use another. Being conformist is necessarily a bad thing. I hope that the pupils at Haberdasher Aske's School conform to the basic rules of English grammar and to a different set of rules for French. I hope we all conform to the relevant speed limit when we drive on the public roads. In 1992 we shall no doubt have to conform in many different ways. There must be more important battles to fight than that of the 'wiggly resistor'.

E.P. Best
Fleet, Aldershot, Hampshire



(a) (b) (c)

Temperature compensation of base/emitter junction

As is well known, the V_{be} of a transistor varies with temperature. Frequently, a diode or transistor is put in the bias chain as shown in **Fig.3a.** This does not give good compensation; indeed, it can be shown that

$$\Delta V_0=\frac{\Delta_{be1}\times R_2}{R_1+R_2}+(\Delta V_{be1}-\Delta V_{be2})$$

which, even if the base/emitter junctions are matched, reduces to

$$\Delta V_0=\frac{-\Delta V_{be1}\times R_2}{R_1+R_2}$$

The circuit of **Fig.3b.** gives better compensation:

$$V_0=\frac{R_2V_1}{R_1+R_2}+V_{be1}-V_{be2}$$

$$\Delta V_0=\Delta V_{be1}-\Delta V_{be2}$$

~0 for matched junctions.

If T_{r2} is replaced by the complementary pair as in **Fig.3c** the current in Tr_2 can be made equal to that in Tr_1 by means of R_3, giving even better compensation.

J.E. Kennaugh
Callington
Cornwall

Alpha-torque force

I read Professor Graneau's article in the June issue with great interest. Other readers interested in underwater arcs may like to look out an article which appeared several years ago in the Amateur Scientist section of *Scientific American*. The authors proposed that the majority of the energy released when a high-voltage capacitor was discharged was dissipated in internal and circuit resistances rather than in the arc. They set about trying to increase the resistance of the arc and hit upon the idea of striking the arc underwater. The authors noted the considerable pressures generated by the arc and in one experiment a spark was fired near the side of a metal tank which was resting on a steel die, resulting in a piece of the side of the tank being punched out at high speed.

My prototype water-arc gun, built out of junk components, will hit the ceiling with a 2.5J charge. I am waiting for a larger capacitor to be delivered for the Mk II version.

Simon Young
Newmarket
Suffolk

Peter Graneau, in his June article 'Alpha-Torque forces' describes some impressive high-current and short-time phenomena in assemblies of conducting materials. However, he attempts to explain them solely in terms of forces between currents, ignoring both electrostatic forces and the forces associated with electromagnetic induction. On this basis he argues that the Lorenz force law between current elements is seriously defective. It is really too much to credit that this deficiency can exist without disturbing the agreement between the complicated behaviour calculated for particles in high-energy accelerators and the detailed experimental measurements of that behaviour.

Many people assume that, because in electrostatics there can be no charge inside the body of a conductor, there can be none in the body of a conductor carrying a steady current. If this were true it would be a tricky matter to determine the specific resistance of a metal by measuring the resistance of a long wire of known cross-section, since the current would be concentrated by the pinch effect towards the axis of the wire. Initially this will tend to happen, but as a result an excess electronic charge builds up near the axis (compare with the Hall effect). In equilibrium this produces a radial repulsion of the conduction electrons which on average balances the pinch effect.

In the cup of mercury the electron currents are diffuse when they leave the ring electrode and have a spread of radial components, but become much more concentrated and almost purely axial just above the rod electrode. The pinch effect is therefore greatest in this region, and falls off progressively as axial positions are taken closer to the free mercury surface. Thus if the resulting forces on the electrons are somehow transmitted to the mercury atoms they will tend to produce just the sort of mercury flow Graneau describes. His argument to the contrary neglects the effect of the axial gradients. How the transmission is effected is much more likely to find an adequate explanation in the theory of solid-state physics, which successfully accounts for some very complex phenomena, than in a revamping of the ideas of Ampère, to whom these phenomena were unknown.

In Graneau's experiments on exploding wires and on water guns the forces between the 'quasi-equilibrium' currents may not be the controlling factors. Instead the critical stresses could be generated during and soon after the initial current buildup, when the inductive effects which he ignores are important. His anti-relativity stance simply antagonises those who might otherwise be seeking to provide a satisfactory theoretical account of an intriguing and technologically promising set of phenomena.

C.F. Coleman
Grove
Oxfordshire

PC graphics

I would like to point out that, of the relatively few typographical errors in the above article in the June issue, three might prove important for anyone trying to use the data. These are:

1. Table 1; for al=07h the memory start address should read B000:0000h, not B000:8000h.
2. Table 3; the second row of data reads the whole palette, not a repeat of the line above.
3. One line of code in the Hercules loading routine reads:

```
    DB      0      curs_mode
```

It should read

```
    DW      0      curs_mode.
```

In general, I would point out that the practice of moving characters to the line below when listing code makes the code totally unworkable if entered that way. While readers familiar with writing assembler code will sort it out, it is a bad practice and not seen in any other journal I have ever read.

Keith Wood
West Derby
Liverpool

CODAS and PCS

We were very pleased to see the review of CODAS and PCS in the July issue of *Electronics and Wireless World*.

There are one or two factual points that I feel ought to be pointed out to your readers.

a) Both CODAS and PCS will operate automatically on a wide range of graphics adapters. There is no such thing as GGA display (your inset).

b) There is a substantial discount for multi-computer sites involved in training or education, eg. an eight-computer licence with eight manuals for CODAS is available for £450 (please see our price list).

There are a number of points in the review with which I could take issue. I will just describe one or two which I feel are particularly important.

The sentence on page 724, "It also outputs the Nyquist plot..." could mislead readers into thinking that Nyquist plots are the only form of frequency response representation. In fact there are six different frequency response views including Bode, Nichols and Inverse Nyquist.

A number of key features of CODAS were simply not reported. No mention was made for example of the digitizing cursor, the availability of a generator (calculator) for synethesising complex waveforms and the ability to handle systems with pure time delay in all three domains.

J. W. Golten
Cheadle Hulme
Cheshire

Merchant Navy College, Greenhithe

May I, through the columns of your journal, inform your readership of the impending closure of the College, and advise past students among your readers as to what they should do should they need to refer to the academic records.

My department, the Department of Electronic Engineering, came here when the present buildings opened in 1975, with a number of staff from the old Norwood Technical College (now South London College). Although, initially, we were primarily concerned with the training of radio officers, the decline of the merchant navy led us to diversify to more general electronic engineering and recently we have been the biggest single BTEC HNC in Electronics and Communication Engineering, certainly in the south east, and probably in the country as a whole. While most of our ex-students obtained employment as technician engineers in shoreside industries, we maintained our share of the much diminished employment market for MN radio officers.

Despite our success and a two-year battle, we will definitely be closed by our authority, the ILEA, at the end of this academic year. Our students who are currently part-way through their course will be dispersing to other colleges throughout the country.

After July 6th 1989, past-students who require references or need to consult their records, including those associated with BTEC, should address their enquiries to South London College, Knight's Hill, London, SE27, telephone number 01-670-4488, to which all records have been transferred.

R.G. Douglas
Vice-Principal
Head of Department of Electronic Engineering
Merchant Navy College
Greenhithe
Kent

Capital appreciation

I have been a regular or frequent reader of *Wireless World* for a good number of years. For most of those years the magazine has been a bastion of correct practice in so far as abbreviations are concerned. However, over the last few months the pages have begun to be littered with such things as upper-case AC, DC, IC, RMS, THD, RF, AM, FM, TTL etc.

I trust that this will be but a temporary aberration and that you quickly act to correct these errors.

Electronics and Wireless World will again become the reference against which lesser magazines may be compared.

D.M. Bridgen
Racal-Tacticom
Reading
Berks

With technical expressions and quantities, we use the following rule. If the acronym can be spoken (or read) as a complete word, then we print the acronym or abbreviation in lower case, so that the reader does not stumble across unnecessary capitals. However, if the abbreviation cannot be read as a word, so that the reader has to spell out the letters for himself as he reads it, then we print the abbreviation in upper case to emphasise the difference.

From a technical point of view, I consider the mix of lower case and upper case to be insignificant, except where electrical quantities are used. Thus, kilohertz will always be printed as kHz, etc.

If we obtain feedback suggesting that we should move entirely to lower-case abbreviation, then rest assured we shall do so.–Ed.

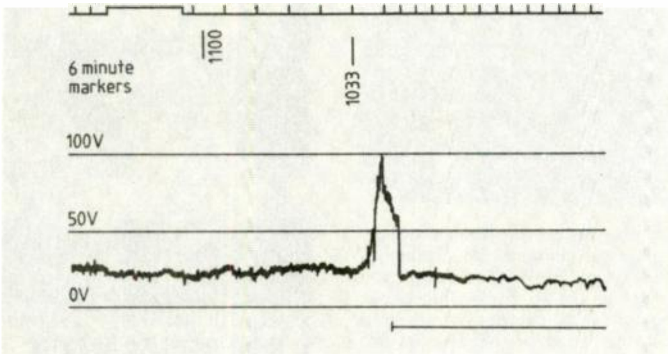
Radio Mirror

Although I have been logging the atmospheric electric field for many years, intermittent inteference began to show up on electrometer recordings of the natural electric field earlier this year. Normally the electric field shows a very regular diurnal profile except during thundery weather, magnetic storms and solar flares.

The interference took the form of a positive transient of over 100V (**Fig. 1**) impressed on a normal antenna background field of between 5 and 15V lasting from 5 to 60 minutes on weekdays between 9a.m. and 5p.m. This 'office hours' pattern immediately suggested an artificial origin, which was confirmed when it was found that audio and data modulation could be extracted from the electrometer signal. The origin appeared to be high-powered microwave transmissions penetrating the ionosphere over the recording station en route to geostationary communications satellites from one of the three large satellite uplink stations in the Malvern/Cheltenham/Hereford region.

The fact that a microwave beam effectively 'cooks' the ionosphere where it penetrates is proved by the very large ionization voltage appearing on a ground electrometer antenna. This is higher than that caused by normal D, E or F layer ionization, which is already used as a natural radio mirror since it follows daily and sunspot cycles. The suggestion that the zone of intense ionization caused by a microwave beam has a possible use appears to be new, and seems to have never been tested, so what are the chances of success?

Experience over many years has shown that even slight ionization anomalies can refract or reflect short radio waves. Television reception is frequently disrupted when a summer anticyclone settles on the British Isles, since it acts a natural waveguide to bring distant tv stations on the same channel to our aerials. Meteor trails act as very good evanescent reflectors. Tropospheric scatter systems have been used for many years to take advantage of slight ionization anomalies to give over-the-horizon communication from fixed, high-power base stations.



The extent of the ionospheric 'hotspot' caused by a microwave beam may have passed unnoticed for several reasons. The main problem is that the lower ionosphere is inaccessible to aircraft and balloons, and can only be probed by sounding rockets and remote sensing. The atmosphere at the levesl of interest is still too dense for satellites, so observations made from higher orbits above the hotspot may well show nothing unusual, although a high-resolution far-infrared scan might show ionospheric excitation over high-power broadcast transmitters. This means that, unless equipment is specifically deployed to look for a hotspot, its discovery remains a matter of chance, as was the case with my own observations using special electrometers.

It should not be difficult to arrange trials to see whether the hotspot from a test beam can be seen by millimetre radar or high-resolution ionosonde, and whether a microwave link between two stations can be set up by aligning the antennas on the invisible hotspot over a vertical power beam. Successful trials will open the way to a practical method of extending the range of microwave and other line-of-sight communication systems, as well as providing a novel means of remote surveillance of sensitive uplinks.

Tony Hopwood
Upton-on-Severn
Worcestershire

Mosfet audio output

With respect to the letter of Douglas Self in the May 1989 issue of *EWW*, I believe that there are widely accepted measurements and design issues other than THD and gross feedback levels.

A published BBC study quoted in *WW* about ten years ago showed the correlation between perceived reproduction quality and a number of objective and repeatable measurements. Three measurements were listed: THD, IMD, and a pseudo-random digital noise correlation test. THD was the least effective predictor of audible quality, IMD was better, and the BBC pseudo-random noise test was the best, being (as I remember) about 100 times as effective as THD measurements.

While the BBC method has not been widely used in the USA, IMD measurements are well known and well quantified worldwide.

Loop gain is an important problem in any feedback amplifier. Many common high-feedback power-amplifier designs have inadequate loop gain at high frequencies, along with forward inherent distortion which increases with frequency.

The (in)famous THD is simply a visible result of forward amplification decreasing to the point that an internal stage becomes very nonlinear. This behaviour can be provoked by very small high-frequency components, especially past 10kHz, since many amplifiers have too little high-frequency gain and heavy frequency compensation.

There is a number of specific points in the circuit requiring special attention from the designer; the stage where frequency compensation is applied, the output drivers, and the output are the most critical. If any of these can be forced to operate with low forward gain, the result will be distortion uncorrectable by feedback. A properly designed class AB stage must run with both output devices in a fairly high transconductance region to avoid this problem.

With some fairly painful mathematics and using detailed transistor models, one can determine that high-frequency distortion products will be primary visible result of low loop gain. Many repeatable listener studies have shown that high-order (especially odd) harmonics, and almost any intermodulation products, are offensive to the listener.

These distortion products are not provoked by a simple sine-wave input. Standard intermodulation tests begin to provoke them by adding a low-amplitude, high-frequency component. The predictable white noise of a pseudo-random digital noise generator effectively produces a continuous version of the attack of a cymbal or other percussive musical instrument.

As a firm believer in engineering, I would like to encourage repeatable, concrete measurements to guide research and development of audio equipment. The measurements and specifications used to develop this equipment should be ones carefully chosen to match the user: the person who buys and listens to the equipment.

Geoff Steckel
Newton
Massachusetts
USA

Combined memory

At present, we are well supplied with rams and roms as separate chips, but not combined rom/ram chips. For example, in a small computer system 32K of program space may be adequate and a combined chip say, 16K rom and 16K "scram", could be very useful. Make the pinout equal to current 32K static rams and the rom an eprom and presto!

Put the scram below the eprom in address order, so the 'sixers' can have their page 0 in ram and the vector addresses in rom all in the same chip.

Alan W. Roscoe
Enfield
Middlesex

Logic programming and artificial intelligence

Computers have the ability to do numerical calculations, but logic programming gives them problem-solving methods as well. As Michael Covington shows, this makes it easier to program computers to make decisions about practical problems.

Logic programs are usually written in special languages such as Prolog, Turbo Prolog and Trilogy, but there are logic programming subroutine packages in Lisp and even C. Special computers are not required; most logic programming software runs on the IBM PC or Macintosh.

A logic program consists of *facts* and *rules*. A fact is a piece of information. For example, in Prolog, the statement

```
in(ely,cambridgeshire).
```

might express the fact that Ely is in Cambridgeshire. To the computer, of course, *in*, *ely*, and *cambridgeshire* are just strings of characters, but their arrangement is what's important.

A rule allows one fact to be deduced from another. For example,

```
in(X,england) :-
     in(X,cambridgeshire).
```

says, "For any X, X is in England if X is in Cambridgeshire". The symbol ":–" means "if", and variables begin with capital letters.

Figure 1 shows some facts and rules about English geography. The facts are like entries in a database, and Prolog retrieves them by pattern-matching. For instance, the query

```
?- in(banbury,oxfordshire).
```

is answered "yes" because there is a fact that matches it.

Prolog can also fill in values for variables. The query

```
/* Fact 1 */   in(ely,cambridgeshire).
/* Fact 2 */   in(cambridge,cambridgeshire).
/* Fact 3 */   in(banbury,oxfordshire).
/* Fact 4 */   in(oxford,oxfordshire).
/* Fact 5 */   in(covington,huntingdonshire).

/* Rule 1 */   in(X,england) :- in(X,cambridgeshire).
/* Rule 2 */   in(X,england) :- in(X,oxfordshire).
/* Rule 3 */   in(X,england) :- in(X,huntingdonshire).
```

Fig. 1. These rules and facts define the predicate "in", which encodes some knowledge about English geography.

```
?- in(X,cambridgeshire).
```

calls up all the values of X that match entries in the database (**Fig.2**).

Prolog rules are procedures: they work by transforming one query into another. Rule 1 in Fig. 1, "X is in England if X is in Cambridgeshire", is really the procedure "To prove that X is in England, prove that X is in Cambridgeshire". When given the query

```
?- in(ely,england).
```

– that is, "Is Ely in England?" – the computer uses that rule to transform the query into

```
?- in(ely,cambridgeshire).
```

This in turn matches a fact in the database and so the computer answers "yes".

If there is more than one solution, Prolog backtracks. This makes it quite unlike conventional programming languages, in which the flow of control proceeds inexorably forward and cannot reverse. Whenever a query matches more than one fact or rule, the computer tries the first one and keeps a record of the next. It can then retreat to this untried alternative if necessary.

To see how this works, consider the knowledge base in Fig. 1 and the query

```
?- in(banbury,england).
```

The query matches Rule 1, Rule 2, and Rule 3, in each case giving X the value 'ely'. The computer tries Rule 1, creating the new query

```
?- in(banbury,cambridgeshire).
```

which fails – it does not match any fact or any rule. So the computer backtracks and tries Rule 2 instead. This time the new query is

```
?- in(banbury,oxfordshire).
```

which succeeds, so the answer to the original query is "yes." **Figure 3** shows the whole process in tree-like form. If there had been untried alternatives at several levels, the computer could have backtracked through all of them.

Computational power

Because rules are procedures, they can express all kinds of computations, not just simple relations between named objects. For example, here is a pair of rules to compute factorials:

```
factorial(0,1).

factorial(X,FX) :-
   X > 0
   Y is X-1,
   factorial(Y,FY),
   FX is X*FY
```

That is: "The factorial of 0 is 1. To find the factorial of any number X greater than 0, find the factorial of X−1 and multiply it by X". The procedure calls itself recursively to perform as many multiplications as necessary.

Prolog has no loop statements; all repetition is expressed as recursion. This is not as inefficient as it sounds, because an optimizing compiler can transform a properly constructed recursive procedure into a loop in machine language. This combines the clear logic of recursion with the efficiency of loops.

Many data structures are available, including character strings, numbers and Lisp-like lists such as [a,b,c]. Further, programs can modify themselves; a program can construct a new fact or rule as it runs, then add that fact or rule to itself. This means you can use Prolog to write programs that "learn" or that help users build their own knowledge bases. Further, several Prolog compilers are accompanied by toolkits for querying files created by dBase or other database software.

Expert systems

Logic programming makes it possible to build expert systems – programs that give advice about real-world situations. An expert system is more powerful than a reference book (even an on-line computerized reference book) because it

Prolog is quite unlike conventional programming languages, in which the flow of control proceeds inexorably forward and cannot reverse...

```
?- in(ely,england).
yes

?- in(madrid,england).
no

?- in(X,cambridgeshire).
X = ely
X = cambridge
```

Fig.2. Prolog can either answer queries 'yes' or 'no', or fill in values of variables.

applies its knowledge to your particular case, but it is less powerful than a human expert because it has only a limited amount of knowledge and a limited ability to use it.

Expert systems are good for diagnosing faults in machines, automated share trading, selecting products from a wide range, and similar tasks where the computer must not only store data but also reason about it. For example, the Richmond Supply Company, a large distributor in Georgia, USA, uses expert systems to select paints from a huge catalogue. The expert system helps inexperienced salesmen give good recommendations.

Best of all, the expert system never forgets a possibility. Even the best human expert would sometimes forget to consider some of the paints. Not so the computer. That is why computers are ideal for sorting through vast numbers of possible choices.

Figure 4 shows part of an expert system written in Prolog that diagnoses why a car won't start. Prolog is easier to read than conventional programming languages; a human motor mechanic, even if not trained in Prolog, can look at these rules and judge whether they are correct. By contrast, imagine how they would look if strung together with pointers in C or Pascal.

Crucially, expert systems are *not* based on decision trees or flowcharts – at least, they need not be, and in Prolog they usually aren't.

The rules are just put into the computer, one by one, and the computer automatically searches through them in a logical sequence. This means that additional rules can be added later without restructuring the ones already present.

Nor do the rules have to pick out a unique diagnosis. If two diagnoses can-

Fig.3. In Prolog, backtracking is automatic – whenever a line of reasoning fails, the computer looks for an untried alternative and goes back to it.

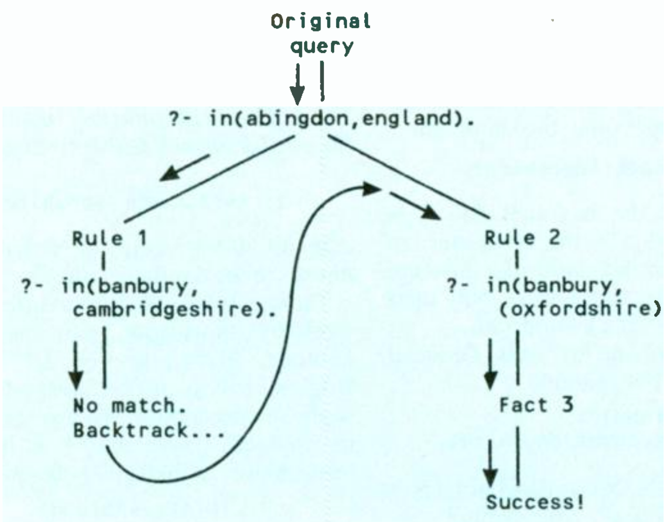


Fig.4. Part of a hypothetical expert system to diagnose why a car won't start.

```
defect_may_be(fuel_pump) :-
   check(fuel_in_carburettor,no).

defect_may_be(battery) :-
   check(starter_rotates_engine,no).

defect_may_be(distributor) :-
   check(starter_rotates_engine,yes),
   check(fuel_in_carburettor,yes).

...
```

Logic programming on your computer: a selection of suppliers

Prolog

Applied Logic Systems, P.O. Box 90, University Station, Syracuse, N.Y. 13210, USA ALS Prolog: threaded-code compiler for IBM PC and Macintosh; native-code compiler for Sun and 80386.

Arity Corporation, 29 Domino Drive, Concord, Massachusetts 01742, USA. Full-featured Prolog compilers for IBM PC family (DOS and OS/2).

Austin Code Works, 11100 Leafwood Lane, Austin, Texas 78750, USA. Low-cost source code for a Prolog interpreter written in C.

BIM, Kwikstraat 4, B-3078 Evberg, Belgium. BIM-Prolog compiler for Sun and VAX. Fast execution.

Borland International, 1800 Green Hills Road, Scotts Valley, California 95066, USA. Turbo Prolog for IBM PC (a non-standard, fast-executing Prolog-like language).

Creative Soft, Turnstrasse 10, D-8510 Fürth, West Germany. CIM-Prolog for IBM PC, Inmos Transputer, Apollo, and Sun. Standard language with object-oriented extensions and concurrency.

IBM Corporation (worldwide). VM/Prolog for IBM mainframes. Non-standard syntax; functionally equivalent to standard language.

InterFace Computer, Garmischer Strasse 4, D-8000 Munich 2, West Germany. IF/Prolog compiler for MC68000, NSC32000, VAX; interpreter and intermediate code compiler for all UNIX machines.

Logic Programming Associates, Studio 4, Royal Victoria Patriotic Building, Trinity Road, London SW18 3SX; 01-871 2016. LPA Prolog for the IBM PC and LPA MacProlog for the Macintosh. Strong on graphics.

Logicware International, 2065 Dundas Street East, Suite 204, Missisauga, Ontario L4X 1M2. MRPROLOG, standard language on widest range of machines: IBM mainframe (TSO, VM), VAX, Sun, Apollo, other workstations, IBM PC, Atari ST, Macintosh. Good tutorial.

Quintec Systems, Wadham Court, Edgeway Road, Oxford OX3 0HD; 0865-791565. Quintec-Prolog for Sun and 80386; high performance.

Quintus Computer Systems, 1310 Villa Street, Mountain View, California 94041. Quintus Prolog for VAX, Sun, and many other workstations (not PC or Macintosh). This Prolog implementation sets the standards that others follow.

SD-SCICON, AI Business Centre, Pembroke House, Pembroke Broadway, Camberley, Surrey GU15 3XD; 0276-686200. SD-Prolog for IBM PC, licensed from Quintec.

Other languages

Complete Logic Systems, 741 Blueridge Avenue, North Vancouver, B.C., Canada V7R 2J5. Trilogy for IBM PC.

Inference Engine Technologies, 1430 Massachusetts Avenue, Suite 306-1, Cambridge, Massachusetts 02138, USA. Sierra OPS5 for IBM PC.

Production Systems Technologies, 5001 Baum Boulevard, Pittsburgh, Pennsylvania 15213. OPS83, a language derived from OPS5 but more versatile, for IBM PC (DOS and OS/2), 80386 (UNIX), Apollo, AT&T, VAX, Sun and other workstations.

Custom programming

AI Associates, 445 Crestwood Drive, Athens, Georgia 30605 USA. Expert systems for industry. Developed the Hill Systems paint selector illustrated overleaf.

not be distinguished with available information, Prolog can report them both as possibilities.

Natural language

Logic programming is also a good way to approach natural language processing (NLP) – the programming of computers to understand human languages. Of course NLP hasn't been perfected, but the technology is already good enough to give useful results. The key is to narrow down what the user can talk about. Today's computers cannot understand Shakespeare, but they can understand weather forecasts or database queries expressed in English.

There are several reasons why logic programming is good for NLP. First, logic programming languages are designed to represent human knowledge. Thus they provide something to translate the English into. It is much easier to translate English into Prolog than into Fortran.

Second, logic programming languages provide good ways to represent sentence structure. The tree diagram in **Fig. 5** can be expressed in Prolog as

```
sentence(noun_phrase(determiner(the),
                     noun(dog)),
         verb_phrase(verb(chases),
                     noun_phrase(determiner(the),
                                 noun(cat))))
```

There is no data structure like this in conventional languages.

And perhaps most importantly, natural language processing requires the ability to backtrack. Consider the sentence "I saw the man with the telescope". This could mean either "I saw the man who had the telescope" or "I used the telescope to see the man". A computer analysing such a sentence might have to try one interpretation and then reverse and try the other. Backtracking is built into logic programming languages but not conventional languages.

Prolog, Lisp, or C?

There is a widespread misconception that Prolog and similar languages are slow, and that serious applications should be re-coded in Lisp or C for speed.

The expert system never forgets a possibility...

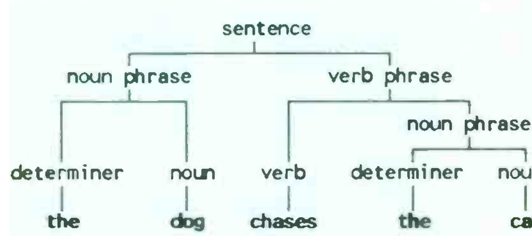


Fig. 5. Structure of an English sentence, easily representable in Prolog.

This may have been good advice five years ago: Prologs available then were experimental and were not designed for speed. The quality of Prolog implementations has risen dramatically in the past few years. Nowadays, any program that really needs the features of Prolog will run faster in Prolog than in Pascal or C. The same goes for other logic programming languages.

The hard parts of logic programming are searching, backtracking, and matching. Good Prolog compilers implement these in hand-optimized assembly language, using techniques that would not be obvious to a beginner. Anyone who sets out to do logic programming in C is claiming that he can implement the essential parts of Prolog better than an experienced Prolog implementor.

A colleague of mine once tested a mediocre Prolog interpreter against a good Pascal compiler, implementing the same list processing algorithm with both. He expected Pascal to win hands down, but Prolog was actually 14 times faster – and today's Prologs are faster than that.

Lisp is an intermediate case – it has the same data structuring power as Prolog, but searching, backtracking, and matching are not built in. They are relatively easy to implement as Lisp subroutines, but Lisp seldom has any performance advantages over Prolog.

Interpret or compile?

Implementing Prolog poses some problems that were not solved well until very recently. A Prolog program can examine and modify itself as it runs. Because of this, Prolog was originally implemented as an interpreter – a program that reads the Prolog code, holds it in memory, and works through it executing queries. This process is not particularly fast.

Programs run much faster if they can be compiled – translated into the processor's native binary code so that, at execution time, the computer need not concern itself with the original programming language. But a compiled program cannot examine or modify itself, because the original code is no longer there. This poses a dilemma for implementors of Prolog. Three main solutions have appeared.

The **Turbo Prolog** solution is to simply discard the features of the language that slow it down. Turbo Prolog programs run very fast, but they can't modify themselves. Turbo Prolog also uses data type declarations to speed programs up even further, at the cost of some versatility.

The second solution, used by **Quintus Prolog, Arity Prolog** and many others, is to include a Prolog interpreter in every compiled program. The parts of the program that need to be modified at run time are run by the interpreter; everything else is run in compiled form. This is a good compromise, but it requires the programmer to divide the program into compiled and interpreted portions. The modifiable parts aren't fast, and the fast parts aren't modifiable.

The third solution, adopted by **ALS Prolog**, is to compile Prolog into threaded code – a special style of machine language consisting almost entirely of procedure calls – from which the original Prolog can be reconstructed whenever needed. This makes programs fully modifiable and at the same time allows them to run with compiled speed.

Logic programming helps a decorator's merchant select paints from a huge catalogue (photo: Hill Systems).

He expected Pascal to win hands down, but Prolog was actually 14 times faster...

Other logic languages

Prolog is not the only logic programming language. **Trilogy**, billed as a "multi-paradigm" logic language, allows the programmer to use Prolog-like, Lisp-like and Pascal-like styles in the same program. This makes it possible to combine logic programming with other techniques without having to recast the other algorithms into Prolog form. A Trilogy compiler is available for the IBM PC and performs well.

OPS5 and its derivatives are "forwarded-chaining" logic programming languages, in contrast to Prolog and Trilogy, which are "backward-chaining." That is, in Prolog, execution starts with a query to be answered ("Can you deduce this?"), whereas in OPS5, execution starts with basic facts ("What can you deduce from this?"). But OPS5 is not indispensable for forward chaining; Prolog can also chain forward in a suitably designed program. ■

Recommended reading

W.F.Clocksin and C.S. Mellish, Programming in Prolog. Third edition. Berlin: Springer-Verlag, 1987. (Originally published 1981, this classic textbook defined the "Edinburgh dialect" of Prolog, on which most implementations are based.)

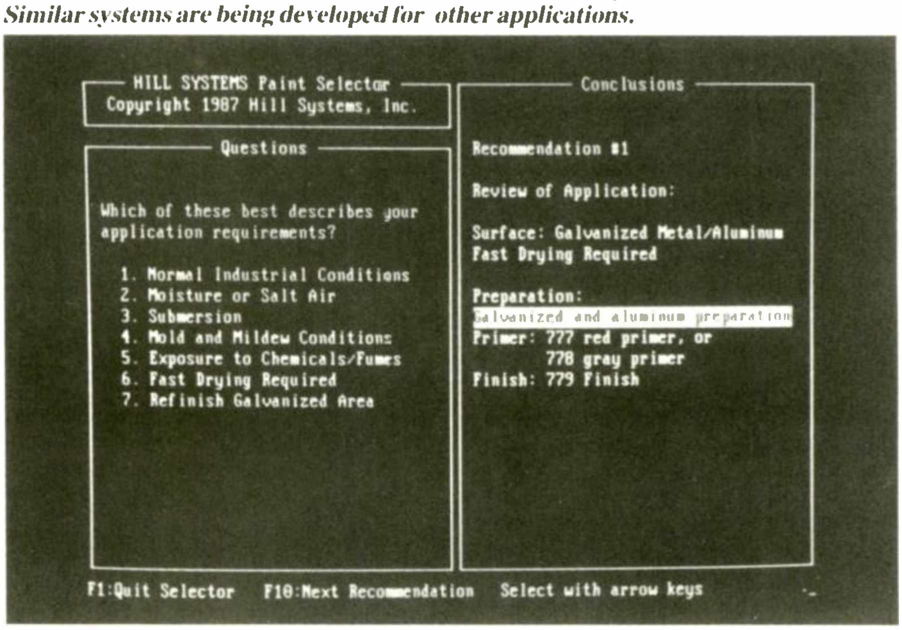
M.A. Covington, D. Nute, and A.N. Vellino, Prolog Programming in Depth. Glenview, Illinois: Scott, Foresman, 1988 (Comprehensive textbook for beginners; especially strong on practical programming and the expression of algorithms in Prolog.)

Peter Jackson, Introduction to Expert Systems. Wokingham: Addison-Wesley, 1986.

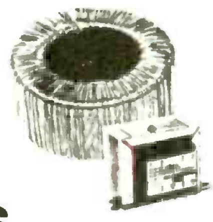
M.R. Genesereth, and N.J. Nilsson, Logical Foundations of Artificial Intelligence. Los Altos, California: Kaufmann, 1987. (Mathematical logic as the basis of machine reasoning.)

Dr Michael A. Covington is at the University of Georgia at Athens, Georgia, in the USA.

This expert system, written in Turbo Prolog, features easy-to-use menus. Similar systems are being developed for other applications.



Toroidal & E.I. Transformers



As manufacturers we are able to offer a range of quality toroidal and laminated transformers at highly competitive prices.

Toroidal Mail Order Price List

prices inclusive of VAT & Postage

15va **9.12**, 30va **9.48**, 50va **10.16**, 80va **11.02**, 120va **12.23**, 160va **14.44**, 225va **16.37**, 300va **18.05**, 500va **26.46**, 625va **30.66**, 750va **34.14**, 1000va **49.40**.
Also available 1k2, 1k5, 2k, 2k5, 3k. Prices on request.

Available from stock in the following voltages: 6-0-6, 9-0-9, 12-0-12, 15-0-15, 18-0-18, 22-0-22, 25-0-25, 30-0-30, 35-0-35, 40-0-40, 45-0-45, 50-0-50, 110, 220, 240. Primary 240 volt.

Quantity prices and delivery on request

AIR LINK

Air Link Transformers

Unit 6, The Maltings, Station Road,
Sawbridgeworth, Herts. Tel: 0279 724425

ENTER 34 ON REPLY CARD

SMALL SELECTION ONLY LISTED – EXPORT TRADE AND QUANTITY DISCOUNTS

RING US FOR YOUR REQUIREMENTS WHICH MAY BE IN STOCK

Cossor Oscilloscopes CDU150(CT531/3) £150 only. Solid state general purpose bandwidth DC to 35MHZ at 5MV/Cm – Dual Channel – delayed time base – illuminated graticule – Beam finder – Calibrator – power 200V – 250 volts AC – protection cover containing polarized viewer and camera adaptor plate – probe (1) – mains lead. Tested in fair condition with operating instructions. FEW AVAILABLE – NO PROTECTIVE COVER BUT MAINS LEAD + 1 PROBE – £125 – TESTED – Manual £15 extra.

Tektronix 475 – 200Mc/s Oscilloscopes – tested from £500 less attachments to £750 as new c/w manual, probes etc.

Telequipment D755 – 50Mc/s Oscilloscopes – Tested c/w 2 Probes – £250. Manual £5 extra.

Marconi TF2002AS – AM-FM Signal Generator – 10Kc/s to 72Mc/s – £85. Tested probe kit – £15 extra – Manual £10 extra.

Marconi TF2002B – AM-FM Signal Generator – 10Kc/s-88Mc/s. – £100 Tested to £150 as new – Probe kit £15 extra – Manual £10 extra.

Marconi TF2008 – AM-FM Signal Generator – Also Sweeper – 10Kc/s-510Mc/s – from £450 Tested to £550 as new with manual – Probe kit in wooden carrying box – £50 extra.

Don 10 Telephone Cable – ½ mile canvas containers or wooden drum new from £20.

Army Whip Aerials screw type F sections and bases large qty available P.O.R.

Test Equipment we hold a large stock of modern and old equipment – RF and AF Signal Generators – Spectrum Analysers – Counters – Power Supplies – Scopes – Chart Recorders all speeds single to multipen – XY Plotters A4-A3.

Racal Modern Encryption Equipment – Racal Modern Morse Readers and Senders – Clark Air Operated Heavy Duty Masts – P.O.R.

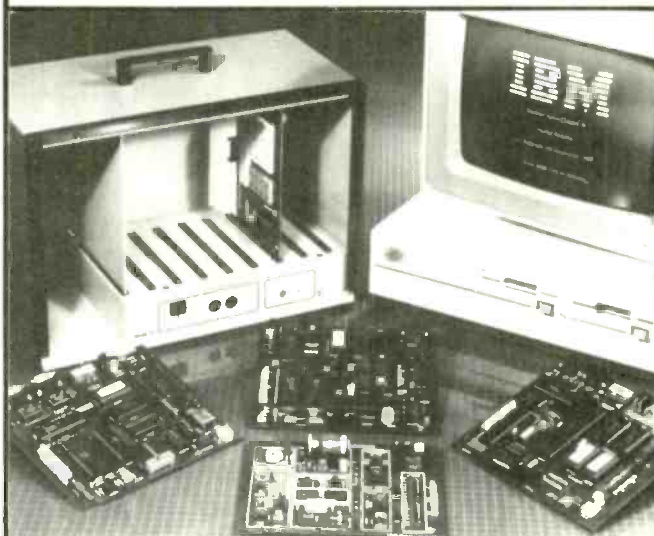
All items are bought direct from H M Government being surplus equipment; price is ex-works. S.A.E. for enquiries. Phone for appointment for demonstration of any items, also availability or price change V.A.T. and carriage extra.

**JOHNS RADIO, WHITEHALL WORKS,
84 WHITEHALL ROAD EAST, BIRKENSHAW,
BRADFORD BD11 2ER. TEL NO. (0274) 684007. FAX: 651160**

WANTED: REDUNDANT TEST EQUIPMENT – VALVES – PLUGS – SOCKETS – SYNCHROS ETC. RECEIVING AND TRANSMITTING EQUIPMENT – GENERAL ELECTRONIC EQUIPMENT

ENTER 13 ON REPLY CARD

DIGIAC 2000



The Next Generation

The D2000 system has been specifically designed to provide a modular, microprocessor technology training resource, that can be used for both traditional classroom based instruction and open-access learning.

This comprehensive system provides a range of both 8 and 16-bit microprocessor boards together with an applications card, keypad/display and powerful Cross Assembler software for use with IBM PC microcomputers.*

A range of open-access style curriculum packages are available, covering both microprocessor applications and troubleshooting for the 6502, Z80 and 68000 micro boards.

For full details please contact LJ today:

LJ Technical Systems Ltd.
Francis Way, Bowthorpe Industrial Estate,
Norwich. NR5 9JA. England.
Tel: (0603) 748001. Fax: (0603) 746340.

*IBM is a registered trade mark of International Business Machines

ENTER 22 ON REPLY CARD

SCSI – Small Computer System Interface

Gerry Humphrey of Rodime describes the development and implementation of SCSI, with particular reference to system integration

The Small Computer System Interface (SCSI, pronounced "Scuzzy") is a standard interface bus, through which computers may communicate with intelligent peripheral devices such as disk drives (hard and floppy), tape drives, printers, plotters, scanners, optical disks and others.

The SCSI bus is extremely versatile, being optimized for use with peripheral devices, and offers many advantages in terms of performance and ease of use. As it has been endorsed by so many major computer and peripheral manufacturers, high-volume production has made SCSI peripherals highly competitive on cost. This article will show how system manufacturers, peripheral manufacturers and system integrators use SCSI technology to provide flexible, high-performance machines – particularly significant with the demand for advanced equipment which can easily be modified and upgraded. Since the specification for SCSI-2 is not yet complete, and to avoid unnecessary confusion, technical details and references are limited to SCSI-1 only.

Definition: The present American National Standards Institute (ANSI) specification which defines the standard for the SCSI bus runs to more than 200 pages. If a short explanation had to be given as to what this specification actually defined, it would probably go as follows. "This standard specifies the mechanical, electrical, and functional requirements for a small computer input/output bus interface, and command sets for intelligent peripheral device types, particularly storage devices, commonly used with small computers."

History

To give the complete history for SCSI would be like discussing the motor-car, "from the wheel to the present day". Although the world of computer hardware is a relatively new one, so many advances and developments have been made in such an incredibly short time that to trace the roots of any specific area of current technology would take us outside the bounds of this article.

IBM started the ball rolling in the 1960s and 1970s with the creation of i/o channel architecture, which enabled intelligent peripherals to communicate with multiple hosts across a single bus. Shugart recognised the advantages of this interfacing concept and improved on it to make the SASI bus (Shugart Associates Standard Interface). This was widely accepted throughout the industry as the "latest" in interface technology, quickly becoming a *de-facto* standard.

The need to have a precisely defined (official) standard soon became clear, so to this end, the American National Standards Institute (ANSI) committee X3T9.2 accepted the SASI bus concept as the basis for a standard. The committee, which included representatives from interested manufacturers, were given the task of providing the specifications governing all aspects of the SCSI interface. The name "SCSI" was carefully chosen to be free from any reference to commercial organisations.

Originally, one of the main reasons for SCSI was to provide true compatibility between storage devices from different manufacturers (mainly disk drives). With disk-drive technology developing at a remarkable rate, it became difficult to maintain a standard system configuration. As improvements in media, data heads and engineering design were made, it became possible to get more data read/write heads and data tracks into the same (and even less) physical space, with a resultant increase in disk capacity and difficulty in maintaining compatibility with standard controllers.

As many manufacturers were working individually, the market was offered a tremendous range of advanced equipment with widely varying disk parameters (cylinders, heads and sectors/track). For the system integrator, this meant that each model of disk drive required a separate device driver and second-sourcing became a problem.

Development of relatively inexpensive VLSI device controllers, capable of being integrated into the disk-drive electronics, meant that these problems could be resolved within the disk drive itself (see **Figs 1 and 2**). SCSI allows much greater flexibility and ease of integration, since it perceives any SCSI device as a series of contiguous logical blocks (for example: 0-40 000 for a 20 Mbyte disk drive having 512 byte/sector), and not as a number of heads and cylinders. This makes the system independent of device type and provides the system integrator with greater choice of storage devices.

The software and hardware structure of the interface meant that it became a natural option for other types of peripherals, making the SCSI bus an extremely powerful and versatile communication tool.

SCSI *v* ST506

Moving from the device-level interface offered in ST506 disk drives to the system-level interface of SCSI disk drives offers several advantages. The most immediate benefit when using disks with embedded SCSI is that no additional controller is required, as in the case of the ST506 interface. The device-level control is built into the drive electronics. To interface it to a system, all that is required is a SCSI host adapter.

Figures 1 and 2 illustrate the manner in which the two types of drives may be integrated into a system. With the ST506 interface we have the possibility of expanding the system with the addition of another six SCSI devices which may be the same, or of different types, all of which should take up only one slot on the AT bus, since they may be able to connect to the same host adapter.

The SCSI disk drive is an intelligent peripheral, capable of correcting errors and handling media defects in a manner which is transparent to the system. In terms of system speed, an average access time of 18ms (fast by disk-drive standards) is extremely slow; SCSI disk drives which support disconnect/reconnect provide multi-tasking operating systems with a greatly improved data throughput rate, since they allow other disks to be accessed whilst they perform a seek operation to a requested block. If arbitration is supported by all devices on the SCSI bus, systems may be connected together via their SCSI ports to allow the disk drive (and all other devices on the bus) to be "shared". The benefits to be gained by this approach are significant.

The maximum transfer rate of an ST506 disk drive is 5Mbit/s. Typically, a SCSI disk drive may have a maximum transfer rate of up to 1.5Mbyte/s, but a drive that uses a cache memory scheme may be able to transfer data at a much greater "burst" rate: figures of 4Mbyte/s (for synchronous transfer only) are not uncommon. Also, cache-memory buffering allows the drive to be formatted at 1:1 interleave, as the transfer will take place from cache memory to host; thus, the drive will always perform at the optimum transfer rate for the system.

Since SCSI uses logical block addressing, the only difference (geometrically speaking) between disk drives from different manufacturers is the total

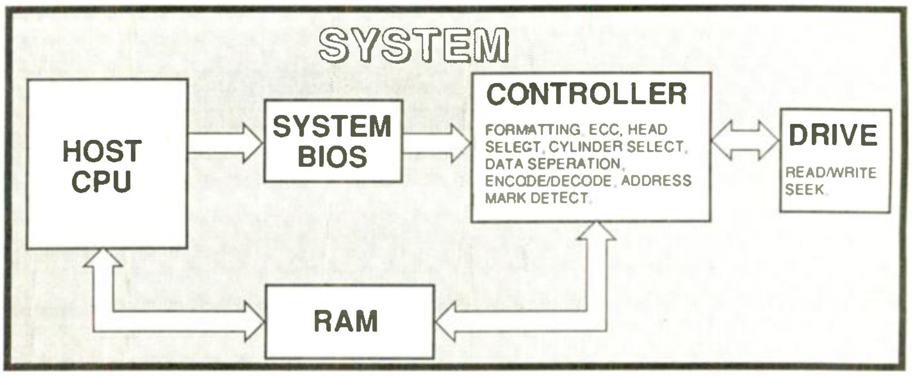


Fig. 1. Typical arrangement for a system using an ST506 interface disk drive.

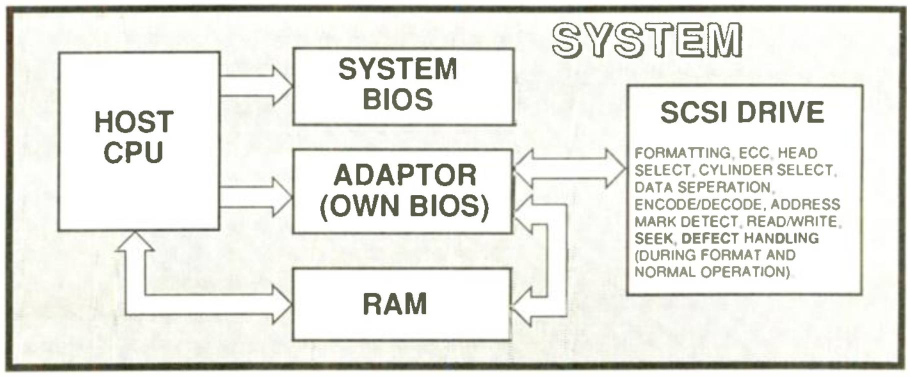


Fig. 2. Typical arrangement for a system using a SCSI interface disk drive.

number of logical blocks which may be addressed. The translation between logical block and cylinder/head/sector is taken care of by the drive's processor; so, too, are other functions such as write precompensation, reduced write current per cylinder, data encoding and decoding (2, 7 run-length-limited code is typically used) and flaw mapping.

From the physical point of view, there are no special mounting, power or environmental requirements for a SCSI drive, when compared to its ST506 counterpart; the specifications are generally the same.

General features

One of the purposes of SCSI is to move the "intelligence" of peripheral operations away from the CPU itself out to the peripheral devices. The system itself becomes a SCSI device, being what is referred to as an "initiator"; that is, the device responsible for originating an operation. A peripheral is normally a "target", the device which performs the operation. Some peripherals may, on certain occasions, act as an initiator: a tape streamer (for example) which supports the COPY command may direct a target (a hard disk, say) to read data which the streamer will then itself write to tape.

Figures 3, 4 and 5 illustrate some

Fig.3

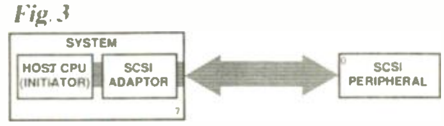


Fig.4

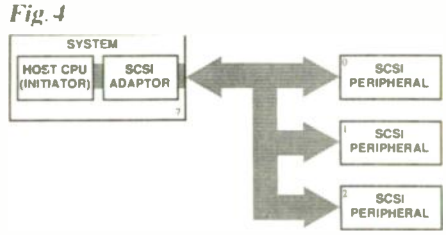


Fig.5

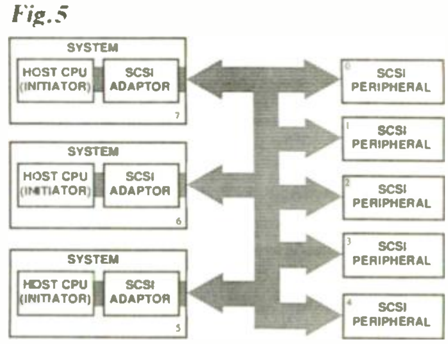


Fig.3, 4 and 5. Configurations for devices on a SCSI bus. Fig. 3 shows a single initiator and single target, Fig. 4 a single initiator and multiple targets and Fig. 5 multiple initiators and multiple targets.

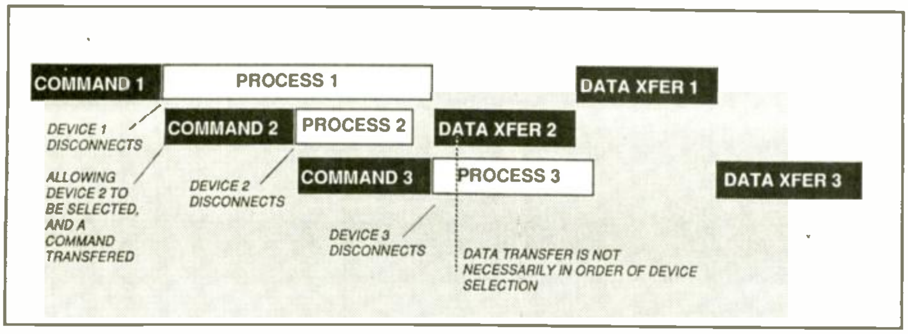


Fig.6. An example of command inter- leaving.

possible configurations for devices on a SCSI bus. From these drawings, it may appear that there is a possibility of a conflict of operations occurring. With several devices using the bus to perform different functions, it is necessary to have a scheme whereby each device is assigned a unique identification and a protocol is used to establish the way in which the bus is shared. This is done by giving each device a "SCSI address": any number from 0 to 7. This may be defined by a link, a switch, or other means and will be "read" and remembered by the device when power is applied. No devices can have the same address.

That takes care of the problem of device identification. The question of protocol is addressed by a scheme called "arbitration". In a configuration containing more than one initiator, or in a multi-tasking environment, where more than one device may require access to the bus simultaneously, each device will monitor the status of the bus and when it is free, will vie for use of it. This is achieved by each device flagging its own SCSI address and asserting the BUSY signal, checking the data bus to see if there are any devices with higher priority. Priority is determined by SCSI address; the higher the address number, the greater the priority. Initiators are generally given the highest priority (7).

In a multitasking environment, the power of SCSI becomes obvious. One of the major benefits is a feature referred to as disconnect/reconnect, which is the ability of a SCSI device to disconnect itself, freeing the bus, whilst performing a slow operation (a seek for example) and then to arbitrate for the bus when the operation is complete. This capability is built into the SCSI device and requires no support from the operating system.

Figure 6 illustrates the way in which multiple operations may "interleaved" on the bus, enabling the system to use other SCSI devices whilst waiting for completion of an operation in one particular device. Even in a high-performance hard disk, an average access time of 24ms is still a relatively long time when measured in CPU machine cycles. The capability to interleave operations means that the bus may be utilised to a very high degree of efficiency, greatly improving the system's i/o throughput.

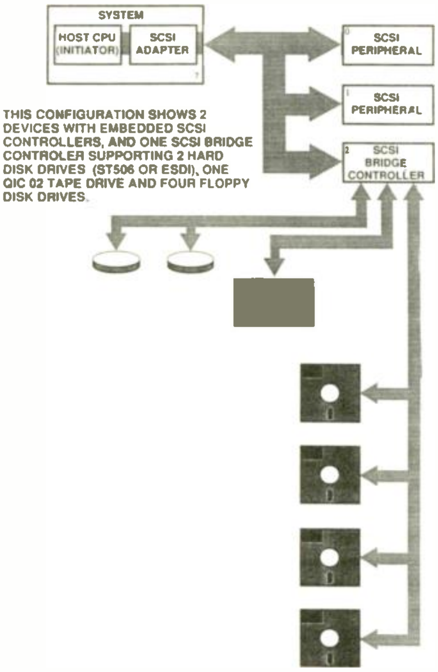


Fig.7. Peripherals with device-level interfaces in operation on SCSI, using a bridge controller. Up to eight peripherals can be attached to each bridge controller.

Implementation

Some computer manufacturers, such as Apple and Sun Microsystems, have already realised the benefits of using SCSI by building-in a SCSI port. In the world of PC-AT machines, the integration of SCSI peripherals, although not as simple as "plug-and-play", is relatively straightforward. A SCSI adapter containing the necessary hardware and firmware for interfacing the PC-AT bus to the SCSI bus must be plugged into one of the slots in the system bus, effectively creating a SCSI port and making the system another device on the SCSI bus. There is a wide range of commercially available SCSI host adapters on the market. Two methods of implementing SCSI in peripheral devices exist.

Embedded SCSI. With VLSI, SCSI chip-sets are now available that allow the SCSI controller to be designed directly into the peripheral's interface circuitry, which means that no other hardware is required for connecting the device to the bus. With mass-production, this method of using peripheral devices with SCSI is both cost-effective and more reliable (the old argument of "the simpler, the better" holds true). Also, embedded SCSI means that compatibility between the SCSI controller and the peripheral device is "built-in" by the manufacturer.

SCSI bridge controllers. It is possible to use peripherals with traditional device-level interfaces on a SCSI bus by using a bridge controller (see **Fig. 7**), which was a method adopted by many peripheral manufacturers in the early stages of the SCSI market, prior to the wide availability of SCSI chips, as a way of offering SCSI devices to their customers.

Bridge controllers are still available, and allow the system integrator to use standard device-level interface peripherals on a SCSI bus. This method may permit the use of logical unit addressing; that is, the capability of having more than one device attached to each controller. With eight SCSI addresses available and each address allowing up to eight logical units to be attached, it is possible to have up to 64 devices sharing a SCSI bus. Figure 7 illustrates how the two methods may be employed on the same SCSI bus.

Software requirements. In the case of hard disks, no special software is required when operating a system with DOS 3.3 or higher. Partitioning may be carried out in the normal fashion using FDISK, and each partition may be system formatted as required. With DOS 4, it is possible to use the disk as one complete partition, without the historical 32Mbyte restriction imposed by IBM.

When using other SCSI device types, and or different operating systems, it may be necessary to use a special installation routine (supplied by the manufacturer) and possibly a device driver. Alternatively, the necessary driver code may be contained in firmware on the adapter card, in the form of a system-accessible rom module which will "hook" itself into the system as required by intercepting interrupt vectors.

There is no shortage of ways to install SCSI devices in PC-AT machines. In general, manufacturers of both adapters *and* peripherals supply utility software that allows a user to configure his device to suit his system's needs. There are also some commercially available utilities that will provide the user with a complete disk-management package.

Peripherals which require special software for installation and/or operation in the AT environment will, as a matter of course, have it "bundled". Along with your SCSI peripheral, your supplier shouldd provide you with any necessary software and a user manual (which you should read in full!).

When it is necessary to obtain specific details for integrating SCSI devices into a system, the user should never hesitate to call upon his dealer for support (make them earn their profits!) and, if not satisfied, contact the distributor or even the manufacturer. It is in the interest of everyone involved in supplying the products to make sure it fits the customers' needs.

A word of caution is relevant here. Amongst the aims of SCSI was the facility to provide device independence and much-simplified second-sourcing. Some manufacturers have chosen not to pass on this benefit to their customers. The features that make SCSI so versatile and powerful may also be employed by manufacturers of systems and adapters to prevent customers from upgrading their system using a third-party SCSI device, so forcing them to buy the peripherals from the original source at a higher cost and with less choice.

A simple method that may be employed is the use of the SCSI INQUIRY command that calls upon the target to return certain device-specific parameters such as the manufacturer's name and product identification. It is a simple process to exclude any devices that do not match up with a table of accepted devices during the installation procedure. However, more subtle and astute means may be employed that would make it difficult for anyone (even for someone with in-depth SCSI knowledge) to use a SCSI peripheral from another source.

It would be advisable to check with the supplier if any of these schemes are implemented, if one is considering using devices from a number of sources.

SCSI specification

SCSI is implemented on a 50-way bus which has multiple independent interchangeable slots. As devices of different types may be connected to the bus in daisy-chain fashion, it is clear that a common code of practice must be observed for details such as the physical interface (signals, drivers, bus timing, connectors, cables and impedance matching) and the software interface.

The ANSI specification (as previously mentioned) is extremely long and complex. To give a brief summary we must divide it into its two main areas: physical and logical. This will allow us to give a description of the fundamental requirements that must be observed for SCSI conformance.

Table 1. Single-ended driver-receiver pin assignments.

SIGNAL	PIN	GND RETURN PIN	SIGNAL NAME
-DB(0)	2	1	DATA BUS
-DB(1)	4	3	
-DB(2)	6	5	
-DB(3)	8	7	
-DB(4)	10	9	
-DB(5)	12	11	
-DB(6)	14	13	
-DB(7)	16	15	
DB(P)	18	17	DATA BUS PARITY
GROUND	20	19	
GROUND	22	21	
GROUND	24	23	
TERMPWR	26	25 (OPEN)	TERMINATOR POWER
GROUND	28	27	
GROUND	30	29	
-ATN	32	31	ATTENTION
SPARE	34	33	
-BSY	36	35	BUSY
-ACK	38	37	ACKNOWLEDGE
-RST	40	39	RESET
-MSG	42	41	MESSAGE
-SEL	44	43	SELECT
-C/D	46	45	CONTROL/DATA
-REQ	48	47	REQUEST
-I/O	50	49	INPUT/OUTPUT

N B
PIN 25 SHOULD BE LEFT OPEN ALL OTHER ODD PINS SHOULD BE CONNECTED TO GROUND
A MINUS SIGN NEXT TO A SIGNAL INDICATES ACTIVE LOW

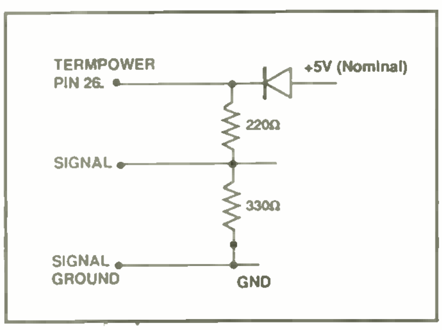
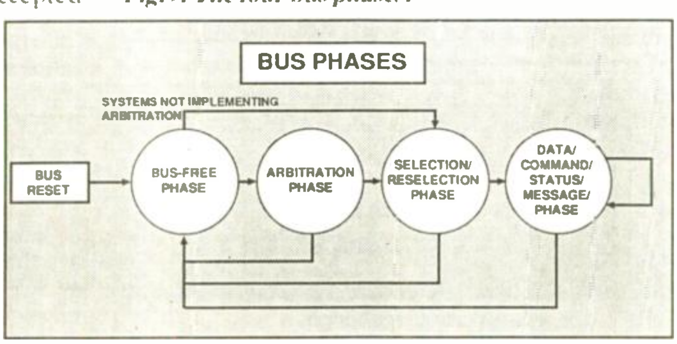


Fig.8. Both ends of the 50-way SCSI cable must be terminated. This is the terminator power connection.

Fig.9. The four bus phases.



Physical. SCSI devices are daisy-chained together using a common 50-way cable. Both ends of the cable must be terminated (see **Fig. 8**). All signals are common between all SCSI devices. There are two driver/receiver combinations available: single-ended drivers and receivers, which allow a maximum cable length of six metres; and differential drivers and receivers, which allow cable lengths up to a maximum of 25 metres. The two kinds may not be mixed on the same bus.

In general, most devices available use the single-ended driver receiver option; Table 1 gives the pin-assignments for this arrangement.

The SCSI bus comprises eight data lines, one data parity line, a terminator power line and nine control lines. The data lines are used for the transfer of data, command, status and message information, while the nine control lines provide the necessary sequencing and hand-shaking information for the transfer of information.

Logical. The SCSI bus can be in any one of four phases at any given time: bus free, arbitration, selection or information transfer. **Figure 9** illustrates the way in which the bus may move through the phase sequence. Arbitration is optional, though most devices now support this scheme.

The way in which the control signals are asserted/deasserted and the timing involved are critical for correct operation. A typical sequence is given in **Fig. 10**.

Bus free. All command sequences begin with this phase. The bus free phase indicates that no initiator or target is currently using the bus, and that it is available for subsequent users.

Arbitration phase. The initiator tries to gain control of the bus by asserting BUSY an its own bus device ID on the data bus; then after a minimum of 2.2 μs examining the data bus to see if there is a device with higher priority (7 is highest). If unsuccessful, the initiator will release BUSY. If the initiator wins arbitration, it will assert SEL and proceed to selection (or reselection).

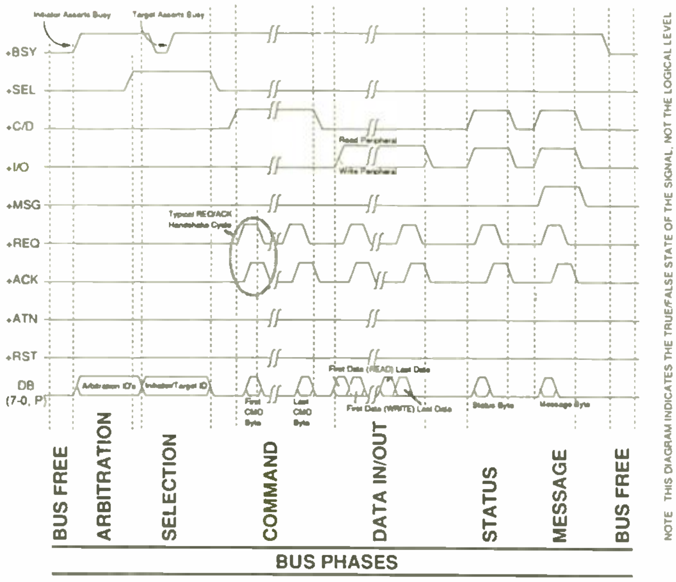


Fig. 10. Typical sequence of signal assertion and de-assertion.

Selection. The initiator will assert its own ID and that of the required target on the data bus, then release BUSY. The target will recognise that it has been selected when it detects that SEL and its ID are true and that BUSY and I/O are false. The target will then assert BUSY, which will allow the initiator to release SEL, and enter the command phase.

Command. The transfer of information will be from initiator to target. The target will assert C/D and deassert I/O and MSG, then move into the REQ/ACK handshake procedure; the target will assert REQ, the initiator will then drive the data lines to their desired values and then assert ACK. The target may read the data bus and then release REQ. When REQ becomes false, the initiator may then change the data and deassert ACK.

The target will continue requesting command data using this procedure. The number of bytes to be sent is encoded in the first byte of command information.

Data in/out. The target will assert or deassert I/O according to whether the transfer is data in or data out, then deassert C/D and MSG and use the REQ/ACK handshake procedure to read or write data as required.

Status. This phase is used to allow the target to request that status information be transferred to the Initiator. It is achieved by asserting I/O and C/D and deasserting MSG during the REQ/ACK handshake of this phase.

Message. Message in allows the target to request that message information be sent to the initiator. The target will assert MSG I/O and C/D during the REQ/ACK handshake for the required number of bytes. The message out phase allows the target to request that message information be transferred to the target. The target will deasset I/O and assert C/D and MSG during the handshake procedure. Table 2 provides reference between phases, signals the devices.

The first byte of every SCSI command is the Operation Code.

The remaining bytes provide the parameters for the command.

Bit / Byte	7	6	5	4	3	2	1	0
0	GROUP CODE			COMMAND CODE				
1	LOGICAL UNIT No.			LOGICAL BLOCK ADDRESS (MSB)				
2	LOGICAL BLOCK ADDRESS							
3	LOGICAL BLOCK ADDRESS (LSB)							
4	TRANSFER LENGTH							
5	CONTROL BYTE							

08
00
00
00
0F
00

This is an example of a Group 0 command, that is requesting the Target to Read from Logical Block zero for a length of 15 Blocks

Fig. 11. Command descriptor block, allowing the transfer of up to 256 blocks for one command.

BUS PHASE	SIGNALS: BSY	SEL	C/D, I/O MSG, REQ	ACK	DB(7-0,P)
BUS FREE	NONE	NONE	NONE	NONE	NONE
ARBITRATION	ALL	WINNER	NONE	NONE	SCSI ID
SELECTION	I & T	INITIATOR	NONE	INITIATOR	INITIATOR
RESELECTION	I & T	TARGET	TARGET	INITIATOR	TARGET
COMMAND	TARGET	NONE	TARGET	INITIATOR	INITIATOR
DATA IN	TARGET	NONE	TARGET	INITIATOR	TARGET
DATA OUT	TARGET	NONE	TARGET	INITIATOR	INITIATOR
STATUS	TARGET	NONE	TARGET	INITIATOR	TARGET
MESSAGE IN	TARGET	NONE	TARGET	INITIATOR	TARGET
MESSAGE OUT	TARGET	NONE	TARGET	INITIATOR	INITIATOR

INITIATOR - IF THIS SIGNAL IS DRIVEN IT SHALL BE DRIVEN ONLY BY THE ACTIVE INITIATOR

TARGET - IF THIS SIGNAL IS DRIVEN IT SHALL BE DRIVEN ONLY BY THE ACTIVE TARGET

WINNER - THIS SIGNAL WILL BE DRIVEN BY THE ONE SCSI DEVICE WHICH WINS ARBITRATION

ALL - ALL SCSI DEVICES WHICH ARE ARBITRATING WILL DRIVE THIS SIGNAL

NONE - THIS SIGNAL WILL NOT BE DRIVEN BY ANY SCSI DEVICE

SCSI ID - EACH ARBITRATING SCSI DEVICE WILL DRIVE ITS OWN UNIQUE SCSI ID BIT ON THE RELEVANT DATA BUS LINE (0 7)

I & T - THE BUSY SIGNAL MAY BE DRIVEN BY THE TARGET INITIATOR OR BOTH DURING THE SELECTION/RESELECTION PHASE

Table 2. Reference between bus phases, signals and peripherals.

Commands

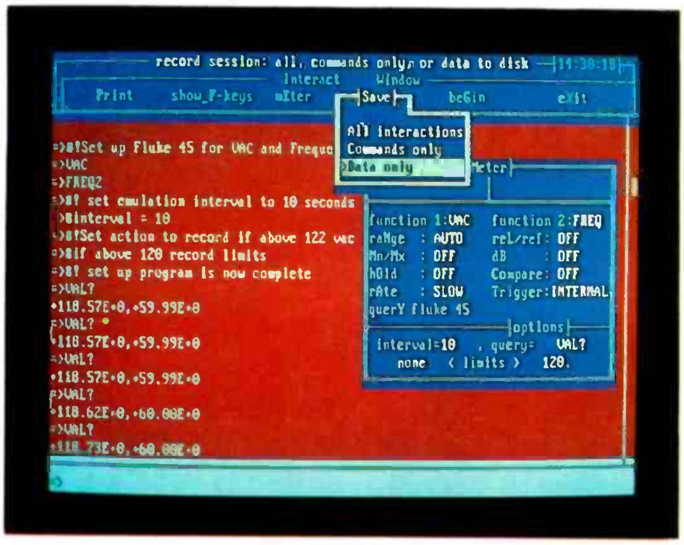
To make a target perform an operation, an initiator must successfully arbitrate for use of the bus, select the appropriate devide and transfer the command to be executed. The SCSI command set is a precisely defined suite of high-level instructions that effectively "cloak" the internal workings of SCSI peripherals. All SCSI devices must support certain mandatory commands; most will also support many of the optional commands available.

Figure 11 shows the structure of a command descriptor block. This is a 6byte Group 0 command, which allows the transfer of up to 256 blocks of data for one command. There are eight groups of commands available which provide for extra addressing, larger data transfers and special commands for manufacturers' use. Group 1 commands, for example, support extended addressing (32 bits) and provide two bytes for the transfer length, allowing up to 65,535 blocks of data to be transferred for one command.

Although users can realise some of the benefits of the performance and versatility of the Small Computer Systems Interface today, operating systems and applications do not yet provide direct support. When this happens, and when SCSI-2 (or greater) is implemented, we will be moving into a new generation of i/o management.

A key objective of the SCSI-2 specification is to move device-dependent intelligence out to the SCSI-2 devices. With the option of a data bus 32-bits wide, and commands such as "Search Data" (for a specified data pattern), "Copy & Verify" and command queuing receiving wide support, and many more enhancements and improvements over SCSI-1, it is clear that extremely powerful file management operations may be carried out at device level.

Meanwhile, the advantages of SCSI-1 are there for the using, and a great deal of SCSI-ready peripherals are available on the open market. ■



RS-232 for instrument control

Philips now offers a low cost multimeter with RS-232 porting. Together with a comprehensive PC-based software driver, the combination competes directly with GPIB instruments.

Robert Gibson

In the "interact window", the selection of functions and values is made by pull-down menus, and when applicable, editable fields. When the Enter key is pressed, the command and values are sent to the instrument. This type of user interface all but eliminates the need to type in command strings, although they can still be entered at any time on the command line.

The basic function of an RS-232 instrument comms program is to provide a means of establishing communications with an instrument, send a series of commands, retrieve and display the responses, and allow for the recording/printing of those responses. This article identifies common instrument communication problems which must be considered. Further, it describes possible enhancements to the communications link.

Establishing communications

To establish communications between a PC and an instrument (connected by the proper cable), both must be set for the same data rate, parity, and number of data bits. Rather than require the user to determine the current settings on the instrument and set the PC's to match, a program should automatically find and match the instrument's settings.

To do this, one needs an instrument command which will always elicit the instrument's "prompt". The program then sends this command to the instrument and examines the response for the prompt. If the correct response is not received, the program alters the communication parameters and repeats the command. This "send command examine response sequence" indicates that communication is established. Such a routine eliminates a major portion of the setup problems people encounter with a serial link, and in a minimum amount of time.

Dialogue

Communication between the PC and the instrument is a two-way process, a dialogue. For each command string sent to the instrument, the program needs to receive a response that indicates completion of the command. This dialogue allows the program to establish synchronization with commands and responses required for command error reporting, testing response data, and preventing the command overrun possible in some instruments. Most instruments return a prompt for just this purpose; i.e., to notify some external device that the last command is completed. The program will wait for this notice of completion before transmitting further commands.

If an instrument does not have a prompt to return, the program needs to force one of its own. The program could accomplish this by issuing a command that elicits a unique and predictable response from the instrument, such as its firmware version, or some other constant value. This command can then be issued routinely after each "real" command, and the returned string then used as the command completion prompt.

Special characters

For a terminal, it makes no difference whether a line is terminated by a <CR> (carriage return) <LF> (line feed) or a <LF><CR>. Nor does a terminal care if the instrument is inconsistent with the order of these terminators, as is sometimes the case. If the program is expected to save data to a file, send it to a printer, or control where the data is displayed on the screen, the program must recognize either order as the termination of a returned string, and then strip the terminators from the data as it is received.

In a like vein, if a terminal receives "123<BS>4" (where <BS> is a backspace character), it will display "124". Given this same character string, a PC will print "123<happy face>4". The program must examine the input string for backspaces and bells. When a backspace character is encountered, it must delete it, and also the character that precedes it. When a bell character is found, it should delete the character and beep once. The program should allow the other control characters to be displayed just as the PC presents them, but should translate the characters to a pair of characters if they are to be passed to a printer.

For example, the PC will display a Control-X as an up arrow, but rather than sending the non-printable Control-X character to a printer, the program can send "X" instead. While treatment of other control characters for the PC display might be similarly translated, doing so may complicate the editing of command strings beyond its worth.

Command errors

Most instruments report command errors upon receipt. The error reporting may be made by the inclusion of an error message, or error code, before the "command completion" prompt. Or, the indication of an error may be made by changing the completion prompt itself. In some cases the user must issue a command to read a command error buffer in order to determine whether there was an error upon completion of a command. In any event, the program needs to routinely check for command acceptance, and issue a warning to the user if an error is detected.

Command sequencing

As described to this point, the PC is essentially operating as a terminal emulator (since its extra intelligence is transparent to the user), allowing the user to enter a command and receive the response for display, printing, and/or recording. On receipt of the command completion prompt, the send/receive process is allowed to continue. The program is now ready to read a sequence of commands from a recorded text file, rather than from the keyboard. The instrument/PC operational process is the same as described for keyboard entry; one command is issued and completed at a time, but in this case, executing the sequence of commands has been automated.

User interface

The Fluke terminal used the <CR><LF> string termination to scroll the 24-line screen. The PC allows for one non-scrolling line at the bottom of the screen so that programmers can give the operator some idea of program status, or options, and still scroll the screen. Whilst one non-scrolling line is better than none, it is insufficient as an effective user interface, and hardly meets the expectations of the typical PC user. While the implementation of screen layout is up to the designer, menu bars at the top of the screen as well as pull-down and pop-up menus, all require that the program controls where the data is displayed. If the program is to make the data appear to scroll in a portion of the display, then the last X lines of data will need to be kept in memory.

There are some advantages in this "manual scrolling" of the display. For instance, the program will hold a history of the last several commands issued, and responses returned, in this buffer. It is a simple matter to allow the user to move within the buffer and reissue, or edit and reissue, a previous command. This type of feature eliminates the need for the user to rekey the command, or a similar command.

If the number of command lines held in memory is increased, the user can be given access to more than the basic 25 lines available for a PC screen display. If the program is made to flag those lines of data in memory that were issued as commands, it can easily create a "sequence of commands" file that can be reissued to the instrument at some later time. With the command lines flagged, it becomes a simple matter for the program to determine which lines constitute data only, and then write this data to a file that can be passed to a spreadsheet program.

Applications

A multi-function instrument, such as a digital multimeter, when coupled to a command sequencer software package, can be used in a wide variety of testing and monitoring situations. Such applications might include control of a test station in a manufacturing environment, accumulating pass/fail data at a receiving inspection station, monitoring a test setup for any out-of-limits conditions, or possibly data logging.

Database or spreadsheet software can also enhance the use of the incoming inspection stations that use the command sequencer/multimeter setup to check components and assemblies for electrical parameters. Here the command sequencer can control the multimeter and write collected parameter values to a file that can be accessed by the database or spreadsheet software. The automated inspection station can be useful, not only in determining the pass or fail status of inspected components, but with the use of the data handling software, can be used to spot failure trends. ■

NPL'S ultrasound beam calibrator

Calibrating the beam of ultrasound used in medical diagnosis calls for advanced hardware and software design techniques that could be applied in other fields of measurement

R.C. PRESTON, D. WILLIAMS AND R.M. RODRIGUEZ

Since the 1960s when pioneers such as Ian Donald (**Fig. 1**) showed that useful medical diagnostic information could be obtained by sending pulses of ultrasound into a patient and detecting the echoes from tissue structures, diagnostic ultrasound has become a widespread clinical tool with obstetric examination being the major application (**Fig. 2**). Despite developments over the years, the concept of ultrasonic imaging has not changed: an ultrasonic beam consisting of a stream of pulses at megahertz frequencies scans a slice of the patient and the echo information is used to build up a two-dimensional picture of the tissue.

The direction of launch of a pulse from the ultrasonic transducer (which generates and receives the ultrasound) and the time of flight before return of the echo locates a feature in the image, the strength of the echo determining the brightness of that feature in the image. Originally, mechanical movement of the transducer scanned the beam, but automatic mechanical and electronic scanning has now reached levels of great complexity and ingenuity. Linear-array, phased-array and mechanically scanned sector scanners are just some of the systems in common use. Nowadays, the change between the received and transmitted frequency of a pulse caused

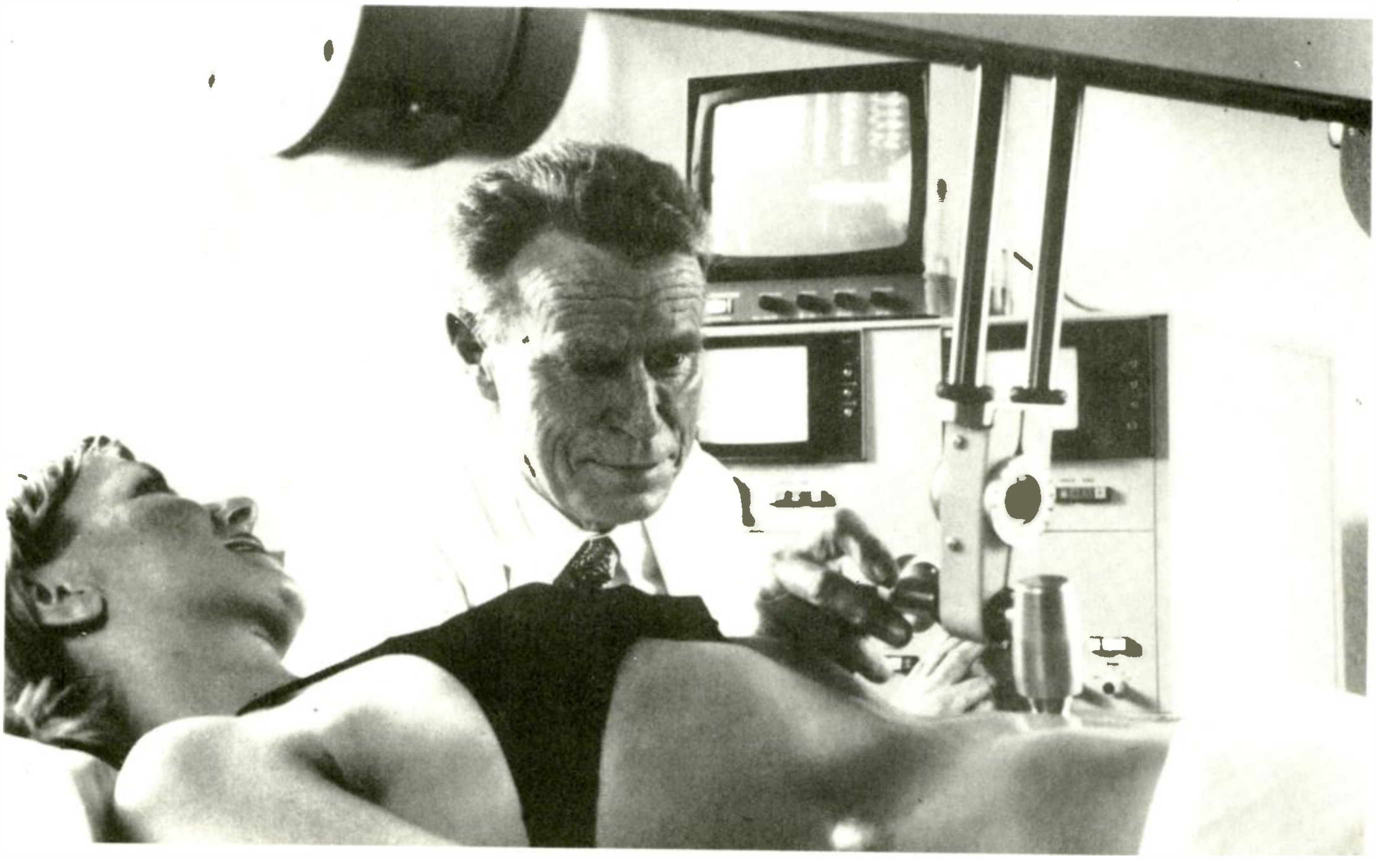


Fig. 1. The late Professor Ian Donald, one of the pioneers of medical ultrasound. (Photo by courtesy of J.E.E. Fleming).

by the Doppler effect can also be used to add information about blood flow, often in the form of colour-coded images.

Safety

From the early days, there has been a need to measure the acoustic output of medical ultrasonic equipment, to give information on the performance of the system and also for safety reasons. Performance information can be obtained from measurements of the beam shape, since this is related to depth resolution; for information, sound travels through tissue or water at a speed of approximately 1.5 mm per microsecond. Although ultrasound has always been considered less of a hazard than X-rays as a diagnostic tool, there has always been concern for safety. After all, the technique relies on acoustic energy being delivered to the patient and virtually all this energy is absorbed in the tissue. Heating of the tissue is one concern, and another is that the acoustic pressures generated by the equipment are extremely high: typically between 5 and 70 atmospheres peak pressure in the microsecond pulses.

Hydrophone

The National Physical Laboratory recognised the need for reliable methods of measurement on medical ultrasonic equipment. Over the past ten years it has collaborated with industry to develop new measuring devices and has led the establishment of international standards for equipment calibration. Measurements worldwide are now based on the use of very small hydrophones which probe the beam radiated by the ultrasonic transducer into a water-filled test tank. A special type of high-quality hydrophone has been developed with GEC-Marconi Research Centre which uses a piezoelectric plastic film called polyvinylidene fluoride, a small region of which, typically less than 1mm diameter, is made sensitive to the ultrasound.

This type of sensor is now widely used for laboratory measurements, but it was soon realised at NPL that the problems of interpreting the hydrophone signals and the time-consuming nature of the measurements made them unsuitable for wider applications in industry and in the medical physics departments of most hospitals. It was seen that a complete and purpose-designed measurment system was needed and, in response, the NPL developed the ultrasound beam calibrator.

Rapid digitisation and presentation of data in a manner similar to that described in this article for the NPL ultrasound beam calibrator is a common problem in many fields of measurement science. Although the beam calibrator utilizes an acoustic sensor with 21 elements, many other multi-element sensors could be interfaced to the analogue multiplexer. For instance, an array of optical diodes for detection of pulsed light beams could provide the basic signal input. Obviously, there would be minor differences in the control of the acquisition process and different requirements for presentation and analysis of the signals, but the concept would be very similar.

System operation

The calibrator is based again on the use of a membrane hydrophone, but this time the device has 21 separate sensing elements arranged in a line. The elements are 0.4mm diameter with 0.6mm spacing between centres and each is connected via a multiplexer and amplifier to a flash analogue-to-digital converter. The ECL output of the A-to-D converter is first stored in ECL memory and then rapidly downloaded into TTL memory for subsequent access by a PC, which controls the whole system. The information so stored represents the acoustic pulse waveform at each element. The process is shown schematically in **Fig. 3**, though it should be recognised that the technical problems of acquiring data at rates of up to 60MHz from each acoustic pulse, and responding to the next pulse within about 120µs, are quite formidable. To achieve these rates, certain compromises had to be accepted, such as limiting the number of bytes per acquisition to 128 or 256.

For modern ultrasonic scanners, it is important to be able to synchronize the acquisition process to a particular pulse in the sequence generated by the scanner. Versatile control of the multiplexer and also of the assignment of the memory locations for incoming waveforms was clearly essential, and a dedicated microprocessor was installed to handle the data-acquisition process and to receive control information and return data to the host PC. It is also important to display the waveform and the beam profile instantaneously so that the operator can position the transducer for maximum signal. Hence, the software control and display requirements were stringent.

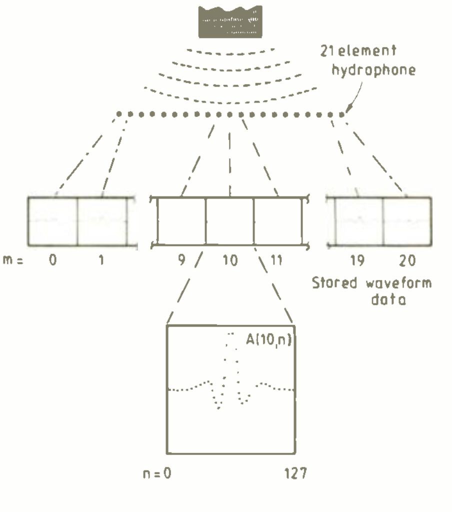
The culmination of this development programme is a unique measurement system (**Fig. 4**) which provides for the first time a method of determining the acoustic output of medical diagnostic ultrasonic equipment in a cost-effective manner. Following the acquisition of data, rapid analysis can be undertaken to give a set of results for immediate assessment or for production of a hard copy record. The interpretation of the data according to accepted international standards is assured by the software, which is an important consideration when comparing results from different sources or obtained at different times.

Signal acquisition

The scanner head of the ultrasonic equipment being evaluated is clamped above the tank such that its ultrasound-emitting face is just below the surface of the distilled water filling the tank. The hydrophone assembly sits in the water directly below the ultrasound scanner head under test, where the twenty-one elements receive the acoustic energy as pressure variations. Contained within the hydrophone assembly, and sealed to operate under water, is a horseshoe-shaped printed-circuit board containing twenty-one buffer amplifiers and a multiplexer, as shown in **Fig. 5**.

Each hydrophone element has its own fixed-gain, dual-fet high input-impedance amplifier with a signal bandwidth of approximately 100MHz. To avoid possible overheating of the amplifiers, the housing is filled with transformer oil to provide good thermal contact

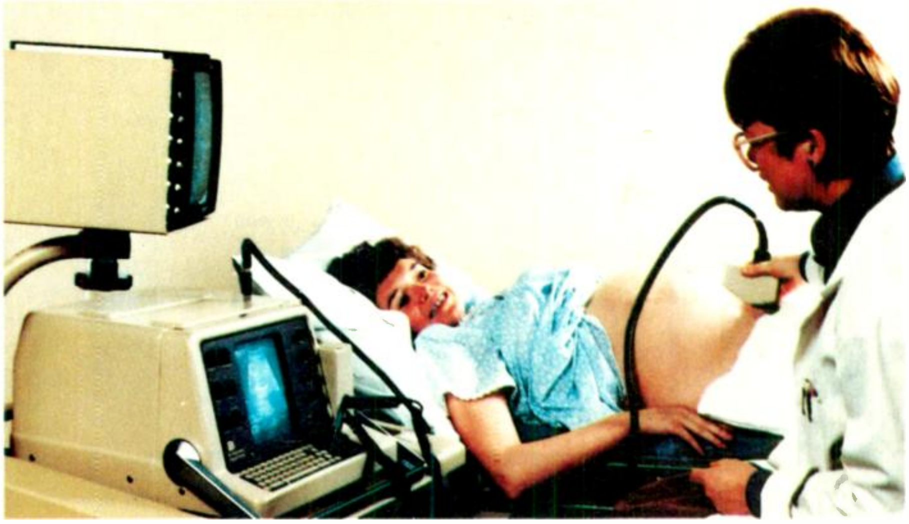
Fig. 3. Method of operation of the beam calibrator. A 21-element hydrophone probes the ultrasound field, the resulting signal being digitized and processed by computer for display and analysis.



to the case and the very effective heat-sink provided by 20 litres of distilled water beyond!

Rather than providing twenty-one direct connections to the digitizing unit, the amplifier outputs are multiplexed and matched to a single 50Ω impedance screened cable which connects to a 50Ω line receiver. But why multiplex the analogue outputs over the comparatively short lead connecting to the digitizing unit? Primarily the reason is to avoid the cross-talk and pick-up between channels that would inevitably result from twenty-one separate cables, however well screened. The analogue signals are transmitted in sequence with a different hydrophone element being monitored for successive ultrasound burst outputs. The process is illustrated by the block diagram at **Fig. 6**.

At the digitizing unit, the analogue signal path is provided with a switched gain stage of 60dB in 1dB steps, a demultiplexer and amplifiers to normalize the signals from each hydrophone



used in its major application – obstetric

Fig. 5. Membrane hydrophone, with 21 piezoelectric sensing elements.

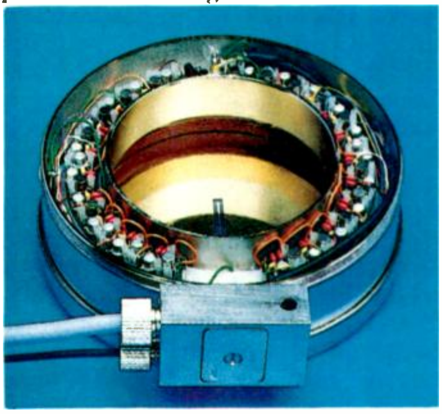
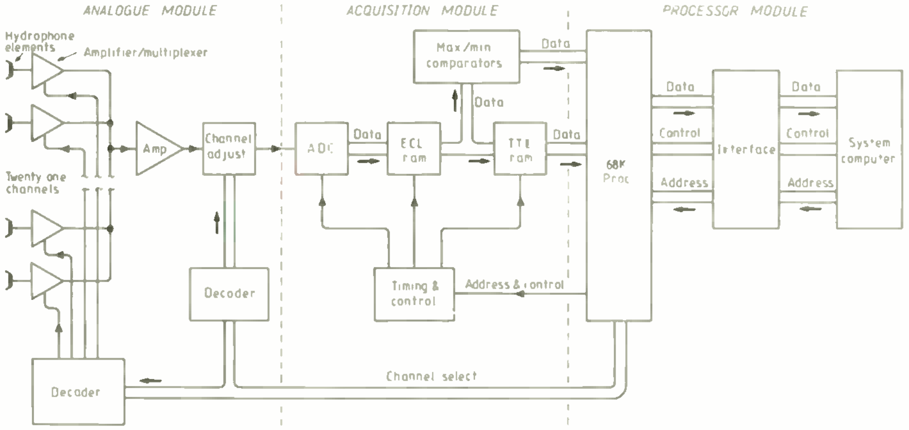


Fig. 4. The calibrator in use.

Fig. 6. Block diagram of the complete system.



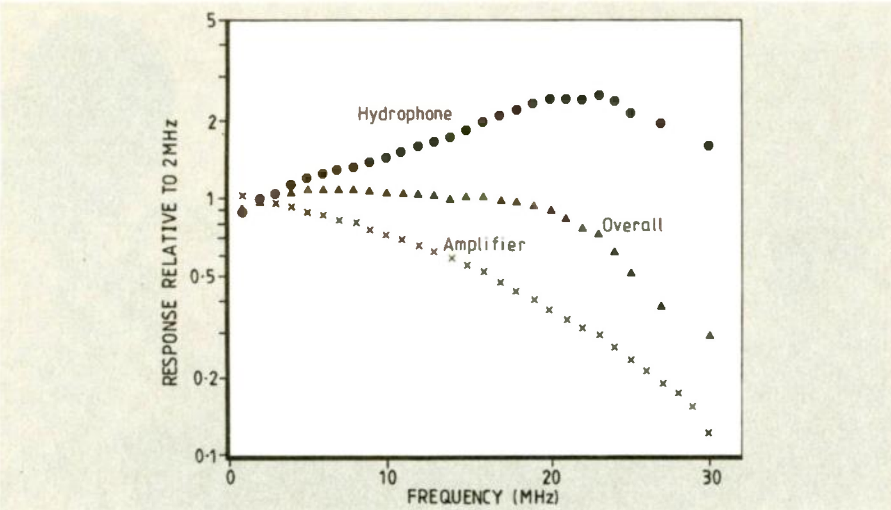
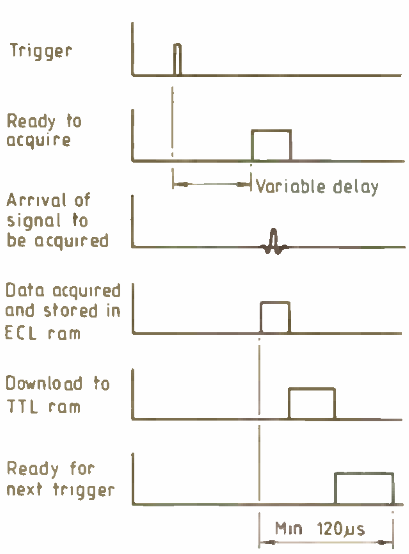


Fig. 7. A typical frequency-response plot from the calibrator, based on product of measured response of amplifier and predicted response of hydrophone.

channel. Normalization is necessary, since the sensitivity of each element on the polyvinylidene fluoride (PVDF) hydrophone varies by about 10%. The elements are piezo-electric and produce an electrical charge for an applied acoustic pressure, the output being measured as a voltage which will change as the element loading capacitance changes due to electrode lead capacitance, wiring and amplifier input-capacitance variations.

As only one high-speed (and expensive) analogue-to-digital converter is used, a further multiplexer stage is required. This is followed by an output amplifier which also provides frequency response shaping to compensate for the increase in hydrophone sensitivity with increasing frequency. The result is an acoustic pressure response which is flat to within ±1dB over the frequency range of 0.5 to 20MHz, as shown in **Fig.** 7. Measurements made by the National Physical Laboratory over a period of a year have shown the system sensitivity to be stable within to 5% or better – quite an achievement considering the many areas of potential drift.

Fig. 8. Timing diagram.



Analogue-to-digitial conversion

The analogue-to-digital converter is a TRW (of Guildford) 1025 8-bit flash converter operating at a rate of up to 60MHz. Sample sizes of 128 or 256 bytes can be selected, which means that for the first burst of ultrasound received, that many samples will be taken for the first monitored hydrophone element, the process being repeated until all the elements have been sampled. A complete set of samples will thus be 21 (elements) × 128 or 256 (samples) and will take 21 × the ultrasound burst repetition period to complete. Synchronisation to the ultrasound bursts is either by a direct trigger connection from the ultrasound equipment or via a pickup sensor mounted close to the scanner head.

Data at this rate is too fast for most families of memory, however, and certainly too fast to be presented directly to the system computer. Each block of 128 or 256 samples of the converter output is stored in fast ECL ram before being transferred to an area within an 8K block of slower TTL ram in the remaining period between ultrasound bursts. During this period, hardware peak detectors scan the data for the maximum and minimum signals received, which represent the peak-positive and peak-negative acoustic pressures and are used in the subsequent data anlaysis and to assist in aligning the hydrophone to the scanner head under test.

Timing and control

Timing is clearly critical to the whole process of signal acquisition and conversion. As well as controlling the timing of the multiplexers, the data acquisition needs to be synchronized to the bursts of ultrasound produced by the scanner under test and the resulting digital data needs to be transferred to the system computer. **Fig. 8** summarizes the timing sequences.

In use, the operator will adjust a trigger-delay control, as a delayed timbase oscilloscope would be adjusted, to allow for the propagation time of the ultrasound signal through water to the hydrophone. Other timings are controlled by a Motorola 68008 microprocessor, which also manages the interface to the system computer, typically an Intel 80286 based PC-AT.

The Motorola 68008, with its 10MHz clock, is housed in the digitization unit and is supported by two 10MHz 68230 parallel port/timer devices. It initiates all data-acquisition sequences, allocates memory for data storage and grants access to the system computer on a priority-interrupt basis. Highest interrupt priority is to the acquisition and safe storage of data, the next level being for the PC-AT requiring access to the data. If access is denied, the PC-AT must wait and try again later. Communications and data transfer to the computer are via one of the 68230 parallel ports connected 'back-to-back' to an Intel 8255 port and a special IBM-compatible interface card occupyuing one back-plane slot.

Software

The functions of this software include management of PC/AT facilities such as displays, disks, printers; transfer of data and information between the user and the calibrator instrument; the processing of raw acoustic pressure response data to determine a number of acoustic parameters to international measurement standards; presentation of those parameters as screen graphs, printout summaries, plots, allowing changes to be made in the calibrator set up; and file storage of raw data for deferred analysis, averaging and/or corrections.

This software is written in poly-FORTH, a professional multitasking version of the high-level programming language FORTH which has been employed for many years in control and instrument applications. It runs under MSDOS, to provide access to the various PC resources, but includes its own editor, assembler, compiler, and interpreter. As these tools are written also in FORTH, their syntax, commands and structures are all the same, and allow any competent programmer to extend the operating system to fit his requirements.

polyFORTH for the PC/AT-MSDOS normally runs in a 64K memory segment. Where an application requires large amounts of data and code, such as in the ultrasound beam calibrator, four techniques are used. Firstly, data arrays and tables required at all times can be held in MSDOS memory outside the program's 64K memory segment. Using MSDOS function 48H, the programmer has control of where data is located.

Secondly, program code can be organised such that there is always a resident "kernel" containing frequently used routines, and a number of "overlays" brought in and out of the program space when the infrequently used routines contained in them are needed.

FORTH was originally invented by Charles Moore in 1973 when he was developing computer programs to control radio telescopes and their instruments. Its unique combination of highly interactive environment and efficient execution makes it ideal for R & D applications where the engineer's goals may be constantly changing. Subsequent developments of the language have made interactive multitasking systems available for most CPUs from VAXs to single-chip microprocessors.

Data and overlay code can also be held in virtual memory. polyFORTH includes a set of words specifically designed for this purpose, which use the disk as a large, virtual-memory space organised in MSDOS files. Up to eight files can be open for access at any time.

Finally, data and code can also be organized in a number of 64K complete polyFORTH shell systems, all linked together by the round-robin FORTH multitask scheduler.

In the beam calibrator software we use the first three, and there is no need for multiple shells.

Communication between the PC and the 68000 CPU take place through an 8255 prgrammable peripheral interface in a specifically designed card, and TTL memory in the calibrator hardware shared with the PC/MSDOS 640K space. This is normally located after the first 512K, so any contentions with PC internal memory can be avoided by switching off this bank.

A simple protocol is used to carry out exchanges. All responses from the calibrator generate an interrupt in the PC; this interrupt can be configured in the 8255 PPI card to avoid clashes with existing PC interupts. In the default configuration, this vector is number 13 or IRQ5. When an access to shared memory is denied by the calibrator, the 8255 PPI card generates another configurable interrupt.

Functions in the software are presented to the user by simple menus and one-keystroke selections.

The beam calibrator is the outcome of combined work by the NPL (Dr R.C. Preston), Frazer-Nash Electronics Ltd (David Williams) and Computer Solutions Ltd (R.M. Rodriguez) ■

INSIDE THE IBM PC

Technical applications of the PC require users to have some knowledge of the internal workings. Roy Levell describes the hardware.

The range of technical applications of the IBM PC has grown enormously. Plug-in cards are now available which turn the PC into a comprehensive laboratory instrumentation system, a cad workstation, a digital storage oscilloscope, an in-circuit emulator for a range of microprocessors and a host system for software development of transputers and risc computers. The PC has become a powerful industrial development tool.

The feature of the IBM PC which contributes most to its versatility is the expansion bus. It allows the computer to be tailored to individual requirements and permits improvements to be made as technology advances, so avoiding rapid obsolescence.

Hardware outline

On the basic PC system board can be found the processor and its support chips, the system rom and up to 640K-byte of ram. One of the expansion slots is normally fitted with a disk drive card and another is occupied by a display adaptor.

On the original XT, the 8088 CPU is wired in maximum mode, so that co-processors can be used with it. In this mode, the CPU status signals are decoded by an 8288 bus controller to form the memory, i/o control signals and an interrupt-acknowledge signal.

To reduce pin-out requirements, the lower eight bits of the address bus are internally multiplexed by the 8088 with the eight-bit data bus. The address bus must therefore be de-multiplexed and latched outside the chip to provide separate address and data buses for memory and expansion.

Internal interrupts are provided on the CPU to notify divide errors on the DIV and IDIV instructions, to provide single-step facilities when the trap flag is set in the status register and to provide software interrupt facilities with the INTn (n<256) and INTO instructions.

Software interrupts can be used to call operating system services from within an application program and to check hardware interrupt service procedures.

Both maskable and non-maskable external interrupt lines are provided on the CPU. One use of the NMI is to inform the CPU of parity errors in the d-ram. An 8259 programmable interrupt controller is used to expand the maskable interrupt, providing eight vectored priority interrupt requests. These are used by the timer, keyboards, serial communications, disks and printer.

Integer arithmetic operations are provided by the 8088 CPU. Multiply and divide instructions can deal with both 8-bit and 16-bit, signed and unsigned integers, making the 8088 CPU useful for real-time data handling.

However, arithmetic operations on real numbers and floating-point numbers require software routines which use many CPU instructions. They therefore take much longer to calculate than integers, and use more memory. Common functions of real variables require still more CPU instructions and take even longer to calculate.

Numeric coprocessor

The 8087 numeric coprocessor, an optional fitting on most machines, is designed to speed up the calculation of real and floating-point numbers, logarithms, square roots and many trigonometrical functions by more than 50 times. It is particularly important for engineering and scientific applications and for complex real-time processing.

The 8087 shares the multiplexed address and data bus of the 8088 CPU. It also uses the status and queueing signals, the clock and the reset. When operating together the two processors appear to the programmer as one single machine with additional data types, more registers and a larger instruction set.

The 8087 can be used with both 8088 and 8086 CPUs. It identifies the CPU from the CPU's response when reset at start-up.

Both processors monitor the incoming instructions. All 8087 instructions are processor control Esc type (escape to external device). They are recognized by the 8087, which requests control of the bus if data transfers are required. The 8088 grants control. The 8087 then executes the instruction and outputs a BUSY signal while doing so. The 8088 monitors this and executes a WAIT instruction.

When the 8087 has finished the data transfer operation it cancels the BUSY signal and frees the bus. It also informs the 8088 on the request line when it has finished an instruction.

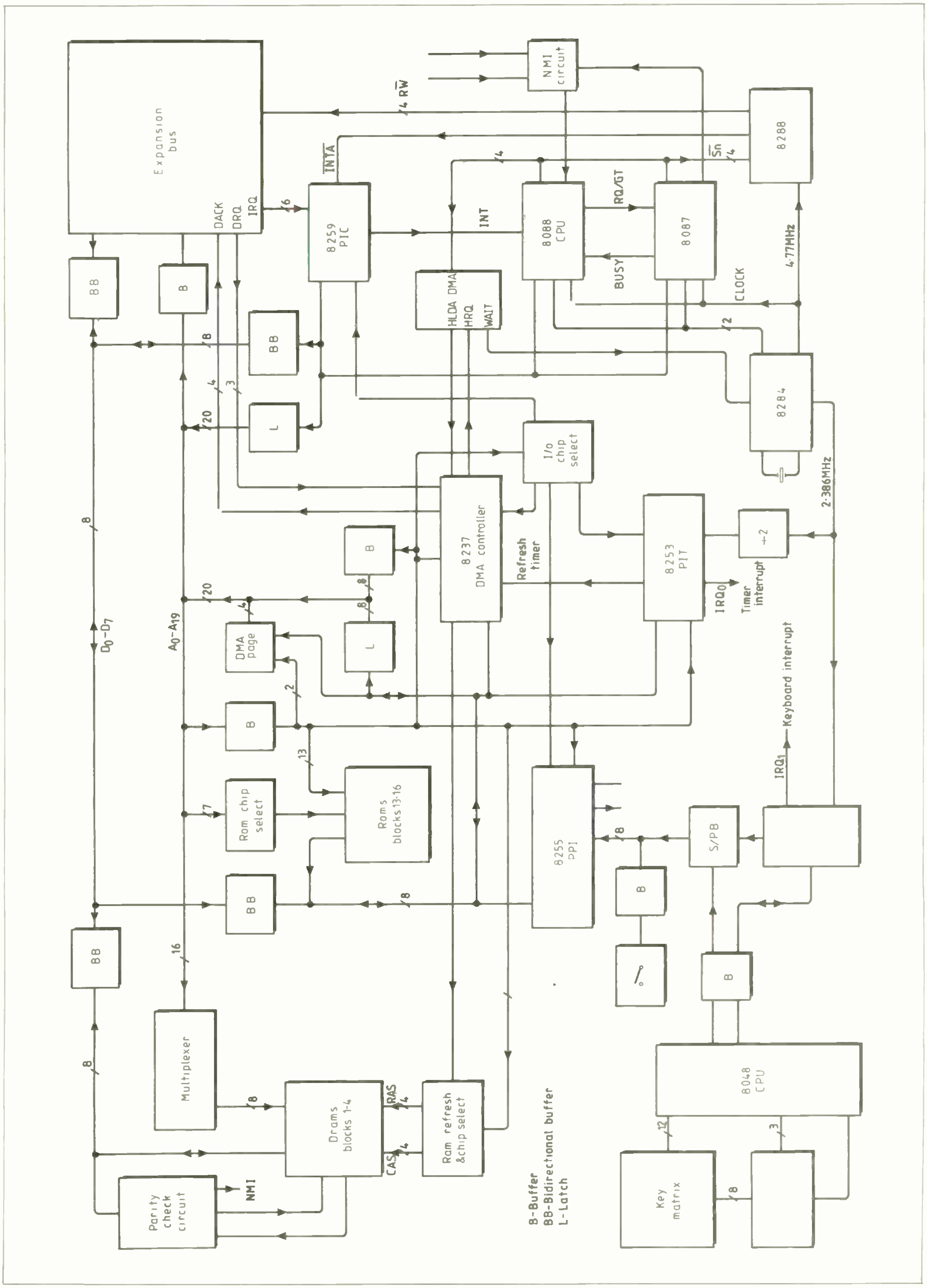
Both processors control their own instruction queues and the 8087 co-ordinates its activities by means of the queue status signals.

If any of the six types of "exception" error occur, a flag is set in its status register. An interrupt request bit is also set if the corresponding mask bit is set in the control register.

In this way the programmer may either use the inbuilt default handling of each type of exception or provide his own in an interrupt routine. The IBM PC uses the 8087 interrupt request to force an 8088 NMI.

Memory organization

Perhaps the greatest deficiency of PC architecture is its lack of linear address space. Just one megabyte of memory is directly addressable by the 8088 CPU, 20 address pins being provided on the chip. The memory can be thought of as being 16 blocks of 64Kbyte each. The top four are used for roms. The adjacent


Expansion bus
DACK
DRQ
IRQ
8259 PIC
INTA
8088 CPU
8087
8288
NMI circuit
RQ/GT
BUSY
INT
CLOCK
4·77MHz
8284
2·386MHz
HLDA DMA
HRQ
WAIT
I/o chip select
8237 DMA controller
Refresh timer
8253 PIT
÷2
IRQ0
Timer interrupt
DMA page
Roms blocks 13-16
Rom chip select
8255 PPI
S/PB
IRQ1
Keyboard interrupt
8048 CPU
Key matrix
Multiplexer
Drams blocks 1-4
RAS
CAS
Ram refresh &chip select
Parity check circuit
NMI
D0-D7
A0-A19
B-Buffer
BB-Bidirectional buffer
L-Latch

two blocks are used for video display ram.

The 20-bit physical addresses are formed by adding 16 times the segment register contents to the offset register contents. The example below combines the code segment register, CS, with the instruction pointer, IP, to form the absolute memory address of an instruction in hexadecimal:

CS: IP EA00:3100 = $ED100_{16}$

Roms

On the IBM original, six sockets are provided on the system board for 8K static roms. The socket spanning the address range FE000-$FFFFF_{16}$ contains the system bios firmware. Rom Cassette Basic, if fitted, occupies the 32Kbyte space from F6000 to $FDFFF_{16}$.

Rom chip selection uses a nand gate and a three-line to eight-line decoder to decode the upper address lines.

The bios rom contains firmware that initializes the system and tests the CPU, the keyboard, the floppy disk interface and the memory at start-up. It also contains the fundamental access procedures for the system services: keyboard, printer interface, serial communications links, disk interface and time-of-day clock. The bios also includes disk boot procedures which read the operating system (MS-DOS) from the system disk into ram and then transfers control to it.

Memory addressing for the dynamic ram is complex. The ninth chip of each bank holds a parity bit for each byte of memory. Parity bits are generated when bytes are written into the d-ram. They are checked again when they are read.

The 74280 nine-bit parity checker gates the bits of a memory byte with its corresponding parity bit and generates both odd and even parity signals. The even parity output forms the parity bit of the selected byte during the write cycle. If the parity is not odd during the read cycle a non-maskable interrupt displays an error message on the screen.

Direct memory access

Direct memory access can be used for the high-speed transfer of blocks of data from input channels to memory, from memory to output channels and between different areas of memory.

The 8237 DMA controller asks the CPU for permission to take control of the system address and data buses to carry out the data transfers. When given permission, the DMAC suspends CPU operation by forcing the 8284 clock generator to change the state of the CPU READY line.

Four separate DMA channels are available on the 8237: each has a 64K address and word count capability. Channel 0 is used for d-ram refresh. The DMA request and acknowledge signals for channels 1, 2 and 3 are available on the expansion bus sockets. DMA channel 2 is used for floppy disk data transfers.

The DMA channels are set up by 8088 CPU software on reset, by loading and sequencing the DMA control registers. These are located at 000-$00F_{16}$ in the i/o address map.

DMA can be initiated by external hardware via the DRQn lines; action is determined by hardware wiring and by the settings of the control registers. Memory-to-memory DMA transfers are not used.

The DMA controller is limited to an address range of 64K. A four-bit hardware DMA page register is provided for each of the four DMA channels. It enables DMA transfers to span the CPU's 1Mbyte address range. The DMA page registers are located at 080-083_{16} in the i/o address map.

Programmable interval timer

The system clock is divided down to drive the 8253 programmable interval timers with a 1.1931817MHz clock signal. The counters are then set separately to produce the following signals:

Timer 0, mode 3: time-of-day interrupt, approximately every 55ms.

Timer 1, mode 2: dynamic-ram refresh signal, every 15μs.

Timer 2 mode 3 produces a square wave for speaker beeping.

The control and status registers for the PIT are located at 004-043_{16} in the i/o address map.

Peripheral interface

The PPI chip on the system board has three eight-bit i/o ports, A, B and C. Port C is split into two four-bit parts. The chip interfaces directly to the system data bus and is situated at i/o address 060-063_{16}.

Port A is configured as an input port and is used to read out the keyboard scan code byte in parallel from the serial input shift register. The system configuration dip switches are also connected to an input port. They are read at start-up to determine the equipment fitted.

Port B is configured as an output port and its individual bits are used for control purposes:

PB0 controls PIT counter 2, producing square waves for the speaker. **PB1** sends programmed data waveforms to the speaker. **PB2** enables Port C lower half to read configuration dip switch Sw_2. **PB4** enables and disables ram parity checking. **PB5** enables Port C, upper half, to read i/o channel status lines. **PB6** controls the keyboard clock line. **PB7** controls Port A, switching between the keyboard and dip switch.

The PIT and PPI control registers can be accessed directly to generate sounds. No rom bios or Dos routines are provided for this purpose.

I/O address map

The 8088 CPU has separate memory and i/o address maps. Both use the same lines for address selection but additional i/o read and write control lines are provided by the 8288 bus controller.

The programmable CPU support chips, timer and peripheral interface chips have their control and status registers located at specific i/o addresses. The control registers are loaded by the CPU at start-up to define the hardware behaviour. They provide dynamic information about events occurring in the hardware. They are consulted following interrupts to identify their cause and to decide the course of action to be taken.

Keyboard processing

The keyboard contains an 8048 eight-bit microcomputer which scans they keyboard matrix and forms a unique scan code for each key pressed. It generates a different scan code when a key is released.

Single key-presses generate codes in the range 01_{16} to 53_{16}. Key releases generate the same codes but set the eighth bit; the range is therefore 81_{16} to $D3_{16}$.

When the 8048 has a scan code byte ready for transmission to the PC, it allows a clock signal from the system board to interrupt its operation and thus transfer the byte serially, one bit at a time, into a shift register on the system board. When all eight bits have been transferred, a counter on the system board generates a hardware interrupt request (IRQ_1) to inform the 8088 that a keyboard byte is ready for collection. The CPU responds by executing the keyboard interrupt routine.

This interrupt routine clears the interrupt, reads the eight bit scan code through Port A of the 8255 PPI, converts it to an eight bit ASCII code and stores both the scan code and the ASCII code in a 32byte circular input buffer held in low memory. This routine also interprets the keyboard input data, tak-

continued on page 902

STANDARD AX700E
SCANNING RECEIVER

The AX700E has been designed as a professional quality scanning receiver covering most of the well used spectrum.

1 The only scanner with a full panoramic display.
2. Covers 50-905MHz.
3. Features a spectral display covering 100KHz, 250KHz and 1MHz bandwidths.
4. Receives AM, FM and NBFM.
5. Scans in 5/10/12.5/20/25MHz.
6. 1/5KHz up/down facility.
7. 12V DC or 110/220/240 with AC adaptor.
8. 100 User programmable memories.

Further information from:

LEE ELECTRONICS LTD

400 Edgware Road, London W2.
Retail Enquiries: 01-723 5521
Trade Enquiries: 01-450 9755
Fax: 01-450 6826
Telex: 298765 UNIQUE

ENTER 45 ON REPLY CARD

ARE SOFTWARE REVIEWS BIASED?
WHY NOT FIND OUT FOR YOURSELF

Electronics & Wireless World is looking for people who are prepared to undertake software and hardware reviews on a freelance basis. We're not interested word processors, spreadsheets and database. Our readers can get that sort of information from a million different places. We want to examine industrial and technical products aimed at the professional market. For instance PCB CAD, modelling, circuit analysis, board level products, etc.

Like you, we want to see unbiased reviews in our pages so you will have to show us your credentials. You will also need access to testbed equipment suitable for the task. Naturally you must be able to communicate the results of your work in jargon free English. In return, we will give you money. Not a lot but some. The fame and glory comes free.

If any of this appeals, then I would like to discuss the possibilities with you. Please contact Frank Ogden, Editor, on 01-661 3128. I shall then be able to give you an unbiased assessment of your potential as an E&WW reviewer.

ENTER 46 ON REPLY CARD

ing into account the keyboard status bits. Specific key codes cause it to set or clear these bits.

The data held in the keyboard buffer is examined and acted on by the main keyboard services routine invoked by software interrupt 16_{16}.

System variables

The bottom 1Kbyte of memory (00000-003FF) is ram which holds the interrupt vectors. Each vector requires two bytes to specify the value of the code segment register and two more bytes to provide the offset start address of the relevant interrupt routine.

Interrupt routines may be invoked by hardware IRQ or by software INTn instructions. Up to 256 software interrupts are possible (00-FF). The bios routines use low memory 00400-$004FF_{16}$ for their variables. MS-DOS and Basic use 00500-005FF for their variables and other system software can use the space above that. High-level languages and applications software can use the remaining blocks of ram.

Expansion bus

The original PC has five expansion bus sockets. The expansion bus uses a double-sided edge connector with 31 contacts on each side. One side contains the whole of the system address (20) and data bus (8) lines; the other is mainly power lines (8) and control lines (six IRQ, three DRQ, four DACK, four R/W and six others).

Floppy disk interface

The heart of a disk drive adapter is the 8272 floppy disk controller. This device can handle up to four drives. It incorporates DMA read/write control logic for transferring data both ways between the system memory and the disks. Data transfers can also be achieved by IRQ_6 hardware interrupts to the CPU. The use of DMA or interrupt-based data transfers can be selected in software through the FDC control interface located at 3F0-3F7 in the i/o address map.

Serial communications

The bios rom contains the firmware for servicing ports. Control and status registers for the primary port are located at i/o addresses 3F8-3FF and for the secondary port at 2F8-2FF.

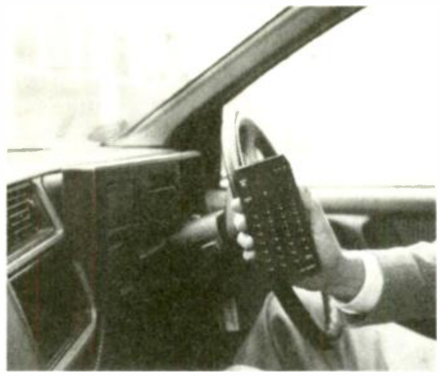
Asynchronous serial communications adapters can use almost any uart chip, but the Intel 8251 usart is representative. It contains a transmit buffer, which is loaded with data in parallel by the CPU and clocked serially from the line and unloaded in parallel to the CPU.

An interrupt announces transmitter buffer empty, receive buffer full, parity, overrun and framing errors. Flag bits set in the status word identify the cause.

The device control registers permit the data rate, the number of stop bits and the use of a parity bit to be specified. ■

On the straight and narrow?

'Autoguide' is the commercial name for a system of electronics produced by Plessey, which transmits travel directions to drivers of cars fitted with the correct receivers. The system is being introduced first in London during the early 1990s, and if commercially successful, to other major cities in the UK.



Suppose, however, the system incorporated the means to identify vehicles in a way similar to the automatic vehicle number plate readers tested by the Police in the early 1980s? Given this fact, could Autoguide become a device capable of being used by a future authoritarian government for mass surveillance?

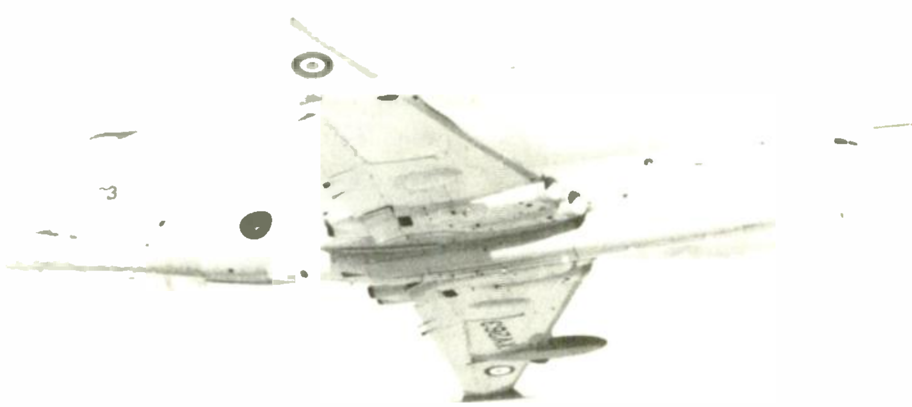
The two London Labour MPs who raised this issue added colour to the parliamentary discussions by giving personal stories about being subject to state surveillance. Joan Ruddock told MPs that the Security Services often trailed her car when she was a senior officer in CND; Jeremy Corbyn explained how the registration number of his vehicle was placed in the Stolen and Suspect Vehicle Index of the Police National Computer (when the car was neither stolen nor suspect) during the 1984 miners' strike.

These recent experiences meant that the MPs closely examined the meaning of a clause in the Road Traffic (Driver Licensing and Information Systems) Bil which states that "no information may be furnished to the Secretary of State... in a way that would enable individual owners or drivers of motor vehicles to be identified". Explaining the wording, Mr. Bottomley, the Minister in charge of the Bill in the Commons, stated that the clause meant that Autoguide data which identified individuals could be withheld from the Minister.

However, alert MPs noted that the word *'the'* was not *'a'*. Thus the MPs maintained that other Secretaries of State could obtain information about individuals from Autoguide for a variety of other purposes; all unrelated to roads, traffic, and transport.

Waxing lyrical about AWACS

In 1986, the Government abandoned the largest and most complex avionics system ever ordered for the RAF. Known as the Nimrod airborne early warning system, it was replaced by a billion-dollar-plus contract with Boeing for the tried and tested Airborne Warning and Control System (AWACS). As the cancellation caused immense political controversy, the Government sweetened the pill by negotiating terms with Boeing that meant that in excess of \$1.5G worth of high technology contracts would be placed in the UK by Boeing by an 'offset agreement'.



Since then the Defence Committee, an all-party group of MPs who monitor the work of the Ministry of Defence, has been considering whether the agreement has worked as planned. Their recent report vindicated the cancellation of Nimrod, and concluded that "at present, Boeing appear broadly on course to fulfil their offset obligation by 1995".

The Committee noted that the offset programme was unlikely to compensate the UK in full for the loss of £375 million's worth of airborne radar technology and avionics expertise caused through cancellation. However, they were keen to ensure, that to qualify for the offset agreement, any work placed in the UK by Boeing must be "of a similar technological standard to that contained in the AWACS purchase", to ensure that "the UK defence industry is stimulated into developing and exploiting its technological capabilities".

Noting that some \$1.3G worth of contracts had yet to be placed by Boeing by 1995 (and this figure is inflation-linked), the Committee stressed that early figures about the offset agreement had to be treated with utmost caution. Consequently, it told the Ministry of Defence to obtain accurate figures concerning the agreement, produce some progress reports to the Committee, and begin to monitor Boeing more closely. Finally, the Committee said that it would "continue to monitor the programme and report to the House as necessary"; a threat of parliamentary action if the situation deteriorates.

1: House of Commons Defence Committee, Third Report, 'The Workings of the AWACS Offset Agreement', £6.80, ISBN 0 10 228668 9 2

Notes on the House are by Chris Pounder.

Dead end for car radio thieves

Stolen car radios could become a thing of the past because there is nothing left to steal. This is the promise of a new digital radio chip set developed by ITT Semiconductors.

The only part accessible to thieves will be the dashboard control panel – useless by itself.

Three 44-pin chips on a board just 80mm×30mm integrate all the RF and audio processing stages of a full-feature AM-FM radio. Car makers can install this module in the engine compartment together with the vehicle's other electronics.

The devices require few external components: little more than a pair of miniature low-pass filters. In a radical break with conventional receiver design, the RF chip, RFP1200, uses a "zero-IF" conversion principle: this makes it possible to eliminate most tuned circuits, so making the circuit much more suitable for integration.

Up to now, says ITT, zero-IF conversion has been an unfulfilled wish of audio engineers because of error compensation problems (in-phase/quadrature symmetry correction, for example). These have become soluble only with the aid of digital strategies.

Digitized IF

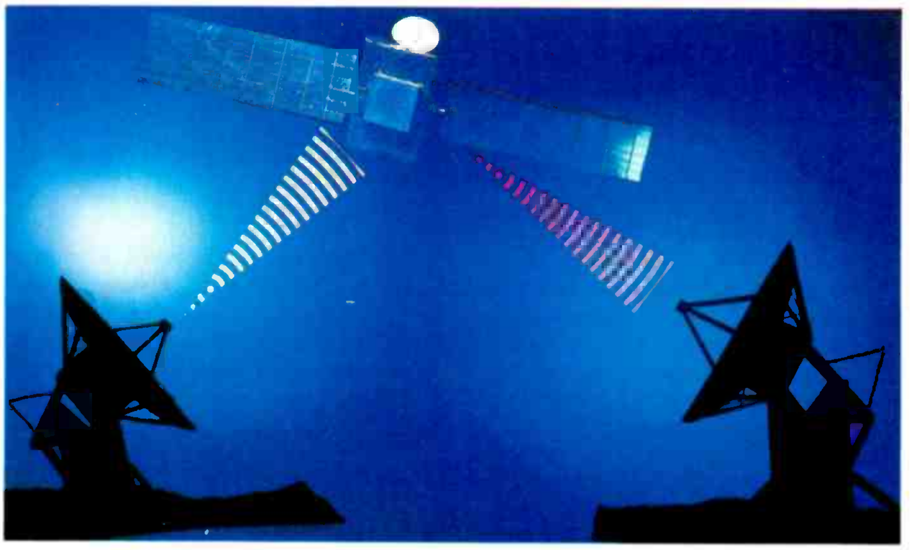
On the FM side, an oscillator running at about twice the tuned frequency is divided by two so as to produce two signals in accurate quadrature for a pair of mixers. The actual IF is about 10kHz. The AM oscillator system is somewhat more complex, but it enables an input frequency range of 3:1 to be covered without the need for an extensive tuned preselector.

Because of the low IF, the received signal can be digitized at an early stage, reducing analogue processing to a minimum. FM demodulation and stereo decoding are carried out digitally in the ACDP1100 chip, which also contains the frequency synthesizer, digital-to-analogue converters and electronic volume control. The same DSP hardware can decode US-style AM stereo transmissions and can even create a dynamic noise reduction system.

The technique used for FM demodulation is the so-called Cordic (coordinate rotation digital computer) algorithm first used by ITT for colour decoding in Secam television sets. A further advantage of digital demodulation is that the Radio Data System (RDS) information now being transmitted by most European broadcasters can be extracted digitally at the same time for feeding to the synthesizer to help control the set. The processing can be added to the duties of the UDPC1000 c-mos microcomputer which completes the chip-set.

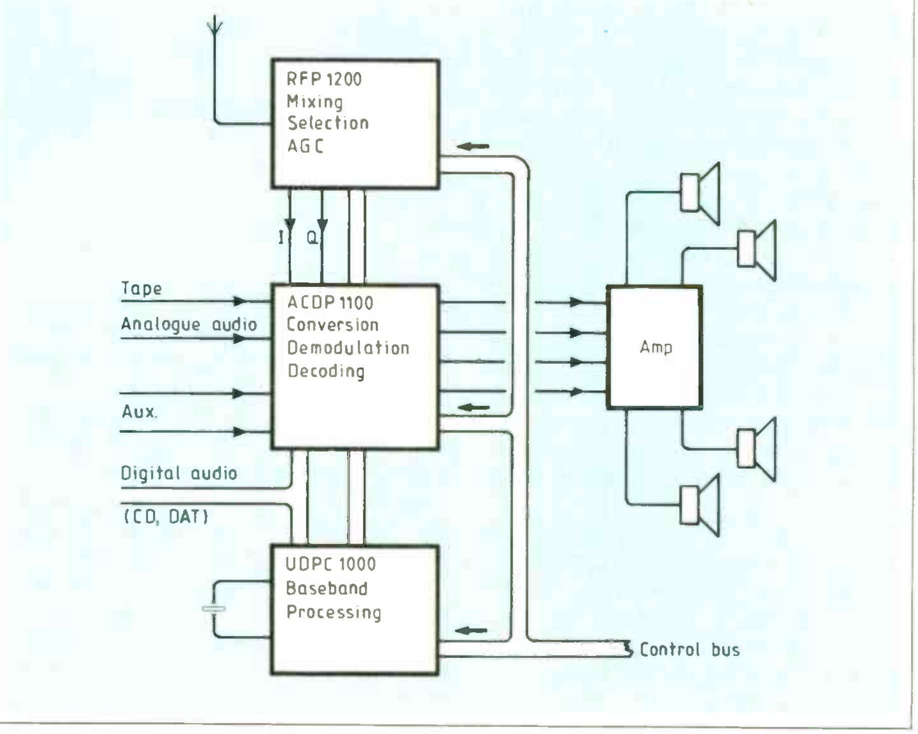
Several variants of the system are possible, including a cut-down version with an external FM front end, and an enlarged version with an additional processor providing features such as a seven-band graphic equalizer.

Further information: ITT Rosemount House, Rosemount Avenue, West Byfleet, Surrey KT146NP.



New consumer integrated circuits from ITT Semiconductors include the digital radio chip set outlined below and a multi-MAC decoder chip for satellite television, a part of the Digit 2000 range (see July issue, page 736). This TV chip not only decodes D2-MAC/packet but D-MAC and C-MAC too. The company already has decoders for D2-MAC and for D-MAC: a demonstration in July showed the D-MAC device successfully decoding a wide-screen D-MAC satellite test transmission laid on by the IBA in the 16:9 aspect ratio chosen for HDTV.

Below: ITT's three-chip car radio set makes extensive use of DSP.

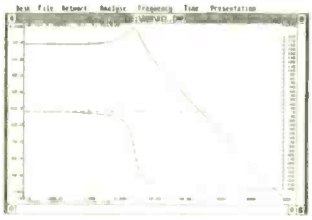


SPICE• AGE

Non-Linear Analogue Circuit Simulator £245 complete

Those Engineers have a reputation for supplying the best value-for-money in microcomputer-based circuit simulation software. Just look at what the new fully-integrated SPICE Advanced Graphics Environment (AGE) package offers in ease-of-use, performance, and facilities:

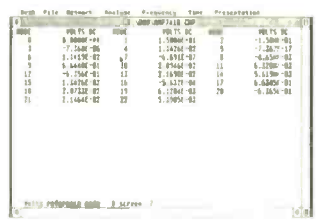
SPICE•AGE performs four types of analysis simply, speedily, and accurately:
● Module 1 – Frequency response ● Module 3 – Transient analysis
● Module 2 – DC quiescent analysis ● Module 4 – Fourier analysis



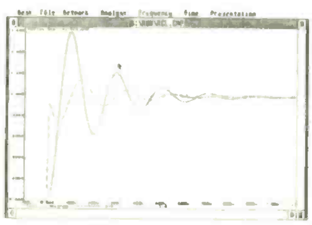
Frequency response of a low pass filter circuit

1 Frequency response
SPICE•AGE provides a clever hidden benefit. It first solves for circuit quiescence and only when the operating point is established does it release the correct small-signal results. This essential concept is featured in all Those Engineers' software. Numerical and graphical (log & lin) impedance, gain and phase results can be generated. A probe node feature allows the output nodes to be changed. Output may be either dB or volts; the zero dB reference can be defined in six different ways.

2 DC Quiescent analysis
SPICE•AGE analyses DC voltages in any network and is useful, for example, for setting transistor bias. Non-linear components such as transistors and diodes are catered for. (The disk library of network models contains many commonly-used components – see below). This type of analysis is ideal for confirming bias conditions and establishing clipping margin prior to performing a transient analysis. Tabular results are given for each node; the reference node is user-selectable.



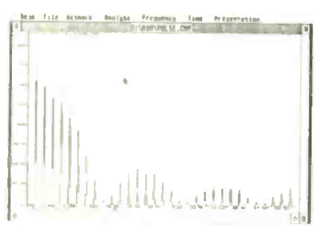
DC conditions within model of 741 circuit



Impulse response of low pass filter (transient analysis)

3 Transient analysis
The transient response arising from a wide range of inputs can be examined. 7 types of of excitation are offered (impulse, sine wave, step, triangle, ramp, square, and pulse train); the parameters of each are user-definable. Reactive components may be pre-charged to steady-state condition. Up to 13 voltage generators and current generators may be connected. Sweep time is adjustable. Up to 4 probe nodes are allowed, and simultaneous plots permit easy comparison of results.

4 Fourier analyses
SPICE•AGE performs Fourier transforms on transient analysis data. This allows users to examine transient analysis waveforms for the most prevalent frequency components (amplitude is plotted against frequency). Functions as a simple spectrum analyser for snapshot of transients. Automatically interpolates from transient analysis data and handles up to 512 data values. Allows examination of waveform through different windows. Powerful analytical function is extremely easy to use.



Spectrum of rectangular pulse train (Fourier analysis)

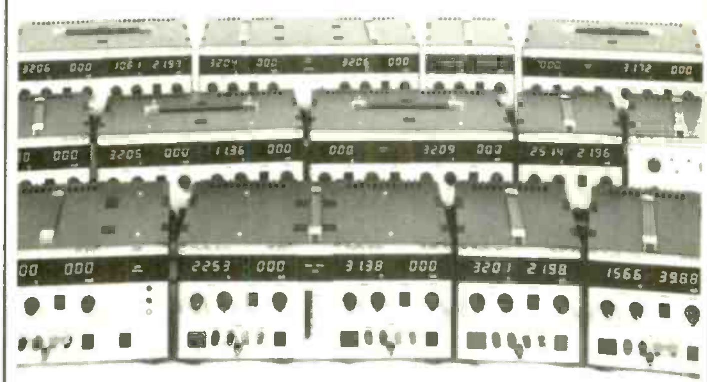
If your work involves designing, developing or verifying analogue or digital circuits, you will wonder how you ever managed without Those Engineers circuit Simulation Software.

A good range of properly supported and proven programs is available and our expert staff are at your service.

Those Engineers Ltd
106a Fortune Green Road • West Hampstead • London NW6 1DS
Telephone: 01-435 2771 ● Fax: 01-435 3757

ENTER 27 ON REPLY CARD

For Bench Power



think

Thurlby

Thurlby's reputation for bench power supplies is second to none.

The Thurlby PL series has re-defined the standard for bench PSU's. Today it is still the only range to offer all of the features that have established it as a best seller. Features such as dual 3¾ digit meters for each output, current limit preview, remote sense, and current meter damping.

The range is vast and includes singles, twins, triples, quad-mode duals (with true parallel and series tracking modes), and IEEE-488 programmable models.

Contact ***Thurlby*** now for the full details of all bench PSU's.

Thurlby
ELECTRONICS LIMITED

Burrel Road, St. Ives, Huntingdon, Cambs PE17 4LE
Fax: 0480 64832 Tel: 0480 63570

ENTER 48 ON REPLY CARD

PIONEERS

Joseph Henry (1797-1875): actor turned engineer and scientist

Too dull to make a silversmith: that was the verdict supposedly given on the young Joseph Henry. Henry had been apprenticed at the age of 14 to a watchmaker and silversmith; and though it never enthralled him, the two years of training came in useful later when he started to make his own scientific equipment.

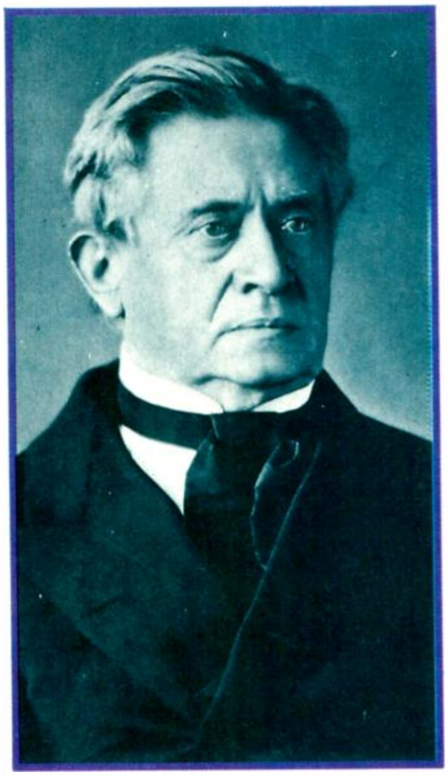
From humble beginnings Joseph Henry became the leading figure in American science, and a benevolent figure, too. He refused to patent his work, preferring that it be available for the benefit of all. In his late forties, with his scientific reputation impregnable, he became the first Secretary (i.e. chief administrator) of the new Smithsonian Institution in Washington, DC. There he used his influence to consolidate in America the professional approach to scientific research.

But it is not however for Henry's administrative abilities that we remember him. The unit of inductance now bears his name; but also named after him was a town, Port Henry. He made large contributions to electromagnetic science and engineering: the joint discovery of electromagnetic induction and self-induction, the manufacture of industrial electromagnetics, and the construction of what might be called the first electric bell, hailed by some as the first electromagnetic telegraph.

Early days

Henry's grandparents, Hendries and Alexanders, had emigrated from Scotland and arrived at New York (then a small city of 30 000 people) on June 16, 1775. His paternal grandfather was proud of having seen bonnie Prince Charlie ride into Glasgow during the Jacobite rebellion of 1745. Despite his love for his old country he nevertheless changed the family name from Hendrie to Henry, a change for which Joseph Henry was later to express some regret.

There is some doubt as to the date of



Joseph Henry: this photograph was taken about 1875, when he was about 78 (Institution of Electrical Engineers).

Henry's birth, usually given as December 17, 1797. The records of the Presbyterian church, a church Henry adhered to for life, give December 9, according his biographer Coulson[1]. But Coulson also records that Henry's cousin, quoting a life insurance policy, was adamant that it was December 1799.

Whatever the date, he was born into an impoverished family with an ailing father. At seven he was sent from Albany in New York State, the family home, to stay with relatives at Galway, some 36 miles away, whilst his mother nursed his father. He stayed about seven years, completed his elementary education and began work in the village shop.

One day, according to the story, his pet rabbit escaped and Henry followed it under the floor of the village church, climbed through some loose floorboards and discovered the village library. There his eyes were opened to a world of books far beyond anything his small school or home had offered. After returning several times in this unconventional manner he was at last discovered and granted access in the normal manner.

Following his father's death, he settled in Albany and started his uninspired apprenticeship as a silversmith. In his leisure time he developed a love for the theatre. This blossomed into a career decision and he turned to acting, writing and producing plays for an active amateur group. The stage was to be his world, until a minor illness changed that.

His mother supplemented her income by taking in boarders. During his sickness one of them lent Joseph an introductory book on science with the rather daunting title "Lectures on Experimental Philosophy, Astronomy and Chemistry". This book inspired him. It became a gift and he kept it for years. As a direct result of reading it he renounced the stage and turned to science. The man we have to thank for lending that book on science chanced to have an appropriate name – Robert Boyle!

The parallel with Michael Faraday is striking. Faraday too was from a poor family; and it was while he was apprenticed to a bookbinder that he chanced to read an introductory book on chemistry which set him on his path to scientific fame*.

Henry, realising that his long-passed elementary education was inadequate for the career he had chosen, now enrolled for night classes in geometry, mechanics and English grammar at the respected Albany Academy. Aged 21,

*See Pioneers, *Electronics & Wireless World* August 1988, p.825-826.

he was much older than the norm. Soon his grammar was good enough to enable him to give private tuition and then to gain a school teacher's post – the only job he ever applied for. The money paid for further study at the Academy.

Before long he was assisting lecturers and preparing himself for a career in medicine. He became librarian of the Albany Institute and gave his first scientific paper in 1824. His studies continued and he undertook survey work, most importantly as surveyor on a project to construct a new road from the Hudson River to Lake Erie. This outdoor project was completed so well that friends tried, unsuccessfully, to get him an appointment as a civil engineer. His surveying for New York State was the only work that ever paid him enough to save money.

In the spring of 1826 he was offered three positions: supervisor for the construction of a canal in Ohio, manager of a mine in Mexico, or Professor of Mathematics and Natural Philosophy at the Albany Academy. The teaching position, for that was what it was, won. But it was a close run thing.

Science and engineering

At 28, Joseph Henry had at last chosen his career, having rejected the village shop, silversmithing, the stage, medicine and civil engineering in favour of teaching.

After seeing a demonstration of Oersted's discovery of the effect of a current on a magnetic needle, Henry turned to electromagnetism. But as a teacher, rather than a research scientist, Henry had to confine his research work largely to the period of the summer vacation and finances were mostly from his own pocket.

His first significant, indeed major, contribution was the vast improvement he made to electromagnets (which had been invented by William Sturgeon in England). Henry was fascinated. He soon improved the design by adding more turns of wire and insulating the wire rather than the iron core around which it was wrapped, as Sturgeon had done. For a time, before shellac was used, obtaining copper wire and insulating it was one of the repeated, boring problems he had to contend with. At one time his wife's white silk petticoat was shredded to provide the strips of silk he needed.

His first magnet, in 1827, lifted 14 pounds and then 28 pounds compared to Sturgeon's nine pounds. Over the next few years he investigated the best and least expensive ways of making his batteries as well as getting better multi-coil magnets. In this work he looked at parallel and series connections and touched on what we would call impedance matching. He came to an empirical understanding of Ohm's Law before he had heard of Ohm and used his own terminology: "intensity" for voltage and "quantity" for current. These terms were adopted by some others and survived for about 30 years[1].

Soon he was asked to make the first industrial electromagnet, for the Penfield Iron Works. The site was later renamed Port Henry in his honour. Yale University ordered a magnet in 1831, a monster weighing nearly 60 pounds and which could lift a ton.

The first telegraph?

It was whilst he was teaching at Albany that Henry made what some have called the first electromagnetic telegraph and others the first electric bell.

For a demonstration of the electromagnet he strung nearly a mile of wire around the classroom, more than enough to impress any class of boys. At one end was a small electromagnet which, when energized, repulsed a pivoted permanent magnet so that it struck a small bell. So far as I am aware, there was no suggestion of signalling messages.

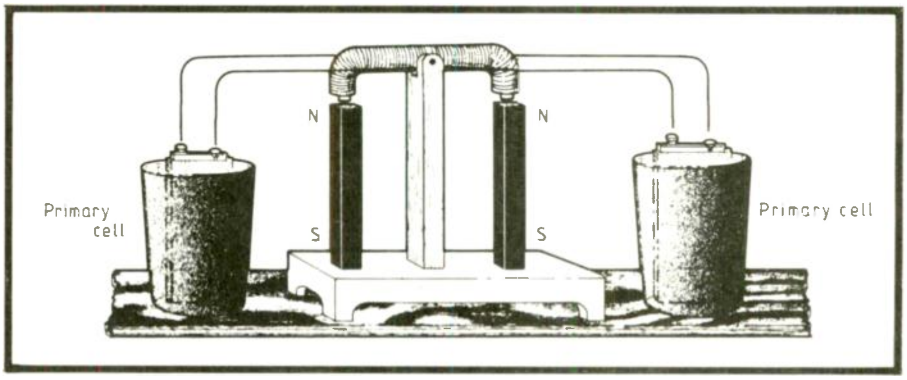
Henry's greatest scientific discoveries were those of electromagnetic induction and self-induction, both also discovered by Michael Faraday. Faraday is credited with priority for induction and Henry for self-induction. Henry in fact learned of Faraday's work after he had discovered electromagnetic induction himself, but before he had published anything. When the self-effacing Henry did eventually publish in 1832 the final paragraph revealed his discovery of self-induction. Some evidence suggests he found this in 1829; Faraday announced the effect in 1834.

Princeton

Henry's successes were, of course, recognized and in November 1832 he became the new Professor of Natural Philosophy at the College of New Jersey, now better known as Princeton University. One of those who recommended him simply said, "He has no equal".

Ten years later Henry turned to examining the discharges from a Leyden Jar capacitor. By studying the way in which the discharge magnetized steel needles within wire coils, he correctly deduced them to be oscillatory. He then teetered on the brink of one of the greatest scientific discoveries.

He observed that a single spark, about an inch long, in an upper room, caused a needle to be magnetized inside a coiled circuit in the cellar, a perpendicular distance of 30 feet. He wrote that he was "disposed to adopt the hypothesis of an electrical plenum, and from the foregoing experiment it would appear that the transfer of a single spark is sufficient to disturb perceptibly the electricity of space throughout at least a cube of 400,000 feet of capacity".



Henry's reciprocating electromagnetic machine, July 1831. As the electromagnet rocked, contact was made first with one cell and then the other, causing a reversal of the polarity of the electromagnet and perpetuating the rocking.

The effect, he said, was almost comparable "with that of a flint and steel in the case of light". As Oliver Lodge later commented, "Comparable it is indeed, for we now know it to be the self same process".

By 1851 Henry could assert that the effects are "being propagated wave fashion" and "to a surprising distance". One of his students recorded in 1844 that sparks produced from "the Electrical Machine in the College Hall" affected the surrounding electricity "through the whole village".

Other experiments confirm that Henry was generating, propagating and detecting electromagnetic waves and was evolving a qualitative theory of the ether. Maxwell's later theory of electromagnetism began with Faraday's ideas, but it could equally have begun with Henry's.

Recognition of Henry's achievements suffered because he was initially slow to publish his work. Later in his career when he published more quickly he used a journal respected in America but then less well known in Europe. Consequently Europeans were slow to learn of his discoveries. However, when the henry was suggested as the unit of inductance at the International Congress of Electricians in 1893, it was proposed by a Frenchman and seconded by a Briton.

Electromagnetism, in its widest sense, was not Henry's only interest. At various time he studied astronomy, geophysics, meteorology, anthropology and ethnology. And at the Smithsonian he proved to be an able administrator.

Joseph Henry: he teetered on the brink of one of the greatest discoveries...

His marriage, to his cousin Harriet, was long and happy and their declining years were enhanced by the care of their three daughters, the only survivors of six children.

After almost 50 years of near-perfect health, Henry's final illness made itself known in December 1877. His doctor gave him six months and he died on May 13, 1878. Friends raised and invested $40 000, the income going first to Henry and then his surviving dependants with the capital eventually passing to the National Academy. With such terms, even Henry could not reject it.

When Henry had tried to settle his account with his doctor he was told, "There are no debts for the dean of American science". The old man was moved. "I have always found the world full of kindness to me", he said, "and now here it is again."

References
1. T. Coulson, "Joseph Henry, His Life and Work," Princeton University Press, 1950.
2. Dictionary of Scientific Biography.

Next in this series of electrical pioneers will be Léon Thévenin.

Tony Atherton is a Principal Lecturer at the IBA Harman Engineering Training College, Seaton, Devon.

Monostable circuit with sinusoidal output

Often a requirement of signal generators for development laboratory use is for a single-cycle sinusoidal waveform output. There are several excellent commercial instruments capable of generating such a waveform but they tend to be expensive, especially for a "one off" requirement. Shown here is a simple way of obtaining up to 360° of sinewave in response to a TTL-compatible trigger input.

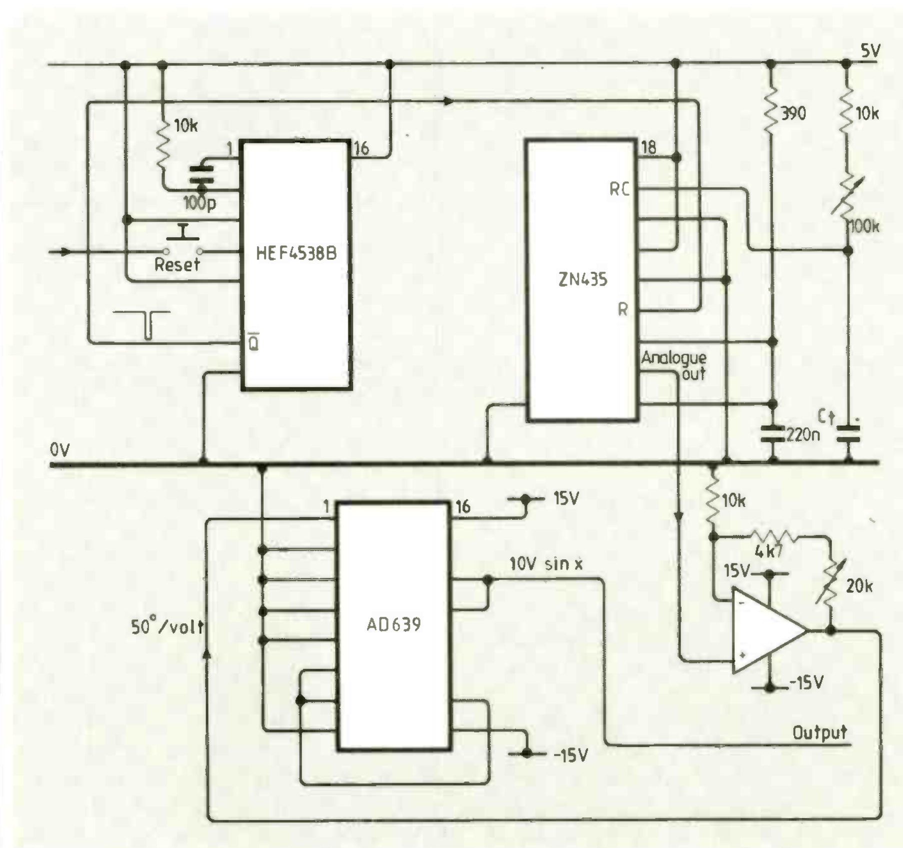
One half of a 4538 dual monostable IC, wired to trigger on the rising edge of its input, is used to derive a 1μs reset pulse for the ZN435 multi-function data converter. This monostable can be omitted provided a suitable negative-going pulse is available.

The data converter is configured, using its control logic pins, to count up and stop at full scale, thus providing a ramp output of 2.5V amplitude and holding this level until receipt of the next reset pulse. Rise-time of the ramp is set by the value of the RC component values of the ZN435; C_t is chosen to suit and adjustment can be made using 100kΩ potentiometer. The ramp is taken to the positive input of operational amplifier. Amplitude is adjusted, using a 20kΩ potentiometer, to give 7.2V. This amplified waveform is taken to the ×1 input of an AD639 universal trigonometric function generator IC whose output is 50° of sinewave per 1V input. You can see that a 7.2V input will result in one complete 360° of output.

Note that the operating characteristics of the operational amplifier determine the integrity of the output waveform to quite some degree, and so it is advisable to choose a device with low drift, offset and temperature coefficient. Also a small feedback capacitor may be desirable to filter out any digital noise from the ZN435.

Photograph shows typical waveforms: top trace, the ramp; and below that, the resulting cycle of sinewave.

T.G. Barnett
London E1



12-bit analogue-to-digital converter

This simple design is based on a bidirectional ramp counter type of converter and is useful for designs where cost is more important than the stunning results of ready-made packages.

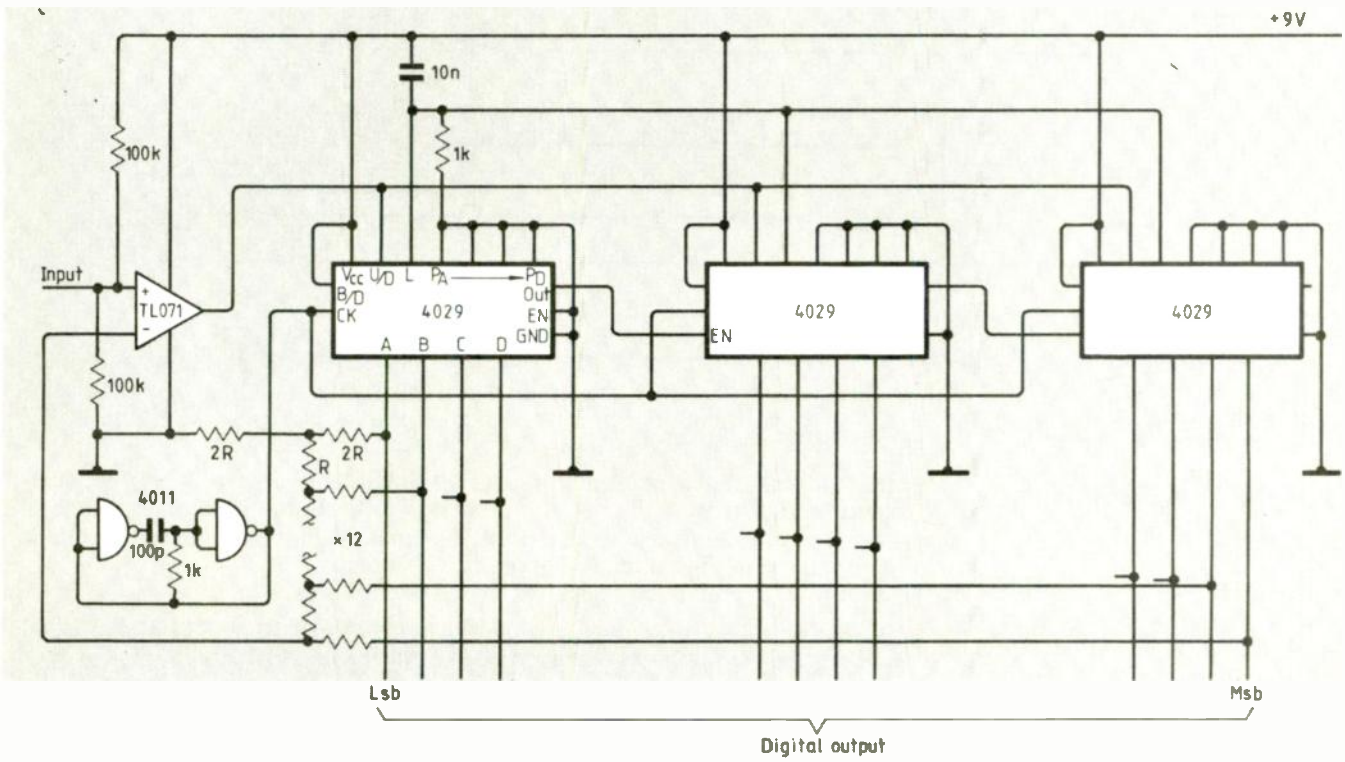
Starting from the front end, the analogue signal comes into the non-inverting input of the op-amp. Assume that input stands at 1V DC. At power-up, the 0.01µF capacitor allows a pulse through to the LOAD point on each of the three counters, loading 000 into each. This is transferred to the outputs of the counters and thence through a resistor network acting as a d-to-a converter, converting the counter value back to a voltage. Initially, with the counter at 0000, this voltage is zero, which is fed into the inverting input of the op-amp; thus its output is high, which tells the counters to count up.

The three counters are connected so that they count synchronously in either direction to reduce any large errors while counting. Hence the counters count up (at a rate of about 4MHz) until such a point arises that the voltage from the resistor network is slightly above the input volage. This causes the op-amp to go low, and start the counter counting down again, until it goes below the input voltage and the counter counts up again, and so on.

This small ripple is an error of one in 4096, which is quite small and will not be too serious. Only half of the 4011 is used in the square wave clock; you might like to use the other half as an added buffer on the clock output or as a Schmitt trigger on the output of the op-amp.

The most critical part of the design is the resistor network. I suggest you use 1% tolerance resistors or small mini-pots and measure accurately their values, which must be in the R-2R ratio for it to work correctly. Layout is critical only in the clock because of the low value capacitor; keep those leads as short as possible.

Darren Yates
French's Forest, New South Wales



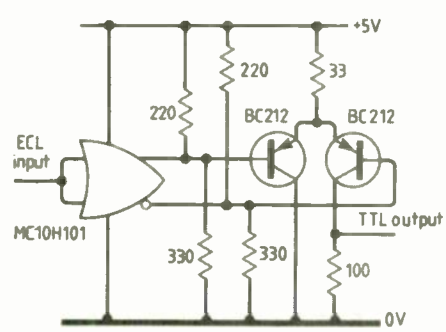
ECL-to-TTL converter

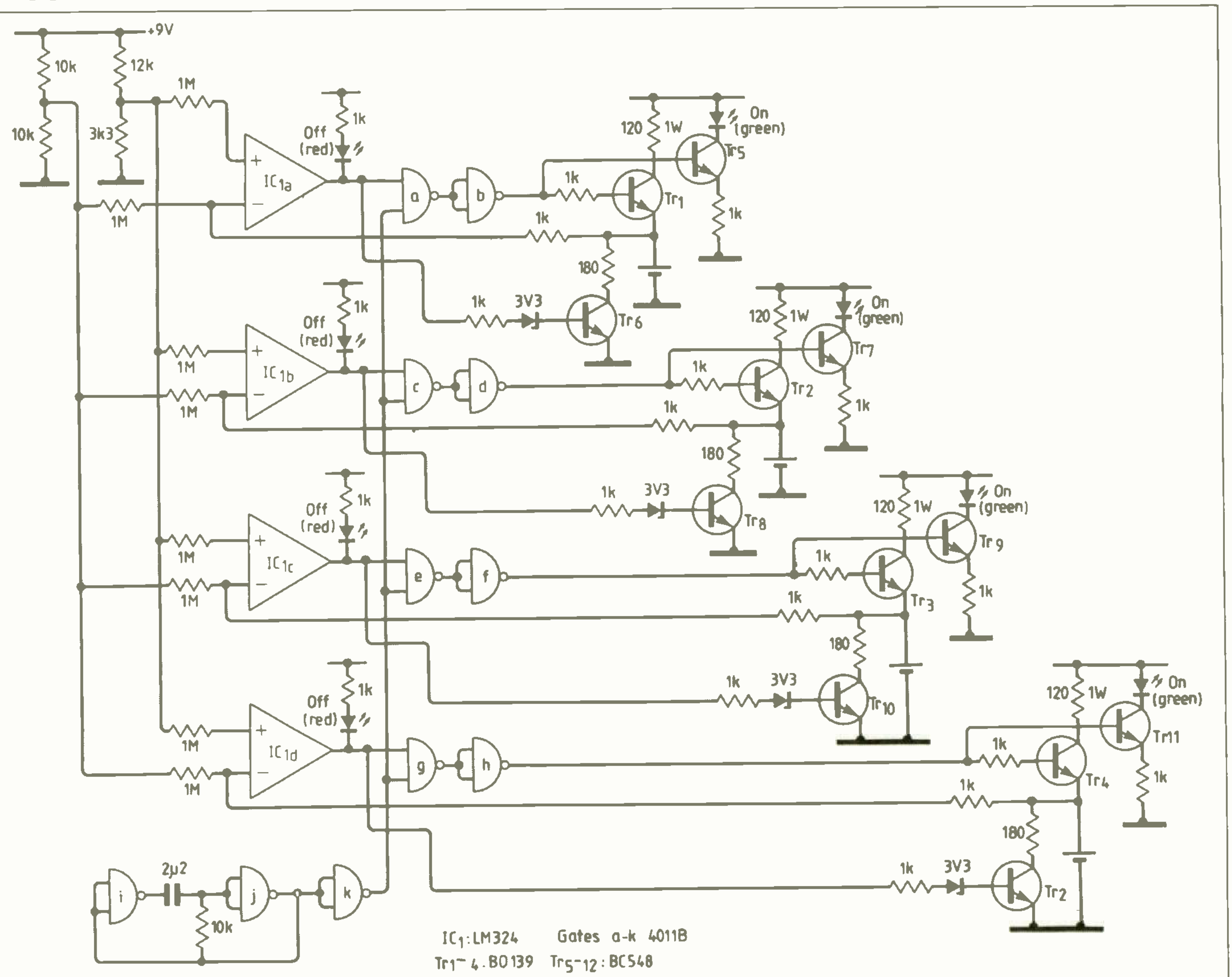
To remove the need for a dual supply rail, ECL and TTL devices are often driven from the same 5V rail. Where this is the case, it is possible to make a 10K and 100K-compatible converter with just two transistors.

The Or/Nor gate drives a differential amplifier which provides TTL voltage levels at its output. We have used the circuit at 50MHz with no problems although the output should be buffered (e.g. with a 74F244) when driving a long connection or a capacitive load at high frequencies. It should work with most small-signal p-n-p transistors and most ECL gates having complementary outputs. When using the complementary outputs of a bistable IC, however, we found that the device misbehaved, so this should be avoided.

This circuit is far cheaper than an equivalent IC (e.g. Brooktree Bt501 at about £12) when you only need to convert one or two signals.

P.N. Zarucki and Dr J.K. Hulbert
Electronic Equipments Ltd
Birmingham





Charger for four dry cells

Benefits of this relatively simple circuit are that it can recharge four R6 (AA) size dry cells in 12 hours. Other size cells can be accommodated by reducing the value of the 1W resistors.

Direct-current charging of dry cells can cause leakage and explosion due to steam build-up. This circuit, which relies on a 50% duty cycle square wave, causes only slight cell warming over the 12-hour charge, and has not been the cause of any leakage or explosions. Charging occurs during one half of the square-wave cycle and discharging occurs during the other. This improves charge retention.

Part of the cell voltage is fed back to the op-amp's inverting input. When this level reaches about 1.6V, the op-amp output goes low and output of the second gate connected to it follows it.

Battery voltage drops a little until the op-amp output returns high, gating the clock back on and again recharging the cell. This produces a flickering effect when the cells have reached the set voltage for both leds.

When no cell is connected, the red led is constantly on. When a cell is charging correctly, the green led flashes and when the cell is charged, both green and red leds flash; if the leds flash immediately on connection of the cell, the cell is faulty.

Darren Yates

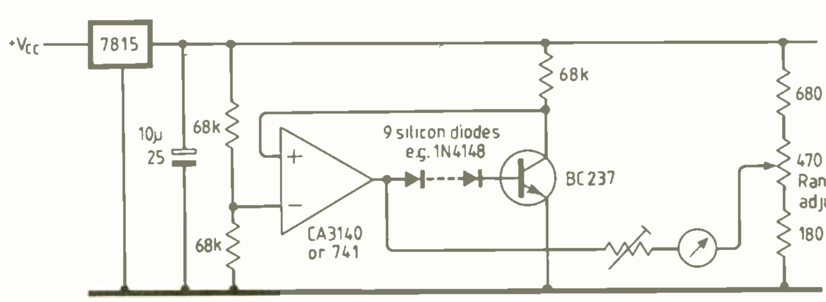
Simple but accurate thermometer

Normally, using semiconductors as sensing elements to measure temperature has the drawback that accuracy is limited by op-amp offset.

In this circuit, offset problems are greatly reduced since the nine silicon diodes exhibit a similar characteristic to the transistor p-n junction.

Output of the circuit – which can form either a switched-range thermometer or part of a thermostat – is 20mV/°C. The transistor should have an h_{FE} of 100 or greater.

Salvador Espin Carreras
Balearic Island
Spain



Electromagnetic units in chaos

Colin White dissipates the confusion that started with Faraday and Ampère and grew ever worse

While discussing the propagation of microwave signals through gyromagnetic media with a group of postgraduate students, I made an unfortunate faux pas. I happened to mention that the gyromagnetic ratio has a value of 2.8 MHz per oersted. "Per what?" they cried. Yet again, engaging mouth before brain, I suggested we had a forum at a later date to discuss electromagnetic units. The lively, albeit sometimes heated, discussions that ensued with my colleagues instigated my own reserarch in an attempt to bring some order to the apparent chaos. The product of my endeavours are presented in this article.

The importance of this subject becomes apparent when one has to work with EM theory in a practical sense; putting real numbers into well established equations to obtain measurable quantities. We are presently educating a generation of students unfamiliar with older systems of units, although 90% of scientific library books and academic papers they refer to still use the c.g.s. system or some other non-SI system. The complexities of EM theory are such that conversions between c.g.s. and SI units do not merely involve changes in the exponent of the number and, in some cases, a deep understanding of EM theory is required before conversion is attempted.

There are two major reasons why EM units cause such confusion: one historical, the other contemporary. Firstly, Coulomb in the 18th century independently laid down the laws of electrostatic and magnetostatic theory and it took almost 100 years before Faraday and Ampère saw the relationship between the two. This delay allowed two separate and distinct systems of units to be well developed before the need for a more unified system arose. Secondly, within narrow fields of EM theory, systems of units are "invented" to simplify specific applications of well established equations. This could explain why, in a recent American journal, magnetic induction was measured in kilolines per square inch!

The origins

In 1785 Coulomb published a paper describing the laws of electric and magnetic attraction and repulsion. The secret of his work was the invention of a simple but successful torsion balance which he used with great experimental skill, measuring forces equivalent to 10^{-5}g.

Coulomb's Law is of the form

$$F = C_e \frac{q_1 q_2}{r^2}, \qquad (1)$$

where F is the force between two point changes q_1 and q_2 spaced a distance r apart. C_e is the constant of proportionality. Now Ampère's Law can be written as

$$\frac{dF}{dz} = \frac{2 C_m I_1 I_2}{r} \qquad (2)$$

where dF/dz is the magnitude of the force per unit length between two parallel wires separated by a distance r and carrying current I_1 and I_2. C_m is another constant of proportionality.

Assuming a consistent set of units for equations (1) and (2) and I given by dq/dt, it can be seen that the ratio of C_e/C_m has the dimensions of $(speed)^2$ and, experimentally, this ratio has been proved to be numerically equal to the $(speed of light)^2$ in free space.

$$\frac{C_e}{C_m} = c^2. \qquad (3)$$

"...in a recent American journal, magnetic induction was measured in kilolines per square inch!"

However we juggle the values of C_e and C_m, equation (3) must always hold for free space. No experiment has yet been devised by which the dimensions of C_e or C_m can be obtained as independent physical entities. It is therefore logical that either the unit of charge, or the unit of current must be specified as a fundamental unit together with the units of mass, length and time. Historically, however, C_e and C_m have been chosen as independent, dimensionless, absolute units.

Electrostatic and electromagnetic systems

Both the electrostatic and electromagnetic systems were based on the c.g.s. system of units and, although they used the proportionality constants of equations (1) and (2) as absolute units, they were popular well into the 1940s.

The electrostatic units used Coulomb's Law as a fundamental result and hence C_e was chosen to be dimensionless and numerically equal to unity. C_m was taken as $1/c^2$ (and took on the appropriate dimensions) and equations (1) and (2) became

$$F = \frac{q_1 q_2}{r^2} \qquad \frac{dF}{dz} = \frac{2I_1 I_2}{c^2 r} \qquad (4)$$

The unit of charge in this system does not require definition and takes on the dimensions $(\text{mass})^{1/2}$, $(\text{length})^{3/2}$, $(\text{time})^{-1}$.

The resulting unit of charge became known as the 'franklin' or simply 1 e.s.u: in fact there was a penchant for referring to all the units in the system as e.s.us. As ever, this would not have created any problems for experienced scientist, but students must have found the system most confusing.

Sometime later, the e.s.u. took on names such as statcoulomb, statamp, statvolt, statfarad and statohm – all derived from the standard equations in c.g.s and using $C_e = 1$ and $C_m = 1/c^2\ s^2\ cm^{-2}$. The e.s.u. magnetic units were derived through Faraday's Law $\nabla \times E = -\partial B/\partial t$. As an alternative there was the electromagnetic system. Here $C_m = 1$ and C_e became $1/c^2$. Hence equations (1) and (2) became

$$F = \frac{c^2 q_1 q_2}{r^2} \qquad \frac{dF}{dz} = \frac{2I_1 I_2}{r} \qquad (5)$$

The abbreviation e.m.u. was used for most of these units, although again the names were later changed to abamperes, abcoulombs, abfarads etc. By comparing (4) with (5), we see immediately one important conversion factor: 1 statamp $= 3 \times 10^{10}$ abamps.

The Gaussian system

Historically, e.s.u. was used for electrostatic problems and e.m.u. for magnetostatic problems. It seems natural that a hybrid system using e.s.u. for electrical quantities and e.m.u. for magnetic quantities should develop. This became known as the Gaussian system. The point of contact between the two systems was the current density, J, such that

$$J_{emu} = \frac{J_{esu}}{c} \qquad (6)$$

Incidentally, just to confuse the issue, equation (3) did not hold. Maxwell's equations were written in the form

$$\text{div } D = 4\pi\rho \qquad \text{div } B = 0$$

$$\text{curl } E = -\frac{1}{c}\frac{\partial B}{\partial t} \qquad \text{curl } H = \frac{4\pi J}{c} + \frac{1}{c}\frac{\partial D}{\partial t} \qquad (7)$$

The field vectors were related by

$$D = E + 4\pi P \qquad H = B - 4\pi M.$$

Also

$$D = \epsilon E,\ B = \mu H,\ J = \sigma E,\ P = \chi_e E$$
$$M = \chi_m H$$

TABLE 1 Used tc convert the 'form' of equations.

Quantity	MKSA	Gaussian
Capacitance	C	$4\pi\epsilon_o C$
Charge	q	$(4\pi\epsilon_o)^{1/2} q$
Charge density	$\rho,(\sigma,\lambda)$	$(4\pi\epsilon_o)^{1/2}\rho,(\sigma,\lambda)$
Conductivity	σ	$4\pi\epsilon_o\sigma$
Current	I	$(4\pi\epsilon_o)^{1/2} I$
Current density	$J,(K)$	$(4\pi\epsilon_o)^{1/2} J,(K)$
Dielectric constant	κ_e	ϵ
Dipole moment (electric)	p	$(4\pi\epsilon_o)^{1/2} p$
Dipole moment (magnetic)	m	$(4\pi/\mu_o)^{1/2} m$
Displacement	D	$(\epsilon_o/4\pi)^{1/2} D$
Electric field	E	$(4\pi\epsilon_o)^{-1/2} E$
Inductance	L	$(4\pi\epsilon_o)^{-1} L$
Magnetic field	H	$(4\pi\mu_o)^{-1/2} H$
Magnetic flux	Φ	$(\mu_o/4\pi)^{1/2}\Phi$
Magnetic induction	B	$(\mu_o/4\pi)^{1/2} B$
Magnetization	M	$(4\pi/\mu_o)^{1/2} M$
Permeability	μ	(1) $\kappa_m\mu_o$, then (2) $\kappa_m \to \mu$
Permeability (relative)	κ_m	μ
Permittivity	ϵ	(1) $\kappa_e\epsilon_o$, then (2) $\kappa_e \to \epsilon$
Polarization	P	$(4\pi\epsilon_o)^{1/2} P$
Resistance	R	$(4\pi\epsilon_o)^{-1} R$
Resistivity	ρ	$(4\pi\epsilon_o)^{-1}\rho$
Scalar potential	ϕ	$(4\pi\epsilon_o)^{-1/2}\phi$
Speed of light	$(\mu_o\epsilon_o)^{-1/2}$	c
Susceptibility	$\chi_e,(\chi_m)$	$4\pi\chi_e,(\chi_m)$
Vector potential	A	$(\mu_o/4\pi)^{1/2} A$

Although in a vacuum, of course, $D = E$ and $B = H$.

It is interesting that E, D, B, H, P and M all had the same dimensions, although some were given different unit names. The magnetic unit for B was the gauss and for H and M, the oersted. Two words of warning here. Firstly, the conversion factors for H and M from the Gaussian system to the SI system (ampere/metre) are different (see Table 2). Secondly, it is madness to name a unit after anyone whose name begins with O! (no disrespect intended). I shudder to imagine how many times answers have been in error by a factor of 10 and possibly the units changed to that of electron charge e (the abbreviation for oersted being Oe).

There are two further variants on the Gaussian system. The 'modified' Gaussian system measures charge in statcoulombs and current in abamps; otherwise the system is identical. This is easily incorporated within the equations by replacing all the current terms by c times the term. Only one of Maxwell's equations is changed. Ampère's Law is now written as

$$\text{curl } H = 4\pi J + \frac{1}{c}\frac{\partial D}{\partial t} \qquad (10)$$

The 'Heaviside-Lorentz' system is simply a rationalized Gaussian system. In this, all the (4π)s appearing in the equations are made equal to unity, so $\text{div } D = \rho$ and

$$\text{curl } H = J + \frac{1}{c}\frac{\partial D}{\partial t}$$

Our present SI system is rationalized, which is fine for equation manipulation but dangerous when results are expected from the equations. If a particular author does not explicitly state the unit system, it is wise to look at the form of some familiar equations and hence deduce the intended units.

The SI system

The Système International d'Unites for electromagnetism is the rationalized MKSA system, which is based on four arbitrarily chosen and defined quantities – the metre, kilogram, second and ampere. Of course, μ_o and ϵ_o now have both values (other than unity) and dimensions.

$$\mu_o = 4\pi \times 10^{-7}\ \text{henrys/m}$$

(exact by definition)

$$\epsilon_o = 8.85419 \times 10^{-12}\ \text{farads/m}$$

(experimentally measured quantity) and equation (3) is obeyed.

There are normally two types of problem associated with unit conversion. The first, and most complex, is the transformation of expressions given in one system of units to another system. The second is in converting numerical values of physical quantities from one system to another.

Converting the form of expressions

Table 1 provides a means of converting from the Gaussian system to the SI system, and vice versa. Conversion to or from the other systems previously mentioned is a trivial exercise and has been explained in the preceding sections. To perform the conversion, one replaces the symbol in the column labelled by the system in which the formula is written by the symbol or combination listed for the other system. Mechanical quantities (length, mass, time, force, work, energy, power etc.) remain unchanged.

As an example, let us transform the Gaussian expression of Maxwell's equation

$$\text{curl } H = \frac{4\pi J}{c} + \frac{1}{c}\frac{\partial D}{\partial t}.$$

From Table 1, we obtain

$$\text{Curl } [4\pi\mu_o]^{1/2} H = \frac{4\pi\,[4\pi\epsilon_o]^{-1/2}}{(\mu_o\epsilon_o)^{-1/2}}\,J$$
$$+ \frac{1}{(\mu_o\epsilon_o)^{-1/2}} \cdot \frac{\partial}{\partial t}[\epsilon_o/4\pi]^{-1/2} D,$$

which reduces to the familiar SI form of Maxwell's equation

$$\text{curl } H = J + \frac{\partial D}{\partial t}$$

Table 2 includes most of the common quantities which may require conversion. The MKSA and Gaussian columns represent equal amounts of each quantity, so a magnetic field of 0.25 Oe ≡ $0.25/4\pi \times 10^{-3}$ A/m = 20 A/m.

But beware!

As with all rules there are the exceptions, mainly due to the possibilities for laziness inherent in the Gaussian system.

Firstly, when converting the form of a Gaussian equation for a wave *in a vacuum*, since D = E and B = H, the symbols tend to be used interchangeably. The problem arises since the conversion factors for D and E, and B and H are different.

"...the characteristic impedance of free space is equal to 1 asyl ohm."

Secondly, when considering fields within a magnetized medium, in the Gaussian system, the equation

$$B = H + 4\pi M \qquad (11)$$

holds. Although H and M were measured in oersteds and B in gauss, dimensionally the equation was correct. Using Table 1 to convert this to SI we obtain

$$B = \mu_o (H+M) \qquad (12)$$

where B is measured in teslas, H and M in amperes/metre. In many recently published and well respected text books using SI units, I have seen M measured in teslas. This is either a total error and the author *meant* ampere/metre or, as is more often the case, (12) has been written in the form

$$B = \mu_o H + M \qquad (13)$$

Although (13) is strictly in error, (neither conforming to SI nor BS 1991 standards) its use is to some extent understandable, since both B and M are measurable. H, on the other hand, can only be calculated.

Let us return to that first fateful statement – "...the gyromagnetic ratio has a value of 1.8 MHz per oersted." We now know of course that I meant to say 28 GHz/tesla (using Table 2). The defining relation comes from the expression for the resonant frequency in a gyromagnetic material (e.g. ferrite), universally given by

$$\omega = \gamma H$$

Where ω is the radial frequency of resonance, H is the applied field, and γ is the dreaded gyromagnetic ratio. Already we see the units are not consistent. In fact, H is usually applied by an external magnet so we ought to specify (14) in terms of the measurable quantity, flux density;

$$\omega = \frac{\gamma B}{\mu_o} \qquad (15)$$

Furthermore, ω is specified as frequency rather than angular frequency. Equation (14) should be quoted as

$$f = \frac{\gamma}{2\pi\mu_o} . B. \qquad (16)$$

It is $\gamma/2\pi\mu_o$ which is strictly the gyromagnetic ratio and specified as 28 Ghz/tesla. I have yet to see (16) written correctly in any of the literature.

TABLE 2 Used to convert actual numerical values.

Quantity	MKSA	Gaussian
Length	1 metre (m)	10^2 centimetres (cm)
Mass	1 kilogram	10^3 grams
Time	1 second	1 second
Force	1 newton	10^5 dynes
Work, energy	1 joule	10^7 ergs
Power	1 watt	10^7 ergs/second
Capacitance (C)	1 farad	9×10^{11} statfarads
Charge (q)	1 coulomb	3×10^9 statcoulombs
Charge density (ρ)	1 coulomb/m^3	3×10^3 statcoulomb/cm^3
Conductivity (σ)	1 $(ohm\text{-}m)^{-1}$	9×10^9 $(statohm\text{-}cm)^{-1}$
Current (I)	1 ampere	3×10^9 statamperes
		$= 10^{-1}$ abamperes
Current density (J)	1 ampere/m^2	3×10^5 statampere/cm^2
Displacement (D)	1 coulomb/m^2	$12\pi \times 10^5$ statvolt/cm
Electric field (E)	1 volt/m	$\frac{1}{3} \times 10^{-4}$ statvolt/cm
Inductance (L)	1 henry	$\frac{1}{9} \times 10^{-11}$ stathenrys
Magnetic field (H)	1 ampere/m	$4\pi \times 10^{-3}$ oersted
Magnetic flux (Φ)	1 weber	10^8 maxwells
Magnetic induction (B)	1 weber/m^2 = 1 tesla	10^4 gauss
Magnetization (M)	1 ampere/m	10^{-3} oersted
Polarization (P)	1 coulomb/m^2	3×10^5 statvolt/cm
Potential (φ)	1 volt	$\frac{1}{300}$ statvolt
Resistance (R)	1 ohm	$\frac{1}{9} \times 10^{-11}$ statohms

And finally...

There is no doubt that the system of electromagnetic units has been, and to some extent still is, a mess.

In an effort to put things in perspective I will briefly describe two systems of units used by practitioners from other fields of knowledge. Firstly, a system regularly used by Quantum Mechanics. The system is based on the MKSA system of SI with the exception of the unit of length. This is given a variety of names (including none at all) and is equal to 2.99792458 × 10^8 metres. Let us call this unit of length the asyl. The velocity of light then equals 1 asyl/s. Both μ_o and ϵ_o can legitimately be made equal to 1 (unlike the Gaussian system which cheats!), the phase constant of a wave in free space is simply equal to the radial frequency ω, (from $\beta = \omega\sqrt{\mu_o\epsilon_o}$) and the characteristic impedance of free space, given by the expression

$$Z_o = \sqrt{\frac{\mu_o}{\epsilon_o}} \text{ is equal to 1 asyl ohm!...}$$

(think about it).

"There is no doubt that the system of electromagnetic units has been, and to some extent still is, a mess."

The other system of units is often used by timber merchants. Forced with the necessity of 'going metric', yet still dealing with customers reared on yards, feet and inches, and unwilling to change the habit of a lifetime, they compromised and invented the metric foot! This is precisely 0.3 m or, very nearly 1 foot... but not quite. So if you happen to be in a timber merchants and order a 6 foot length of wood, you are absolutely guaranteed to receive at least 1.8 m, or just a touch under 5ft 11 in. You think we've got problems!

References

1. R. K. Wangsness, Electromagnetic Fields, 2nd. ed., Ch.23, Wiley, 1986.
2. A. J. Baden Fuller, Units of Magnetisation, *IEE PROC.*, vol. 129, pt. A No 3, p.203, May, 1982.
3. L. J. Giacoletto, Standardized use of SI Magnetic Units, *IEEE Trans., MAG-10*, pp.1134-1135, 1974.
4. J. A. Stratton, Electromagnetic Theory, McGraw-Hill, 1941.
5. P. Silvester, "Modern Electromagnetic Fields", Prentice-Hall, 1968.

■

Broadcast satellite links improved

Recent developments in OB satellite links include the adoption by BBC Radio of the DS1/QPSK system for its new OB links; work by the IBA to reduce the failure threshold of digital sound-in-syncs to enable a link system to take advantage of the improved video performance of its FM enhanced threshold-extension system; and trials by the German Post Office Research Institute (DBP/FTZ) showing that multiplexed 64Kbit/s data channels can be carried on DS1 satellite channels with bit error rates better than 1 in 10^7.

DS1 is part of the digital satellite radio broadcasting system developed a few years ago in Germany to permit 16 high-quality digital stereo channels to be carried on a DBS satellite transponder. Originally it was intended for use on the ill-fated German TV-Sat that failed on launch in late 1987.

At Kingswood Warren, BBC engineers, with the co-operation of the EBU, IRT and TDF, carried out comparisons between the MVS620/FM transmission system (the first system to be proposed as a potential EBU standard for such applications) and the DS1/QPSK system. This led the BBC to choose the latter system for its new radio OB links with modems conforming to the American IBS/SMS SCPC (single carrier per channel) modems. For DS1, a Rohde & Schwarz audio codec samples the programme signal at 32kHz to 16-bit accuracy and then compresses it to 14 bits, a scale factor being added to identify the degree of compression of each group of 64 samples. This results in a 1024kbit/s data signal.

The modulator adds 1:2 forward error correction to produce a 2048kbit/s data signal. The Hughes QPSK modem modulates this signal on to a 70MHz carrier. The 2048kbit/s signal is sometimes termed DS2. The channel arrangement for EBU-leased transponders may be changed to permit each transponder to carry two television signals (video and sound) plus one digital stereo radio channel using DS1/QPSK although the final configuration has not yet been decided.

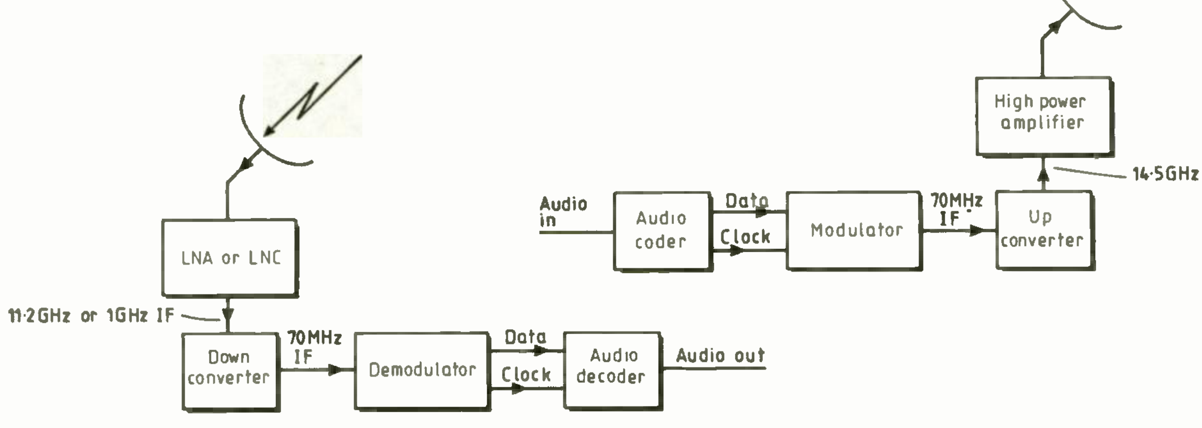
The very strong error correction applied to digital sound radio (DSR) transmissions has been shown by FTZ (*EBU Review – Technical*, February 1989) to be well suited to data transmission of 22 (plus three) multiplexed 64kbit/s data channels over a single DS1 stereo channel. The scale factor generation sub-system and the error concealment in the DSR multiplexer must be disabled when transmitting data; however, special hardware for the FTZ experiments was restricted to a serial/parallel converter with delay compensation at the sending end, and a unit to convert the data bursts at the receiver output to a continuous data stream. With the BCH code used, a bit-error ratio of about 10^{-7} can be achieved wth a carrier-to-noise ratio (CNR) of 10dB measured in a bandwidth of 27MHz. The receiving antenna dish can be as small as 2m in diameter.

Since 1987, ITN has been making use of the IBA-developed enhanced threshold-extension system suitable for video signals and using a line-store "predictor" (now being manufactured under licence by Multipoint Communications as the M1400) in conjunction with an analogue sound subcarrier. Although this system has proved very attractive, the presence of a large-amplitude sound subcarrier inevitably causes some (slight) degradation to the vision threshold. The IBA has therefore been investigating alternative systems.

To improve the audio SNR at low CNR, it is desirable to use the digital sound-in-syncs (SIS) system. The problem then is to guarantee a safe fade margin when using SIS for low-power operations. IBA investigations reported recently at the IEE by Brian Beech show that, under normal circumstances, using a limiter discriminator demodulator, SIS failure occurs at about 11dB CNR, which would be unacceptable for low-power SNG links. The failure point can be reduced to 7dB by (a) reducing the amplitude of the SIS waveform from 700mV to 300mV pk-pk; (b) using an enhanced threshold-extension demodulator at the receive terminal; and (c) fitting an improved sync detector to the SIS decoder. The reduction to 300mV does not materially affect performance of receivers not equipped with enhanced threshold detectors (i.e. failure at about 11dB CNR).

Brian Beech pointed out that it would be theoretically possible to reduce the SIS failure point to 4dB (5dB has been demonstrated) by reducing the SIS amplitude to 100mV pk-pk, but this would require a total redesign of the SIS decoders. IBA are therefore proposing 100mV SIS as a standard for low-power satellite transmission.

Broadcasting is written by Pat Hawker.



Block diagram of a satellite link suitable for carrying digital audio signals.

European SNG: costly for TV, cheap for radio

An IEE colloquium "Outside Broadcast & Satellites" underlined the regulatory difficulties and "extraordinarily high costs" that need to be overcome if full advantage is ever to be taken in Europe of the potential advantages of satellite news gathering (SNG) for television. But it became clear that the present problems are primarily man-made rather than imposed by the state of the technology. Fortunately they apply to a far lesser extent to the introduction by BBC Radio of its new mobile satellite link which can transmit digital stereo signals (DS-1 coding) from remote sites to Broadcasting House, London via the EBU-leased transponder on Eutelsat 1-F2. This equipment includes a 300W Ku-band up-link transmitter and 1.9-metre dish supplied by Advent Communications Ltd.

The BBC Radio OB equipment can be transported by air or road in the "flyaway" mode packed in portable cases, but is normally transported and operated inside the OB vehicle which has been fitted with two simple stabilizers. The unit was first used operationally from Stroud, Gloucestershire on June 4 and from Glyndebourne on June 15, and is being used this summer for the Radio 1 Roadshow programmes five days a week from a variety of British coastal resorts.

The key to the viability of satellite OB links for relatively low-budget radio, while proving so costly for television news gathering, is clearly the use of the BBC's own 3m receive-terminal, the use of an EBU-leased transponder rather than bookings on the main communications satellites of the international telecommunications carriers, and the ability to apply for site clearance (frequency co-ordination) for scheduled programmes well in advance.

None of these conditions applies to the ITN SNG operations. ITN pioneered in Europe the use of satellite links when, on September 25, 1978, a news bulletin was transmitted from IBC78 at Wembley using the IBA's transportable satellite terminal. In 1985 it acquired a GEC-McMichael "Newshawk" flyaway terminal.

At the IEE colloquium, Mike Neuston and Trevor Davies emphasized that the ITN's experience had been generally disappointing owing to the difficulty of obtaining rapid approval of sites to

BBC Radio's new transportable satellite dish makes it possible to relay events in stereo from sites far from the UK's main telecommunications trunks, where stereo links are not easily obtainable. Signals are downlinked to Broadcasting House.

enable its terminal to be used at major hard-news locations which could not be foreseen in advance and the extremely high costs incurred in using the space segment and in receiving signals through the large BT Earth stations remote from London. Costs are also pushed up by the insistence by BT and European PTT administrations that one of their own engineers should always be at the uplink terminal.

Satellite news gathering is also proving difficult to "sell" to newsrooms. It is unpopular with television reporters, partly because the high costs mean that space bookings are often limited to 15 minutes, making it impossible to send back to London a preliminary report.

Trevor Davies noted that although the basic weight of the Newshawk terminal is roughly 300kg, the addition of communications and baseband equipment, emergency generators and a spare high-power-amplifier (HPA) brings the weight to about 1200kg which, in the flyaway mode, has to be carried in about 18 boxes. This load has frequently been flown as excess baggage or by cargo, the main difficulty being transport from the airport to site.

Mike Neuston (ITN) questioned whether, with the development of detachable petal-type and folding antennas, the time has come to think less of using the smallest possible dish antenna and rather more of larger (erected on site) antennas that would permit the use of much lower-power up-link transmitters. These might be operated, if only for a short time, from batteries. John Rogers (Multipoint Communications) noted that solid-state amplifiers were still limited to about 10-20 watts output, requiring the use of at least a 4.5m dish

But the meeting emphasized that the major drawback for hard-news SNG is the delay involved in obtaining frequency co-ordination clearance for a site when a major news story breaks without warning. Ron Bedford (DTI) stressed that the DTI is continuing its efforts to speed up the process of site clearance, but pointed out that Europe is very different from the USA where the FCC administrates the entire country. DTI has been unable to persuade neighbouring countries such as France, Belgium and Holland to agree to a single clearing centre working to pre-agreed rules; the Ministry of Defence and the Civil Aviation Authority are also involved. DTI is currently introducing a new 24-hour, seven-days-a-week facility for initiating clearance procedures, "but there are limits to what we can do."

Mike Neuston said that broadcasters would be willing to accept and adhere to operational restrictions on the use of up-link terminals if this meant that clearance could be achieved in the couple of hours it takes a transportable up-link to get to the site. He added: "Unless the log-jam breaks, expansion (of SNG) won't take place. News is about now and is governed by speed. Site clearance needs to be done within the time it takes to get on site. Are we trying to protect ourselves from interference to terrestrial services that doesn't in practice occur?" ■

Improving MF and LF AM receivers

Although few would disagree with the view that, for domestic listening, VHF/FM stereo broadcasting is superior to AM on medium- and long-waves in terms of fidelity, dynamic range and relative freedom from interference, there still remain a number of practical advantages that seem certain to ensure that the MF and LF bands will continue to be used for broadcasting well into the 21st century. Indeed it could be argued that, were it not for the overcrowding of these bands in Europe, the consequently limited 9kHz channels and the excessive night-time sky-wave interference, AM broadcasting could still provide a most useful and convenient service, particularly for reception on portable and car-radio receivers – if only there were better AM receivers.

Since the introduction of FM broadcasting, the emphasis in most AM designs has been on low cost rather than good RF performance. On the whole, current models compare poorly with those of the 1930s which were usually considerably more expensive in "real money" terms. Probably the single most significant improvement, which came in the immediate post-war period, has been the use of built-in ferrite rod antennas which are significantly less vulnerable to the electric near-field component of domestic appliance interference and offer the capability of nulling out day time co-channel interference, especially if made rotatable and not mounted too close to metalwork. But in terms of pre-mixer selectivity to reduce 'image' reception and other spurious responses due to harmonic mixing, variable IF selectivity rather than a fixed (−6dB) bandwidth often under 3kHz, and ease of station selection, 'progress' has tended to be backwards. I recall building in the 1950s a very simple MF tuner with regenerative RF amplifier and infinite-impedance detector that gave reasonable quality on local signals yet was capable of receiving foreign stations quite well. It is often forgotten that in Europe 'straight' (i.e. not superhet) designs remained widely used for broadcast receivers until about 1936-37, with positive feedback ('reaction') providing a simple, low-cost form of variable selectivity sometimes enhanced by bandpass tuned circuits.

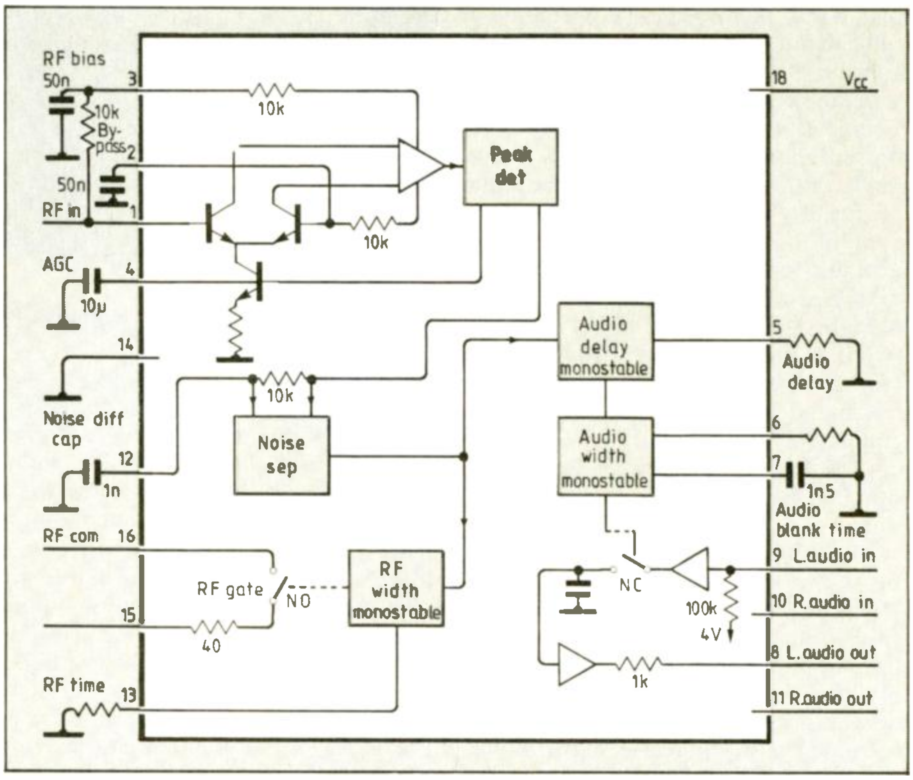


Fig. 7. Block diagram of Sprague's ULN3845 noise blanker IC.

The 1930s also saw rapid progress in the design of high-performance HF communications receivers. Several different forms of noise limiters were developed for use on AM signals, which were affected by ignition interference in the days before the introduction of television led to the compulsory fitting of car ignition suppressors. Such circuits as the Dickert, Bacon, Lamb noise-silencing circuits operated either by shorting transient noise-pulses to earth or by opening an electronic switch in series with the audio signal when a noise pulse was detected.

Such arrangements were reasonably effective, particularly above 20MHz where ignition interference was most pronounced. They largely overcame the fundamental problem that noise pulses are stretched in time when passing through highly selective resonant circuits in RF or IF stages and thus tend to be effective only when applied before the noise impulse has been lengthened in this way. Such circuits have seldom, if ever, been used in normal broadcast receivers – though this could now change, particularly for car radios.

Sprague in the USA has recently developed a monolithic IC noise-blanker device type ULN3845 (described by Oliver L. Richards in *RF Design*, February 1989). This is primarily intended for use in AM entertainment receivers, including mono or AM-stereo car radios where ferrite-rod antennas are not used. The device is, however, applicable to any receiver with an RF or IF bandwidth that is substantially wider than the audio bandwidth. The basic operation is similar to that of the Lamb noise-silencer (*QST*, February 1936) and puts the electronic switch ahead of most of the gain and selectivity to overcome much of the stretching and AGC blanking problems. The IC incorporates a noise pulse detector, RF gate and dual audio gate making it suitable for use in AM-stereo receivers. The input stage is the open base of a differential amplifier and can be connected to an RF or early IF stage of the receiver.

RF Connections is written by Pat Hawker.

OSCILLOSCOPES

Telequipment D755 Dual Beam 50MHz

£275.00
+ VAT
Carriage £8.75

5mv/div/sensitivity. Sweep 2s to 100ns/div
Delayed timebase 8 × 10 div crt

TEKTRONIX 475 200 MHz Dual Beam

£599.00
+ VAT
Carriage £8.75
2miv/div 1 n/sec Sweep rate, delayed sweep.
Trigger view 8 × 10cm display.

All items checked/tested with 30 days warranty. All in good clean condition.

M and B RADIO

86 BISHOPSGATE STREET, LEED LS1 4BB
Telephone: 0532 435649 · Fax: 0532 426881

78270

ENTER 23 ON REPLY CARD

COMPUTER APPRECIATION

The Penny Theatre, 30/31 Northgate, Canterbury, Kent CT1 1BL
Telephone: (0227) 470512

HEWLETT PACKARD MODEL 5501A LASTER TRANSDUCER. With piezoelectric tuning for precise control of wavelength in measuring applications. With various mirrors and accessories £250 00

VICKERS INSTRUMENTS MODEL M17 METALLURGICAL MICROSCOPE with binoculars micrographic head and all eyepieces With 4 Microplan objectives & **Nomarski interference contrast**, variable illuminator etc An immaculate instrument from the clean-room of a major semiconductor manufacturer New cost over £6500 00 .... £1250.00

KRATOS MS30 DOUBLE BEAM MASS SPECTROMETER Approximately 8 years old with negative ion capability & fast atom bombardment (FAB) With gas & direct introduction sample probes & with gas chromatograph inlet system Output spectra are available directly via a HEWLETT PACKARD storage display & a UV recorder An on line DATA GENERAL DS60 computer system which includes a graphics printer & two TEKTRONIX 4014 terminals analyses output The various sections of the instrument may be available separately A new high flux magnet was fitted shortly before the instrument was decommissioned .... **P.O.A.**

SPECTRA PHYSICS MODEL 164 4 WATT ARGON ION LASER with MODEL 265 POWER SUPPLY and transformer for 3 phase supply. Suitable for research applications or a light show £1500.00

SPECTRA PHYSICS MODEL 164A 30mW HELIUM NEON LASER with power supply A powerful Helium Neon laser ideally suited for holography £350.00

LUMONICS SYSTEM 2000 RUBY LASER with Q switch temperature controlled KDP frequency doubler output monitor 0 3 Joule per pulse Q switched output 6 ppm Suitable for holography involving moving objects A low power He/Ne laser for mirror alignment and all manuals are included Current new price of equivalent model exceeds £15000 00 .... £3500.00

HEWLETT PACKARD Model 5045A digital IC tester with CONTREL Model H310 automatic handler. With IEEE interface & print out of test results either pass fail or full diagnostic including pin voltages at point of failure With full complement of pin driver cards & complete with substantial library of mag card test programs for 74 series TTL & other ICs CONTREL handler allows fully automatic testing of ICs which are sorted into 2 bins Price includes a **second HP5045A** (believed fully operational) for maintenance back up Very useful for recycling chips originally cost over £6000 00 .... £150.00

ITT PERFECTOR TELEX MACHINE. With 32k memory screen with slow scrolling keyboard etc together with operators and service manuals £99.50

BIOMATION Model 810D LOGIC ANALYSER. Combines with any oscilloscope to provide 8 channel logic analyser Size and colour to match Tektronix 400 series portables £75.00

DIGITAL Q-BUS, box, power supply, and 8 · dual slot backplane, all brand new Needs easy modification (14 wirewrap connections) to update. £75.00

TEKTRONIX Model 4051 intelligent graphics display with BASIC in ROM and RCA tape cartridge drive Good tube and useful for maintenance purposes £99.50

TRIUMPH ADLER/ROYAL Office Master 2000 DAISY WHEEL PRINTERS. 20 cps, Full IBM & DIABLO 630 COMPATIBILITY, CENTRONICS INTERFACE. Features include underscore bold subscripts superscripts underline etc 132 **column**; micro proportioned spacing Complete with typewheel & ribbon manufactured to highest standards in West Germany by Europe s largest typewriter manufacturer & offered elsewhere at over £350 00 Ex demonstration condition Guaranteed 90 days .... **£69.00 (£6.50 carr)**

PLESSEY Model T24 V22/V22 bis 2400 Baud MODEM. Including free software disc for IBM or MATMOS PC Compact **automatic** moderm featuring the latest technology & the highest possible data rate over the ordinary phone system Offers both V22 & V22 bis compatibility 1200/2400 Baud operation with auto bit rate recognition operation on both ordinary phone (PSTN) & private circuit (PC) auto call and auto answer **duplex** operation allowing simultaneous transmission & reception of data at 2400 Baud in both directions over a single phone line compact size (9 · 9 · 21½) BT approved & suitable for new **PRESTEL V22bis** service £59 50 (carr. £5.00)

Please note: ★VAT & carriage (also · VAT) must be added to all prices. ★Guarantees vary from item to item, please enquire before purchase. ★A full stock list with many other items and special offers is available on request.

ENTER 28 ON REPLY CARD

SMC South Midlands Communications

RADIO RECEIVERS AND TRANSCEIVERS

RECEIVERS

SMC the leading European specialist in general radio communications have developed modular systems for rapid delivery, particularly useful for emergencies, disasters, political unrest and aid concerns This can consist of rugged, simple to use, HF transceivers i e the FT80C with a frequency range of 1 5 30MHz used with either one of the SMC basic wide band antennas or more efficient, the multi spot frequency antennas complete with transportable masts

More powerful and complex transceivers are also available

Where monitoring or reception is required then either the FRG8800 HF receiver with VHF option or the FRG9600 VHF, UHF all mode scanning receiver are available with proven quality, sensitivity and reliability, at realistic prices

ANTENNAS

The TWB2530 and TEB3 are just two samples of the large range HF, VHF and UHF antennas available from SMC Both have been specifically designed for users with very different requirements showing the breadth of our capability The rugged transportable TWB2530 is a full self contained extremely lightweight, yet tough enough to withstand rough handling and quick assembly in adverse terrain

The TEB series of spot frequency HF beam antennas give excellent forward gain, rugged construction for long life, at a cost effective price

If you require further information on the 300 various support mounts, HF VHF or UHF antennas, simply call for our new shortform catalogue
Both can be supplied with the most efficient antennas and desirable accessories

SMC LTD, SM HOUSE, SCHOOL CLOSE, CHANDLERS FORD INDUSTRIAL ESTATE, EASTLEIGH, HANTS SO5 3BY.
Tel: (0703) 255111. Telex: 477351 SMCOMM G. Fax: 0703 263507

ENTER 26 ON REPLY CARD

NICAM DIGITAL STEREO

This month a digital sound service is launched on two of Britain's television networks. Paul Gardiner concludes his description of the signal and outlines the IBA's implementation of it.

The 728kbit/s digital multiplex is conveyed on a digitally modulated carrier, spaced 6.552MHz (for UK System I) above the vision carrier (**Fig.5**). This is additional to the conventional analogue FM carrier at 5.9996MHz. The FM sound carrier power is nominally 10% of peak vision power, while the digitally modulated carrier is just 1% of peak vision power. The level of the digitally modulated carrier was set at a sufficiently high level to ensure rugged reception; at the same time it is at a sufficiently low level to avoid interference to pictures or sound on existing receivers. The frequency of the digital carrier was chosen so as to avoid interference both to (or from) the analogue mono FM carrier, and to (or from) signals on the upper adjacent channel. The spacing of 6.552MHz is numerically equal to nine times the bit rate of 728kbit/s.

Prior to modulation, the bit-stream is scrambled to ensure that the transmitted signal appears as noise-like as possible, irrespective of content, so as to reduce further the likelihood of interference to the analogue FM or picture signals. This is achieved synchronously with the frame structure by the modulo-two addition of a pseudo-random sequence. The frame alignment word is not scrambled, since this is needed to synchronize the pseudo-random sequence generator used for descrambling in the receiver. The generator is re-initialized on the first scrambled bit of each frame.

The method of modulation that is applied is known as differentially-encoded quadrature phase shift keying (DQPSK), also referred to as four-phase differentially encoded phase shift keying (4-phase DPSK, **Table 3**). This makes very efficient use of the transmission bandwidth, while allowing reliable reception with a simple demodulator. The overall bandwidth is about 700kHz (see **Fig.6**). The same data spectrum shaping is applied both at the transmitter and the receiver, giving 100% cosine roll-off (in the case of System I) for the overall data-channel spectrum.

Table 3: DQPSK modulation scheme.

Input bit-pair A_n	B_n	Carrier phase change
0	0	0° (i.e. no change)
0	1	−90°
1	0	−270°
1	1	−180°

DQPSK is a four-state phase modulation system in which each phase change conveys two bits (**Fig.7**). The four rest-states are 90° apart; phase changes are caused from input bit-pairs as shown in Table 4. The input data stream at the modulator is differentially encoded by first forming bit-pairs by a serial-to-two-bit-parallel converter. The entire process of differential encoding, data-signal spectrum shaping and modulation at the transmitter is illustrated in **Fig.8**.

NICAM IN BRITAIN

In the UK, the BBC has annouced plans to introduce NICAM digital stereo from seven main transmitters (and their relays) reaching 70% of the population in autumn 1991. The IBA began trade test transmissions from the Crystal Palace and Emley Moor main transmitters in March 1989 in order to gain some operational experience prior to the launch of a full service, and to give dealers the opportunity to demonstrate receivers. A preliminary service in London and a major part of Yorkshire is due to start in September, and is hoped to include up to two hours of stereo programming per day on both ITV and Channel 4. The service will be extended to other areas from April 1990, reaching 75% of the UK by end of 1990 (areas shaded red, right). Complete national coverage is dependent upon progress of subsequent phases of the IBA's current re-engineering programme, but could be achieved by about the mid-1990s.

On the Independent Television networks, initially it is normally intended to use the additional dual-channel facility to provide stereo sound, rather than additional separate mono sound channels. The existing analogue mono sound will continue to be transmitted, but will be derived at the transmitter from the incoming digital stereo signals. It is planned to equip the entire distribution network (both ITV and Channel 4) with dual-channel sound-in-sync equipment, dispensing with the existing separate analogue sound circuits on ITV.

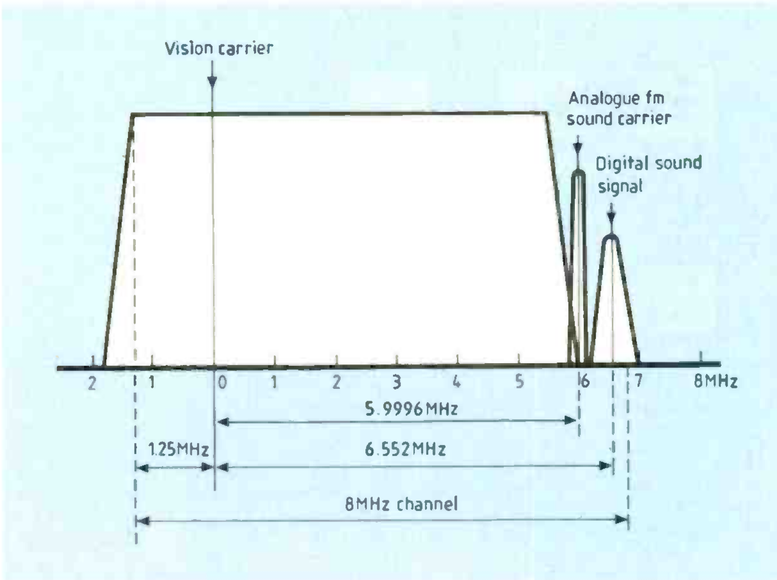


Fig.5. Frequency spectrum occupied by the NICAM 728 digital sound signal in relation to the picture signal (UK System I). Vertical axis is not to scale.

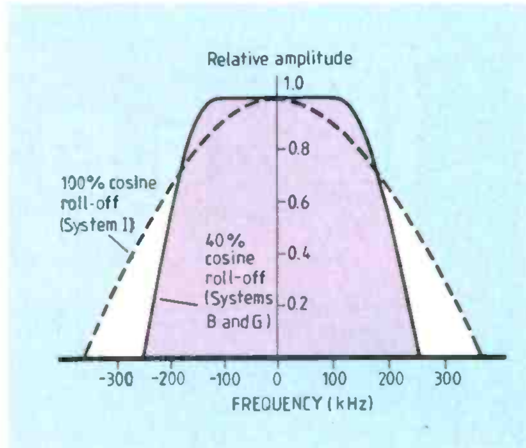


Fig.6. Spectrum shaping (due to combined transmit/receive data-shaping) for System I and Systems B and G.

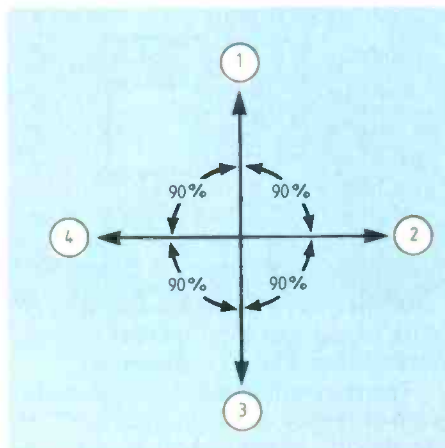


Fig.7. The four rest-states of carrier phase of the digitally modulated carrier for NICAM 728 are 90° apart.

Satellite broadcasting: MAC/packet

The broadcast terrestrial television signal consists of a frequency multiplex of vision carrier, colour subcarrier, FM carrier and digital carrier. For satellite broadcasting (or, indeed, for cable distribution), the MAC/packet format comprises a time-division multiplex. Digital data in duobinary form is inserted into intervals between picture lines: in the case of D-MAC/packet at the rate of 20.25Mbit/s, and for D2-MAC/packet at 10.125Mbit/s (**Fig.9**). The useful data conveyed is structured in the form of packets of 751 bits; each contains a header, followed by a sound/data area of 720 bits (**Fig.10**). Each packet header includes a 10-bit address field to provide for the identification of 1024 possible sound/data services. A particular sound or data service is made up of many such packets: unlike the continuous transmission of sound/data frames for terrestrial NICAM 728, packets containing data for a particular sound channel are multiplexed with packets containing data related to other services.

NICAM 728 is able to convey only two high-quality sound channels. The MAC/packet format however, allows a much higher data capacity – 4100 packets per second in the case of D-MAC (a mean data rate of almost 3Mbit/s), sufficient for up to six or eight high-quality companded sound channels, depending on the level of error protection. In the absence of pictures, the digital

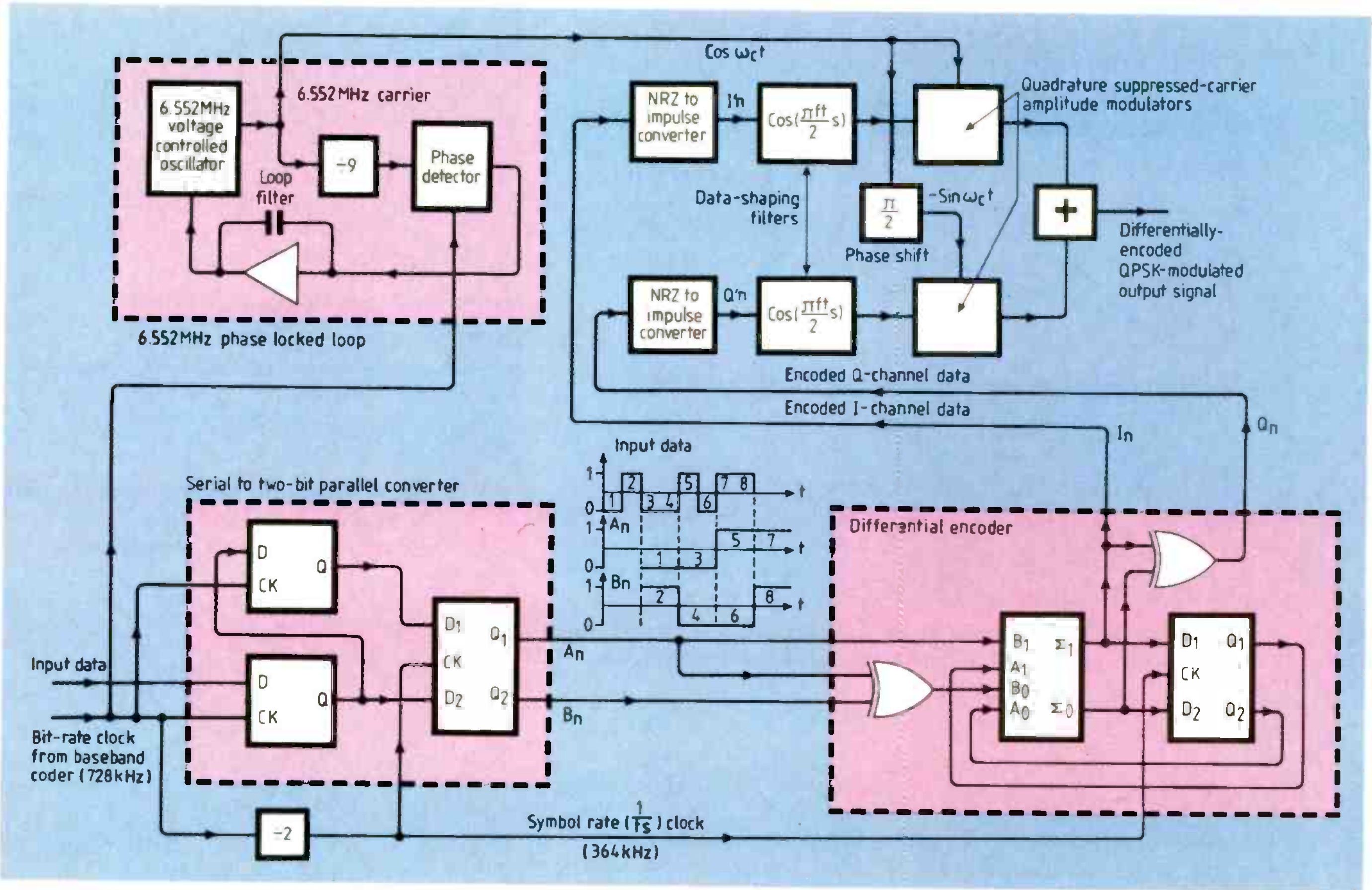
The present mono sound-in-sync equipment for distribution of the fourth channel will also be replaced by dual-channel equipment. The IBA expects the national dual-channel sound networking arrangements to be in place in early 1990.

Meanwhile, transmissions in the European 12GHz direct broadcast satellite (DBS) band will also benefit from the use of digital techniques for the sound, using the MAC/packet system (MAC refers to the multiplexed analogue component vision format which is accompanied by a high-capacity digital packet multiplex for sound and data). The first UK DBS test transmissions are due to begin this autumn, using the D-MAC/packet transmission system, with NICAM coding for the sound. Although the structure of the digital multiplex for MAC/packet transmission is very different to that of dual-channel terrestrial NICAM 728, the method of companding for the digital bit-rate reduction of individual sound channels is identical. Instead of just two sound channels, however, D-MAC/packet has sufficient data capacity to allow as many as eight high-quality sound channels in NICAM format to accompany the pictures.

Table 4: provisional dates for NICAM digital stereo transmission from IBA transmitters (ITV and Channel 4/S4C). The service will also become available at the same time from each of the main stations' dependent relays.

Transmitting station	Programme company	Transmission capability	Service date
Crystal Palace	Thames/LWT	March 1989	September 1989
Emley Moor	Yorkshire	March 1989	September 1989
Wenvoe	HTV Wales	March 1990	April 1990
Winter	Granada	April 1990	May 1990
Mendip	HTV	April 1990	May 1990
Caradon Hill	TSW	May 1990	June 1990
Black Hill	STV	May 1990	June 1990
Durris	Grampian	June 1990	July 1990
Divis	Ulster	July 1990	August 1990
Sandy Heath	Anglia	July 1990	August 1990
Caldbeck	Border	August 1990	September 1990
Pontop Pike	Tyne Tees	September 1990	October 1990
Rowridge*	TVS		Autumn 1990
Dover*	TVS		Autumn 1990
Sutton Coldfield	Central	October 1990	November 1990
Bilsdale	Tyne Tees	November 1990	December 1990
Belmont*	YTV		Autumn 1990

*These stations are being *modified* for dual-channel sound and there is some flexibility in timescales for the engineering work.



data capacity of MAC/packet could be increased by a factor of about six.

The packet multiplex can be used to convey either medium-quality (7kHz bandwidth 'commentary' sound using 16kHz sampling) or high-quality (15kHz bandwidth, 32kHz sampling) using either 14-bit linear or 14-to-10 bit NICAM coding. In each case, there is the option of one of two levels of error protection. In the case of NICAM, the sound companding process is identical to that of terrestrial NICAM 728. However, a three-bit scale factor value of 000 is used to identify periods of low-level sound (1/64th maximum amplitude or less) with a duration of at least 8ms. This allows for the management of the receiver buffer storage to obtain a smooth, regular output of sound samples since, unlike the continuous transmission of NICAM 728, packets related to a particular service are not transmitted continuously. As I have already mentioned, it is for the reason of this use of scale factor 000 that there is no eighth protection range in NICAM 728; both 001 and 000 are valid conditions in the seventh protection range to allow for the possibility of the transfer of sound between NICAM 728 and MAC/packet in digital form.

The 704 bits of data for a high-quality stereo sound coding block (using first-level protection) are identical to that of

Fig.8. Block diagram showing the processes of differential encoding, data-signal shaping and modulation at the transmitter (NICAM 728).

NICAM 728 and can simply be accommodated within a single packet, as shown in **Fig.11.** However, the first 16 bits of the 90-byte data area of the packet are not used. The use of a single parity bit to protect the six most-significant bits of each sample, and 'signalling-in-parity' of the scale factor information are identical to that of NICAM 728.

The MAC/packet specification also allows for an alternative higher level of protection for the sound, although it is not planned to use this for UK DBS, since for first-level NICAM a basic receiver will have an FM threshold for vision and a digital sound threshold (bit-error rate of 1 in 10^3) both in the region of 10-11dB **(Fig.12)**. A more sophisticated receiver using Viterbi techniques could allow sound decoding at lower carrier-to-noise ratios of 8-9dB.

'Second level' protection is achieved by applying a standard Hamming (11,6) code to each sample. The use of five protection bits instead of a single parity bit enables the correction of one single error (and the detection of two errors) in the six most-significant bits of each sample. As with first-level protection (and NICAM 728) the scale factor is signalled in parity. The penalty for the greater degree of protection is that a higher bit-rate is required. A single 704-bit stereo sound block would occupy a 120-byte coding block instead of a 90-byte coding block. The 120-byte coding blocks would be inserted in to the packet stream by placing three successive coding blocks in four successive packets.

The flexibility of the packet multiplex does result in some extra complexity compared to NICAM 728; for example, there is an additional overhead in the form of sound control packets which contain 'interpretation blocks', sent between one and three times per second to ensure that the receiver has knowledge of the coding format of the sound channel.

UHF transmission

The addition of the 6.552MHz digital carrier does, in general, require some modifications to be made to existing main transmitting stations, particularly in modulation and IF processing. Many transmitters use separate high-power klystron amplifiers for the conventional FM sound signal. These operate with relatively high efficiency and narrow bandwidths. The amplification of a

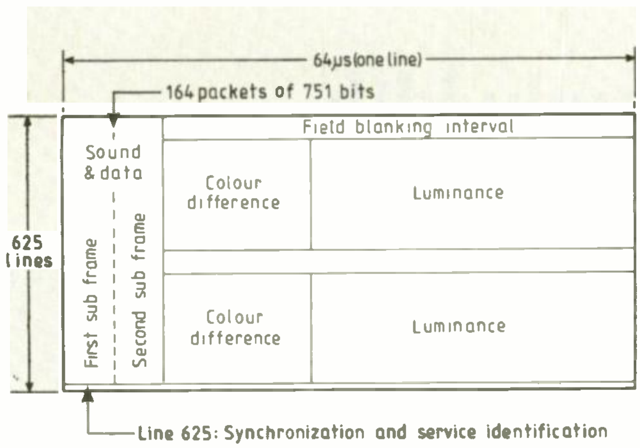


Fig. 9 (above). Structure of a 625-line MAC/packet frame, showing the time-division relationship between digital data (at the rate of 20.25Mbit/s for D-MAC) and the vision signal. The data is structured in the form of packets (of 751 bits).

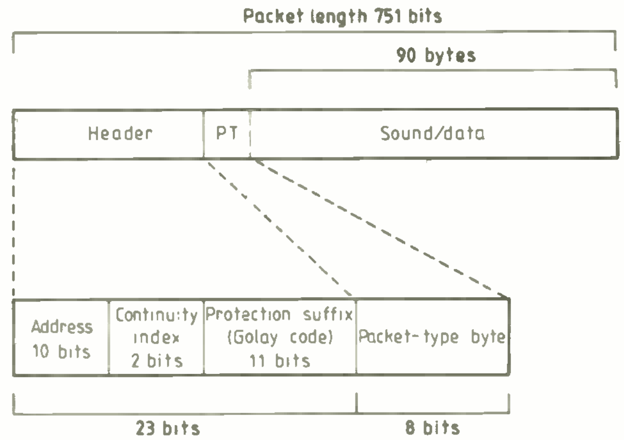


Fig. 10. Structure of a single 751-bit packet: each conveys a useful data area of 720 bits.

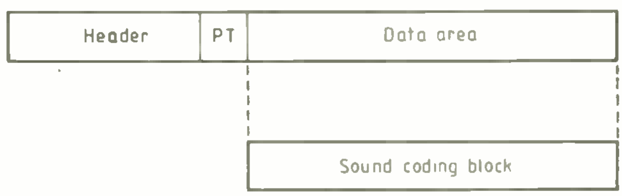


Fig. 11 (left). Insertion of a 720-bit NICAM (first-level protection) coding block into the 90-byte data area of a single MAC packet. The first 16 bits are unallocated; the remaining 704 bits of sound/data are indentical to those of NICAM 728.

second, digital, sound carrier requires more linear operation with a wider bandwidth, as well as IF pre-correction of intermodulation products. Other transmitters use common amplifiers for sound and vision signals; the inclusion of a third carrier will necessitate modification or replacement of existing circuits.

Further modification may be required to the sound/vision combining units. The IBA is currently modernizing many of the early ITV main transmitter installations, and the new replacement equipment is specified to deal with the NICAM 728 carrier. However, modifications are being carried out to existing fourth-channel transmitters to enable them also to provide NICAM digital stereo.

With relay stations the situation is more straightforward, since the input-channel signals are converted first to an intermediate frequency and then to the new output channel without demodulation, in broadband form. In general, satisfactory performance is obtained without adjustment, even for chains of several relays operating in tandem. Any limitations will be due to the cumulative effects of intermodulation products causing visible patterning on the pictures, rather than any degradation of the digital sound.

Much of Europe uses television Systems B and G, rather than System I (used by the UK and Eire). System B uses VHF channels with 7MHz channel-to-channel spacing, compared to 8MHz channels on UHF. To accommodate the 728kbit/s data signal in the narrower channel, a carrier at 5.85MHz above vision is used instead of 6.552MHz. A change of data-shaping filtering at the source and receiver (40% cosine roll-off overall instead of 100%) is also required to prevent interference to the upper-adjacent vision channel. In practice, reception of NICAM 728 has been found to be extremely rugged. Sound failure occurs only under very poor picture conditions, in the case of both weak-signal reception and in situations affected by multipath distortion.

Whether broadcast from satellite using the MAC/packet system, or terrestrially using NICAM 728, NICAM is set to become the new standard for high-quality television sound broadcasting. NICAM offers the domestic viewer the benefits of stereo, together with a subjective sound quality that compares very favourably with the Compact Disc. ■

Paul Gardiner is Principal Engineering Information Officer at the Independent Broadcasting Authority

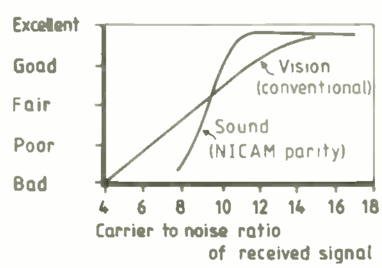


Fig. 12. Satellite reception quality of a D-MAC/packet signal using a conventional decoder illustrating the relative performance of vision and sound using first-level protection NICAM. More sophisticated decoding techniques allow a 2dB improvement in sound decoding.

1GHz gain-bandwidth op-amp

Last month I described a new breed of low cost, current-mode architecture op-amps, with very wide bandwidth and high slew-rate. These devices owe their conception to semiconductor process developments that have created fast vertical p-n-p devices, giving IC designers the freedom to develop truly complementary BJT amplifiers.

Elantec, whose products are aimed at the transmission, reception, processing, measurement and display of high speed analogue and digital signals, was the first company to market the current-mode type of op-amp. The complementary BJT process relies on the ability to create vertical, rather than lateral p-n-p devices, to match the performance of vertical n-p-n transistors. Elantec achieves this using the technique of dielectric isolation (DI), illustrated in **Fig. 1**. Some advantages of this process are high speed n-p-n and p-n-p transistors having sustainable high voltages, low capacitance, a virtual absence of parasitic transistors, high electrical isolation and no latch-up, high temperature operation and good radiation resistance.

A new op-amp launched by Elantec, the EL2038, performs very impressively: it features a 1GHz gain-bandwidth product with a slew-rate of 1000V/μs, giving a full output power capability of about 16MHz!

The op-amp is built using Elantec's dielectric isolation process. It costs about £2.93 per piece for quantities of 100 up. It is not a current-feedback architecture op-amp, but is almost conventional in structure, as can be seen from the simplified diagram, **Fig. 2**.

The circuit is symmetrical about a line drawn straight through the amplifier from input to output, with a full complementary structure. The conventional long-tail pair input stage is there, with output collectors feeding common-base transistors, in what is referred to as a folded-cascode configuration. The advantage of this arrangement for high-speed work is that there is only one truly high-impedance node in the circuit and hence the amplifier is easily stabilized with a single on-chip capacitor, resulting in a dominant-pole open-loop characteristic. The output is a high input impedance, super voltage-follower, very similar to the output stage used by PMI and Analog Devices in their new breed of current-mode op-amps, OP260 and AD844, which I mentioned last month. It is capable of swinging ±11V at the output with typically ±50mA maximum output current.

Unfortunately, as must inevitably be the case for high-speed BJT amplifiers, the transistors are operated at relatively high bias current levels to provide adequate transistor high-frequency performance; this means that the input bias current to the op-amp is some 5μA. Further consequences arising from the relatively high collector currents are that the input impedance of the amplifier is around 10kΩ and, since r_{CE} is inversely proportional to collector current, the low-frequency open-loop voltage gain is only a little over 80dB (10^4).

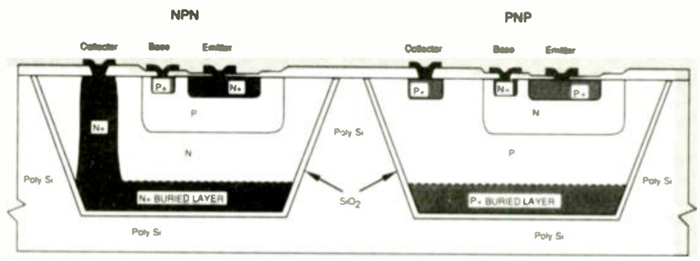


Fig. 1. Elantec's complementary diffusion isolation (DI) process gives the company's new op-amp an exceptional gain-bandwidth product.

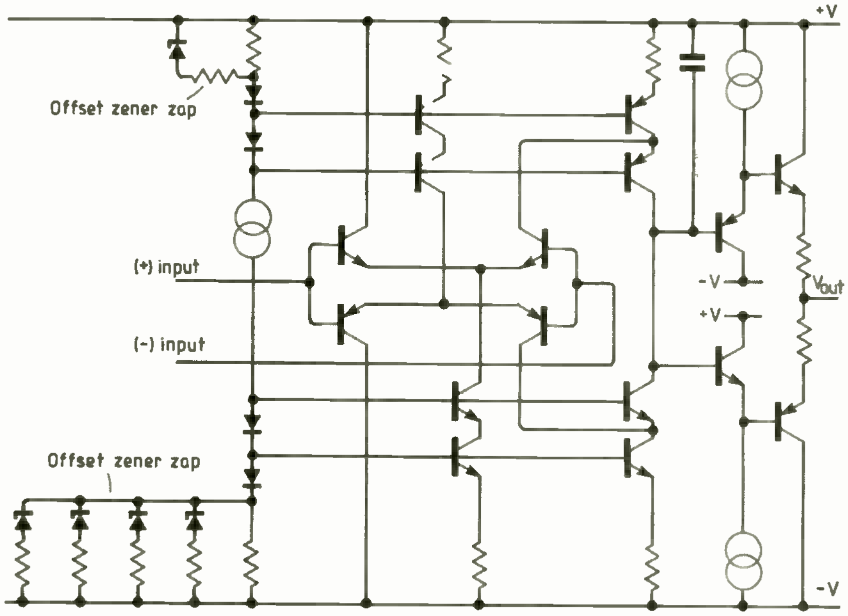


Fig. 2. Simplified diagram of Elantec's EL2038 1GHz op-amp, based on the DI process shown in Fig. 1.

"Fastest power mosfets"

Direct Energy Incorporated (DEI) of Colorado is a relatively new company, founded in 1987. Its speciality is the design and manufacture of high-speed, high-power, high-frequency electronic components and systems. In its literature DEI makes the bold claim that it makes the "best fast power mosfet in the world".

From their inception, power mos devices held great promise because of their potential speed and its advantages. Switching speed in a typical silicon cell is around 200ps, but conventional mosfets have required significantly better packaging to improve their speed performance.

DEI adopted a new approach to mosfet design. Beginning with the silicon parameters, it optimized the die to obtain best performance in relation to the high speed and high power goals. Then DEI's designers tackled the packaging, attempting to reduce the overall package inductance to a minimum; they were able to reduce this to less than one nanohenry. The next problem, as with all power devices, was how to dissipate heat when cycling power at high frequencies. This they achieved by minimizing the number of thermal barriers from silicon to heat-sink, selecting an insulating ceramic substrate (BeO) with good thermal properties on which to attach the die.

DEI markets three series of power mosfets. The DE-150 devices feature rise-times of 3ns, 2kW average power (DC), 72A peak current and 70W power dissipation; they are designed for operation at multi-megahertz PRFs. Then DE-275 devices also have a 3ns rise-time, but with higher power ratings. The most powerful device, the DE-375X4, can handle 30kW average power at 400A peak current and can dissipate 500W. It has a rise-time of some 7ns. These figures are very impressive indeed. Costs range from £130 per piece for the DE-150 to £300 per piece for the DE-375X4 (100-up quantities).

High power op-amps and power boosting

With the increasing complexity of electronic systems, it is always worth considering using a single-chip or single-packaged device, rather than a discrete circuit. The main reasons are reliability, ease of manufacture and small size. However, ready built single-chip or single-packaged devices to suit high power applications are not always available.

Apex Microtechnology Corporation of Tucson, Arizona, entered the op-amp market seven years ago to provide a very broad range of op-amps from low-power, low-speed parts to high power and high speed. It has recently introduced two new power op-amp products.

The PA04 is a power op-amp that can dissipate 200 watts internally and provide an output voltage swing of ±100V and a peak output current of 20A! It also has a slew-rate capability of 50V/µs and a DC open-loop voltage gain of 100dB. Quite a formidable beast, currently priced at around £141 per piece for 100-up.

The PB50 is not a full op-amp but is intended to be used to power-boost a conventional op-amp to provide up to 2A continuous output current and ±100V output voltage swing. Priced at around £42 per piece for 100-up, it represents good value for money.

Both devices are built around high voltage mosfets together with BJTs. A diagram of the PA04 is shown in **Fig. 3.**

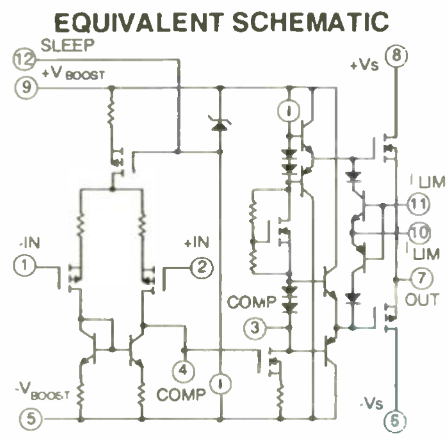


Fig. 3. Equivalent diagram of a fast power op-amp by Apex µtech.

The circuit is quite conventional, the high power features coming from the high voltage mosfets. The device comes in a proprietary 12-pin power dil package; the additional pins provide the user with some interesting features. Total quiescent bias current is about 70mA, but this can be reduced to only 3mA (referred to as the sleep mode) if the internal reference that provides the long-tail current is shorted by connecting pins 9 and 12. The two sets of power pins make another useful feature. With a V_{BOOST} supply 5V greater than the V_s supply, the output transistors can be driven close to saturation, allowing the amplifier to operate very efficiently at high current levels. Compensation is added externally, as is output current limiting, the latter being via the current-robbing current limit n-p-n and p-n-p transistors linking the gates of the output mosfets. A small series resistor, R, is added between pins 11 and 10, the output and negative feedback connections taken from pin 10. The output current limit, (in amperes) is simply given by 0.7/R, where R is in ohms.

Applications suggested for the PA04 extend from sonar transducer drivers through linear and rotary motor drives to audio at up to 400 watts. The manufacturer quotes total harmonic distortion figures below 0.01% for a power output of 200W over the entire audio range!

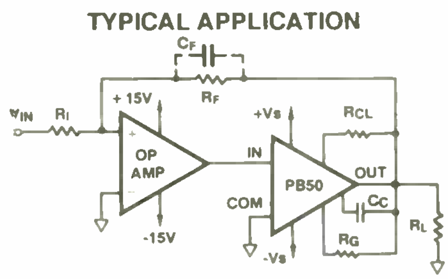


Fig. 4. Suggested application for Apex µtech's PB50 power booster is in this inverting composite amplifier.

The PB50 power booster is a single-ended input inverting amplifier, designed to be nested within the feedback loop of an op-amp (**Fig. 4**). Cascading two amplifiers within a single negative feedback loop has many advantages but requires careful consideration. To achieve a stable design, the lowest value of booster gain should be chosen so that the bandwidth of the booster is much greater than the driver's; then the driver's bandwidth is dominant, determining the bandwidth of the composite amplifier. Compensation capacitors are then selected to minimize the loop phase-shift. The slew rate of the composite amplifier is equal to the slew rate of the driver op-amp multiplied by the gain of the booster, with a maximum value equal to the booster slew rate of 50V/µs minimum.

Analogue Action is compiled by Dr John Lidgey of the School of Engineering, Oxford Polytechnic.

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+
74LS00	0.15	0.08	2.4576 MHz Crystal	0.75	0.55
74LS32	0.15	0.08	4 Meg Crystal	0.45	0.26
74LS125	0.15	0.11	6 Meg Crystal	0.45	0.26
74LS241	0.30	0.18	8 Meg	0.45	0.26
74LS244	0.30	0.18	1488	0.25	0.16
74LS245	0.30	0.19	1489	0.25	0.16
74LS373	0.30	0.18	2732A	2.50	2.30
74HC00	0.14	0.09	2764A	2.20	1.80
74HC02	0.14	0.08	27C64-20	2.50	1.80
74HC147	0.25	0.14	27128A-25	2.80	2.30
74HC153	0.24	0.12	27256-25	2.80	2.50
74HC194	0.25	0.15	27C256-25	2.90	2.30
74HCT04	0.16	0.13	27C512-25	5.20	4.60
74HCT32	0.16	0.08	8259AC-2	1.60	1.20
74HCT74	0.16	0.12	8255-5	1.90	1.30
74HCT123	0.23	0.16	82C55	1.50	1.10
74HCT138	0.23	0.16	8085	1.60	1.00
74HCT373	0.35	0.28	6522P	2.50	1.65
74HCT374	0.35	0.28	Z80ACPU	1.00	0.65
74HCT574	0.40	0.32	Z80AP10	1.00	0.65
74HCT643	0.42	0.30	Z80ACTC	1.00	0.65

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

**178 Brighton Road,
Purley, Surrey CR2 4HA
Tel: 01-668 7522. Fax: 01-668 4190**

ENTER 35 ON REPLY CARD

Field Electric Ltd. Tel: 01-953 6009.

**3 Shenley Road, Borehamwood, Herts WD6 1AA.
Fax: 01-207 6375, 0836 640328**

SPECIAL OFFERS

NEC 9" Green Screen Monitors 75 comp video input. Plastic case with handle 240 VAC input 20MHz bandwidth **£24.95** c p 5.00
Motorola TTL Monitor Chassis 7" Green Screen 22MHz bandwidth 12V DC input. New & boxed with circuit diagram compatible with IBM BBC computers **£25** c p 4.00
Mitsubishi M485 4 new 1/2 height disk drives 80 track d sided d density 360 rpm no info **£40.00** c p 3.00
Black & White Monitors with new tubes fitted 12" Comp video input **£57** c p 6.75
Cherry TTL Alpha Numeric ASCII Coded Keyboard including 8 colour coded graphic keys 108 keys form X Y matrix, full cursor control 6 encode keys 5V rail new **£5.75** c p 3.25
Astralux Pro Headphones 6mm mono jack fitted new & boxed 200 OHM MP **£15.00** c p £2.25
Astralux Pro Headphones [illegible] jack plug fitted with built in boom mic ideal for communications **£30.00** c p 2.25
Tandberg Series [illegible] reel to reel tape recorder chassis **£15.50** c p 4.50

5.25 Winchester (half height) hard disc drive by Tandon TM 252 unformatted 12.8 Mb new ex equipment **£69.00** c p 4.25
Peripheral coms controller BX MC 68661 BXMC14891 BXMC 1488P 13 various chips all in holders new ex equipment **£9.95**
Power supplies Switch mode units 240V AC input 5V 20A **£18.50**, 5V 40A **£25.00** 5V 60A **£22.00** Farnell 6V 5A ultra small **£25.00** 12V 2.5A ultra small **£38.00** Astec SA40 SM PSU 5V 5A [illegible] MA NEW [illegible] **£22.50** c p 2.50
Farnell Fan Cooled SM - 5 10A 5 1A 12 3A 12 1A **£35.00**. [illegible] 5V 40A **£15.00** [illegible] 5V 40A 12 4A - 15 1A **£30.00** [illegible] 200W - 15 4A - 15 4A - 5 30A **£27.75** [illegible] linear **£19.50** [illegible] 5 A linear **£22.50**.
Portable [illegible] Transformers 240 VAC 110 VAC 500VA cont rating [illegible] 750 VA [illegible] is potted within a yellow splash proof case **£45.00** c p 6.50
MPI full height floppy disk drives 40 track single sided **£10.95** c p [illegible]

HEWLETT PACKARD/TEKTRONIC EQUIPMENT

HP5000A Logic State Analyzer **£50.00**
HP1607A Logic State Analyzer **£150.00**
HP1611A Logic State Analyzer **£800.00**
HP693D Sweep Oscillator 4 8GHz **£475.00**
HP606B Sig Gen 50KHz to 65MHz
HP486A Thermistor Mount **£115.00**
HP1900A Pulse Generator System **£375.00**
HP651B Test Oscillator 10MHz **£200.00**
HP3450B Multi function meter **£200.00**
HP62605M DC PSU 5V DC [illegible]A **£60.00**
HP Voltage Divider Probe 10004D New **£85.00**
HP C34 431C Power Meter 10MHz [illegible] **£40.00**
HP3330B Auto Synthesizer 0 13MHz **£750.00**

HP6824A DC PSU Amplifier **£50.00**
HP86A Personal Computer New boxed **£195.00**
HP82901S 2 × 5.25 d drives new cased **£200.00**
HP616B Sig Gen 1.8 to 4.2GHz
HP612A Sig Gen 450 to [illegible] MHz
Tek Plug In Type 7B53AN **£225.00**
Tek Plug In Type 7B92 **£225.00**
Tek Plug In Type 7B70 - [illegible] guarantee **£100.00**
Tek 286 Sampling Head Multiplier Unit **£75.00**
Tek 178 Linear IC Test Fixture **£120.00**
Tek 6045 FET probe **£75.00**
Tek S3A Sampling Head **£100.00**
Please ring for quote on c p rates

GENERAL TEST AND MEASUREMENT EQUIPMENT

Marconi Inst [illegible] Universal Bridge [illegible] **£200.00**
Fluke AC DC Differential Voltmeter **£100.00**
Datron 1051 Multifunction Meter **£200.00**
Datron 1030 RMS Digital Voltmeter **£125.00**
Exact 3[illegible]7 Digital Phase Gen [illegible] **£175.00**
Solartron Frequency Res Analyzer [illegible] **£220.00**
Feedback Variable Phase Osc [illegible] **£100.00**
HML 411 Capacitor Charger 20Kv New **£1,000.00**
Devices Instantaneous Ratemeter [illegible] **£40.00**
Bell & Howell Datatest Cal Unit for FM **£120.00**
Dawe Type 1209D Transistor Strobe **£60.00**
Singer Gertsch Phase Angle Voltmeter **£200.00**
Advance Inst PG52A Pulse Gen **£100.00**
Unigor [illegible] Multitester **£50.00**
Philips PM5168 Function Gen **£50.00**
SE Labs O scope EM[illegible] **£160.00**
Advance OS2[illegible] 30MHz [illegible] **£140.00**
Watanabe MC611 S2L Multicorder **£50.00**
Rikadenki [illegible] 4 2 Pen Chart Recorder **£50.00**

Advance SG62B Signal Generator **£50.00**
Chessall [illegible] Single Pen Recorder **£70.00**
H P 5[illegible]7B timer counter DVM **£175.00**
AMF Venner Digital Counter [illegible]7A **£55.00**
Wayne Kerr B224 Universal Bridge **£250.00**
Wayne Kerr B641 Universal Bridge **£125.00**
No guarantee
AVO Universal Bridge D150 **£160.00**
Ampex VR[illegible] Video Recorder **£150.00**
EMI BTR Recorder 2C [illegible] (Mint) **£150.00**
KEPCO PSU [illegible] 2000V 0 1[illegible]MA PSU [illegible] **£60.00**
Farnell DAV[illegible] AC Voltmeter
Gould OS[illegible]000A [illegible] scope 40MHz delay **£325.00**
[illegible] 25 MHz dual beam [illegible]
Sanders Flexaguide
Dynamic [illegible] scope 25MHz Dual trace **£115.00**
Bryans X Y Plotter from **£75.00**
Solartron CD1400 [illegible] tube [illegible] guarantee **£25.00**
Please ring for quote on c p rates

COMPUTER EQUIPMENT

Altos Computer Systems DMA8[illegible] **£120.00**
DEC Rainbow 100A **£120.00**
DEC PC [illegible] **£200.00**
Ferranti [illegible] **£150.00**
[illegible] computer **£60.00**

Computer Automation [illegible] Mini Computer **£250.00**
SOME DATA AVAILABLE
[illegible] We cannot guarantee [illegible] **£100.00**
[illegible]

We would like the opportunity to tender for surplus equipment

Official Orders/Overseas Enquiries Welcome/Order by phone or post. Open 6 days. Postal rates apply U.K mainland only. All test equipment carries warranty. All prices include 15% VAT unless stated. Phone your order for quick delivery. Access Amex Diners Visa accepted. We can supply telephone and some audio equipment electrical and aerial equipment, much more than is shown in our ad. Please ring

ENTER 9 ON REPLY CARD

With 48 years' experience in the design and manufacture of several hundred thousand transformers we can supply:

AUDIO FREQUENCY TRANSFORMERS OF EVERY TYPE

YOU NAME IT! WE MAKE IT!

OUR RANGE INCLUDES:

Microphone transformers (all types). Microphone Splitter/Combiner transformers. Input and Output transformers. Direct Injection transformers for Guitars. Multi-Secondary output transformers. Bridging transformers. Line transformers. Line transformers to B.T. Isolating Test Specification. Tapped impedance matching transformers. Gramophone Pickup transformers. Audio Mixing Desk transformers (all types). Miniature transformers. Microminiature transformers for PCB mounting. Experimental transformers. Ultra low frequency transformers. Ultra linear and other transformers for Valve Amplifiers up to 500 watts. Inductive Loop transformers. Smoothing Chokes. Filter, Inductors, Amplifiers to 100 volt line transformers (from a few watts up to 1,000 watts), 100 volt line transformers to speakers. Speaker matching transformers (all powers), Column Loud-speaker transformers up to 300 watts or more.

We can design for RECORDING QUALITY, STUDIO QUALITY, HI-FI QUALITY OR P.A. QUALITY. OUR PRICES ARE HIGHLY COMPETITIVE AND WE SUPPLY LARGE OR SMALL QUANTITIES AND EVEN SINGLE TRANSFORMERS. Many standard types are in stock and normal dispatch times are short and sensible.

OUR CLIENTS COVER A LARGE NUMBER OF BROADCASTING AUTHORITIES, MIXING DESK MANUFACTURERS, RECORDING STUDIOS, HI-FI ENTHUSIASTS, BAND GROUPS AND PUBLIC ADDRESS FIRMS. Export is a speciality and we have overseas clients in the COMMONWEALTH, EEC, USA, MIDDLE EAST, etc.

Send for our questionnaire which, when completed, enables us to post quotations by return.

SOWTER TRANSFORMERS
ESTABLISHED 1941

**PO Box 36, Ipswich IP1 2EL, England.
Phone: 0473 252794 & 0473 219390 –
Telex: 987703G Fax: 0473 236188**

ENTER 21 ON REPLY CARD

M & B RADIO (LEEDS)

THE NORTH'S LEADING USED TEST-EQUIPMENT DEALER

TEST EQUIPMENT

Bradley 156 Oscilloscope Calibrator	£200
Bradley 192 Oscilloscope Calibrator	£400
Bradley 171 - 171B Meter Calibrator	£150
Radiometer SMG1 Stereo Generator	£150
Wandel Goltermann SP60 Level Gen	£200
Hatfield Psophometer Type 1000	£125
RS Huze 470-850MHz Field Strength	£100
RS Huze 44-210MHz Field Strength	£75
Gen Rad 1390B Random Noise Generator	£100
Gen Rad 1617A Capacitance Bridge	£200
Gen Rad 1900 1521B Wave Analyser	£300
Radford LD02 - DMS Audio Test Set	£200
Marconi TF2000 OSG - ATT	£300
HP 202C Oscillator	£75
Radford DMS3	£150
Marconi TF2331 Distortion Meter	£295
Marconi TF2120 Waveform Generator	£245
Marconi TF1313A 1% LCR Bridge	£150
Marconi TF2700 in situ Bridge	£50
Marconi TF2700 LCR Bridge	£100
Aim Inst 401 LCR Bridge 402 Comparator	£295
Radiometer MM2 LCR Bridge	£95
Gen Rad 1383 20Hz-20MHz Random Noise	£150
HP415E SWR Meter	£100
HP5300B Counter	£125
HP654A Test Oscillator	£200
HP651A Audio Oscillator	£175
HP3465A Digital Voltmeter	£175
HP3403 True RMS Voltmeter	£500
HP5381A 80MHz Freq Counter	£125
HP5045A Digital IC Tester	£750
HP3761A 3760A 3722A Error Detector	
HP7035B XY Plotter	£150
HP461 Amplifier IKcs 150Mhz	£95
HP3200B VHF Oscillator	£150
HP8330A Radiant Flux Meter	£75
Farnell SG1B Interface New	£100
HP141A Storage Frame	£125
Racal IEE Counter Interface 9932	£100
HP3495A Scanner	£150
HP5253B Counter Unit 500MHz	£100
HP250B RX Meter	£350
Tektronix Multi User Software Development Unit 8560/8561/8562	
RS Process Controller Type PUC	

SPECTRUM ANALYSERS

HP8559A 10MHz to 21GHz New boxed	£6000
HP8558B 1 to 1500MHz	£3250
HP5420A Digital Signal Analyser	£1900
HP141T Brand new boxed	£3000
HP141T 8556A 0 300KHz 8552B IF	£2000
HP141T 8554B 1200MHz 8552B IF	£3000
HP141T 8553B 110MHz 8552A IF	£2000
Tektronix 491 40GHz Analyser	£795
Scientific Atlanta 4657B 4651B	POA
Marconi TF2370 110MHz	£3000
HP8443A Teaching Generator	£750
HP8750A Storage Normalizer	POA

SIGNAL GENERATORS

HP8640B AM/FM 1024MHz	£1500
Adret AM/FM 300KHz 650MHz	£850
Marconi TF2015 AM/FM 10-520MHz Signal Generator TF2171 Synchroniser	£500
Marconi TF2016 AM FM 10KHz 120MHz - TF2173 Synchronizer	£375
Marconi TF2012 400-520MHz	£100
Marconi 995 A3 1.5-220MHz AM/FM	£70
Marconi TF2008/2 AM/FM 10KHz 520MHz with Sweeper	£350
Marconi TF2002 100MHz 72MHz AM/FM	£75
Marconi 2022 1000MHz AM/FM	£2000

OSCILLOSCOPES

Tektronix 2445 4 Trace 150MHz	£1500
Tektronix 475 Dualtrace 200MHz	£600
Tektronix 465 Dualtrace 100MHz	£475
Tektronix 466 Storage	£450
Telequipment D83 Dualtrace 50MHz	£300
Telequipment D755 50MHz D/L time	£260
Tektronix 7603 with plugins	£750

SPECIAL OFFERS

Cossor CDU150 35MHz Dual Beam Oscilloscopes with X1X10 probe and front cover	£170
0-250MHz 50Ω 300 watt dummy load	£25
Bradley CT471 RF Multimeters 1200MHz	£25
Brandenburg HT PSU 0-2.5hv 5MA	£45
HP532 Freq Meter 26-40GHz	£100
½kG Cored Solder 22-18 SWG	£6
Racal RA17 Receivers 500MSC 30MHz	£150
Datong FLI Audio Filter	£30
Black Star Pal TV Generator	£140

ALL PRICES PLUS VAT AND CARRIAGE

**86 Bishopgate Street, Leeds LS1 4BB.
Tel: 0532 435649. Fax: (0532) 426881**

ENTER 16 ON REPLY CARD

THE WHAT AND HOW OF CRCs

Cyclic redundancy checks are widely used to finger-print data, for determining its validity later on. Graham Stephens explains how they work.

The use of cyclic redundancy checks (CRCs) is widespread in disk drive controllers and data communications protocols, and CRCs have been used to guard against deliberate program errors. Their manipulation is also one of the more elementary methods of copy protection on disks.

Those wishing to understand and use these ideas more fully may have been attracted by phrases such as "completely error-free", but discouraged by concepts such as "polynomial". Some may already use peripheral devices, from ICs to "error-protected" modems, which incorporate CRC techniques, but find such devices to be unsatisfactory or inadequate in certain applications. For example, many all-singing and dancing protocol controllers will not perform CRCs when in asynchronous mode, or are inflexible as to what characters and sequences are and are not included in the CRC calculations. (This can lead to difficulties in transparency, encryption and compression.) Others may wish to use two different CRCs at the same time.

Limitations

It is important to understand the limitations of CRCs and therefore their subsequent applications. They do not, in their own right, correct errors. The correction process is one of error detection followed by the re-transmission of the affected block of data. Also, the technique cannot possibly detect all errors. "Error-free" is an absolute term, and should therefore be qualified by "almost" or "virtually". Those who qualify in the other direction ("completely", "totally", 100%, etc.) are either deliberately misleading or lamentably naïve! It must also be remembered that any technique depends upon its inherent characteristics, which may be weakened by a poor implementation.

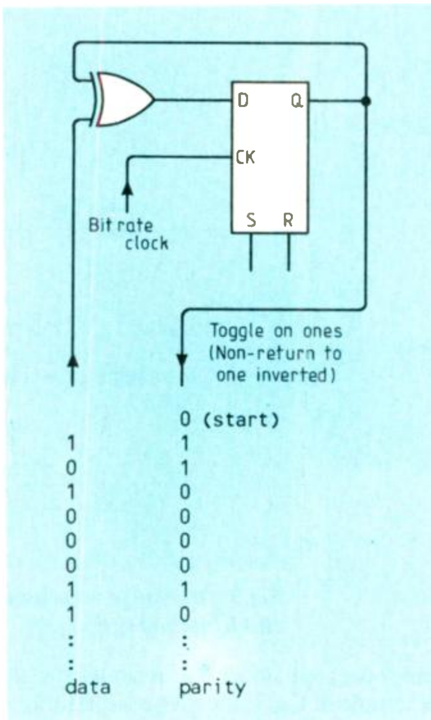


Fig. 1. Simple error detection can be achieved by a D-type flip-flop, to provide a one-bit delay, and an exclusive-Or gate.

Error detection

An error is quite simply the inversion of a bit, i.e. a one has become a zero, or a zero has become a one. A single error is therefore very easy to detect by counting the number of ones or zeros in the data block. Merely knowing whether this total number is odd or even is sufficient to detect one error. This odd or even nature may be determined by the status of the remainder following a division by two. (The quotient is discarded.)

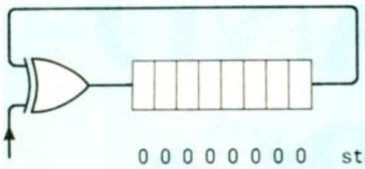
In hardware terms this may be accomplished, among other ways, with a D-type flip-flop to provide a one-bit delay and an exclusive-Or gate (**Fig.1**), and with preset/clear being used to set the initial status. The check-bit present in this register at the end of the serial data is appended to the data block. At the receiving end, this process is repeated to generate a local check-bit which is compared with the received check-bit. If they are different, then an error has occurred. If they are the same then no error has been detected, but this does not necessarily mean that no error has occurred. For example, if two bits are transposed or the number of errors is even then no error would be indicated.

Rather than just one check-bit per block, it is common to have one check-bit per character. In asynchronous format data this is known as the parity bit, and as the vertical redundancy check (VRC) in blocked synchronous data.

The protection afforded by parity is poor – especially in view of its high overhead. The performance of parity may be improved by performing a check in the horizontal direction. This is effectively the exclusive-Or of each data byte, and is known as the longitudinal redundancy check or LRC. This is also an example of the well-known datacomms characteristic of increasing the complexity of the terminology in the hope of improving performance!

An LRC may also be accomplished by the standard datacomms building block of shift registers and exclusive-Or gates (**Fig.2**). In this example, the shift register performs the eight-bit separation for the bit-by-bit exclusive-Or, i.e. bit-by-bit every eighth bit. The receiver performs in a similar manner, but clocks around the LRC as well so that the checksums are effectively subtracted (in modulo-2) to give all zeros on no detected error. Obviously, very many errors can still slip through undetected, but its performance is significantly better than VRC/parity alone.

The generation and comparison of check-bits and bytes shown so far may be consi-



```
   00000000   start
1  10000000
0  01000000   C5₁₆
1  10100000
0  01010000
0  00101000   LSB
0  00010100   first
1  10001010
1  11000101

0  11100010
0  01110001
0  10111000   78
1  11011100
1  11101110
1  11110111
1  01111011
0  10111101   =BD (checksum)

1  01011110
0  00101111
1  00010111
1  00001011   BD
1  00000101
1  00000011
0  00000001
1  00000000   = no error

C5 Ex-or 78 = BD
BD Ex-or BD = 00
```

Fig.2. Improving the performance of a parity check: a longitudinal redundancy check, effectively the exclusive-Or of each data byte.

```
Data                1 1 1 0 0 1 0 1 1 0 1 1 0
Divisor (d)                       1 0 1 0 1 1

Quotient    1 1   1 1     1 1   1
(a 1 at
every d)    1 1 1 0 0 1 0 1 1 0 1 1 0 0 0 0 0 0

 d          1 0 1 0 1 1
Ex-or       0 1 0 0 1 0 0
 d            1 0 1 0 1 1
Ex-or         0 0 1 1 1 1 1 1
 d                1 0 1 0 1 1
Ex-or             0 1 0 1 0 0 0
 d                  1 0 1 0 1 1
Ex-or               0 0 0 0 1 1 1 1 0 0
 d                          1 0 1 0 1 1
Ex-or                       0 1 0 1 1 1 0
 d                            1 0 1 0 1 1
Ex-or                         0 0 0 1 0 1 0 0 0
 d                                  1 0 1 0 1 1
Ex-or (remainder)                   0 0 0 0 1 1

1st bit    1 1 1 0 0 1 0 1 1 0 1 1 0 0 0 0 1 1    last bit

        Data plus remainder, transmitted to left

           :          As above          :

                      No error    0 0 0 0 0 0
```

Fig.3. Division process used for generating and comparing check bits and bytes.

dered to be part of a more complex and generalized scheme. Its principle is one of dividing the block of data by a constant, discarding the quotient and adding the remainder to the data so that the whole block is now exactly divisible by the constant. At the receiving end, the equivalent process results in no remainder if no errors have occurred.

This division process is based upon modulo-2 arithmetic, and an example of the method is shown in **Fig.3.** The block of data is "multiplied" first by the number of places in the divisor, less one to make room for the addition of the remainder. Division results in a quotient and, upon running out of dividend to bring down, a remainder. The remainder is added to the data block. At the receiver, the whole lot is divided and should result in no remainder (all zeros) on no detected error.

Most descriptions of this process talk in terms of polynomials. Data to be transmitted (the dividend) is regarded as being a polynomial expression which is divided by another polynomial (the divisor) to give two further polynomials – the quotient and the remainder or residue. In the example of Fig.3, the divisor is 101011. In polynomial descriptive terms this is equivalent to

$$(1)x^5+(0)x^4+(1)x^3+(0)x^2+(1)x^1+(1)x^0$$

or, more commonly,

$$x^5+x^3+x+1$$

It is also apparent from Fig.3 that the whole process is essentially one of shifting, aligning and exclusive-Or. This is relatively simple to implement in both hardware and software, and **Fig.4** shows the same data to be transmitted being processed by an equivalent multiplier/divider constructed from shift registers and exclusive-Or gates.

It is important to understand the limitations of CRCs…

All the registers are initially cleared, and the data is transmitted to line while the registers are cycling around. Contents of these registers are clocked out at the end of the data. Note that the x^0 column is the serial quotient.

The receiver goes through the same procedure and clocks around the remainder as well. Register contents at this point should be all zeros in this example if no error has been detected.

Order of transmission

Before any further design is possible, there must be a general agreement on this bit sequence for serial transmission. Whilst this may not appear important in byte-based protocols where each byte is synchronized within its "window", experience dictates otherwise.

Most data communications protocols transmit each character's LSB (right-most bit) first, and this arrangement is supported by the wide range of peripheral components available. However, CRCs are generally transmitted MSB (e.g. x^{15}) first and would therefore require rotation before transmission through such devices. Since the whole process is one of shifting and rotating, it is simple enough to reverse the direction so that the CRC MSB (highest power) is right-most during accumulation.

Practical guidance

The divisor polynomial conversion to shift register/exclusive-Or equivalent with the remainder's highest power out first may be performed as follows:

1. write polynomial in ascending power of x, remembering that 1 is really x^0;
2. convert to binary form where each polynomial equals 1 and no term equals zero. Bracket the highest (right-most) term.

Now, either

- design the equivalent hardware using shift registers and exclusive-Ors, where the bracketed term becomes the feedback (quotient) to the lowest (leftmost) term and the other exclusive-Or inputs. All other "1" terms are register stages fed by exclusive-Or outputs.

or

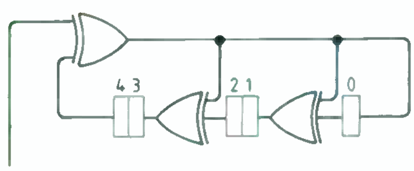
- convert to hexadecimal for use in an equivalent software routine. The LSB is the one just before the bracketed term, and unused terms are zeros.

...An example of the well-known datacomms characteristic of increasing the complexity of the terminology in the hope of improving performance...

In most instances it is not necessary to generate and check CRCs "on the fly" during actual transfer, and it is generally quite adequate to run the complete data block through the appropriate CRC routines just prior to transmission or following complete reception. This is, of course inescapable if a "reverse" CRC is used as this must be sent before the data, having been calculated in the reverse direction.

A simple and reasonably fast software routine which emulates the hardware equivalent is shown in **Fig.5.** Although it is specifically for the 6502, it is easily changed to suit other microprocessors. If time is not of the essence then a higher-level language may be applicable.

For those who wish to explore CRCs further, the example in **Fig.6** should be useful for debugging purposes. CRCs of




```
    00    00    0    start
1   01    01    1
1   11    10    1
1   11    01    0
0   11    11    1

0   10    10    1
1   01    01    0
0   10    10    0
1   01    00    0

1   11    01    1
0   11    10    1
1   11    01    0
1   10    10    0

0   00    01    1    checksum
↑
    shift out   ↑
    at end      x^0, serial quotient

:   :     :     :
:   :     :     :
0   00    01    1
0   00    11    0
0   01    10    0
0   11    00    0
1   10    00    0
1   00    00    0    no error detected
```

Fig.4. Hardware for implementing the division process of Fig.3, which is essentially one of shifting bits, aligning and exclusively-Oring.

Fig.5 (right). Simple software routine in 6502 assembly language for generating CRCs.

```
                 ; CRC routine for 6502
                 ; memory usage as follows!
                 ;
0080  =          data = &80               ; 8 bit character
                                          ; for crc accumulation
0081  =          remls = data + 1         ; low remainder byte
0082  =          remms = remls + 1        ; high
0083  =          polyls = data + 3        ; low order polynomial
0084  =          polyms = polyls + 1      ; high order polynomial
                 ;
                 ;
2010                     ORG &2010
                 ;
2010             .crc1
2010 A008            LDY #&08      ; counter
2012 A900        1%  LDA #&00      ; init clear
2014 4680            LSR data      ; data LSB to carry...
2016 2A              ROL A         ; ...and into A
2017 4581            EOR remls
2019 4682            LSR remms
201B 6A              ROR A
201C 900E            BCC 3%        ; no further Exor
201E 4583            EOR polyls
2020 8581            STA remls
2022 A582            LDA remms
2024 4584            EOR polyms
2026 8582            STA remms
2028 88          2%  DEY
2029 D0E7            BNE 1%        ; do 8 times
202B 60              RTS ; exit
                 ;
202C 8581        3%  STA remls
202E 90F8            BCC 2%        ; always
                 ;
                 ;

Symbols:

2010 CRC1  0080 DATA  0083 POLYLS  0084 POLYMS  0081 REMLS  0082 REMMS

No error(s) detected
629D bytes free
```

Table 1. Some practical CRC schemes.

Polynomial	Hex (ms/ls)	Type
$x^{16}+x^{12}+x^5+1$	8408	CRC-CCITT (e.g. V.41, X.25 etc.)
$x^{16}+x^{15}+x^2+1$	A001	CRC-16 (e.g. IBM 3270, 3780 etc.)
$x^{12}+x^{11}+x^3+x^2+x+1$	0F01	CRC-12
x^8+1	0080	LRC-8
$x+1$	0001	Parity (pre-set 0 or 1 for even or odd)

Where a reverse CRC is required, write out the binary equivalent of the forward polynomial and then reverse the order.

$x^{16}+x^{12}+x^5+x^0$

10001000000100001
10000100000010001
$x^{16}+x^{11}+x^4+x^0$

Remember to reverse all shifts, rotates etc.

16 bits or fewer which are commonly used are shown in **Table 1**. Some varieties of CRC are also known as block check characters (BCC) or frame check sequences (FCS).

Note that the CCITT CRC may be used in different ways. Some applications (disk, V.41 etc.) preset the registers to all zeros, transmit the remainder unchanged and look for all zeros as no detected error. Other applications (HDLC, X.25 etc.) pre-load all ones, invert the remainder prior to transmission and then require the constant $F0B8_{16}$ (MS LS, or x^0 x^{15}) as indicating no detected errors. The principle is exactly the same, though. The designer should also be aware of some protocols which do not include certain control characters or sequences in the CRC accumulation.

Levels of protection

As I have mentioned, it is not possible to detect all errors, and therefore "error-free" is not realistic. Also the CRC technique itself has some peculiarities. Nevertheless the protection afforded by CRCs is impressive, considering its simple implementation and low overhead. The detection rate diminishes with increasing block size since there is greater opportunity for dividend errors which still result in exact divisibility. (A sliding scale of block size is often employed to improve detection and, indirectly, data throughput in high error-rate environments.)

In general, CRCs usually detect all odd numbers of errors (so does parity!), error bursts not exceeding the CRC length and a large percentage of other patterns of errors. As errors may occur in various ways and for various reasons (although rarely at "random") in a data communications environment, they may have different effects. It is therefore only possible to generalize on the frequency of undetected errors and to note that for a block size of 260 bits the possibility of an undetected error is between 0.002% and 0.007% depending upon the simulation. Note also that there is a possibility of 0.0015% that the 16-bit CRC could be changed into another which could be correct for an erroneous data block. Then there is the possibility that the request for re-transmission could be erroneous...

Polynomial = $x^{16}+x^{12}+x^5+1$ (CCITT-CRC)

x^0 x^5 x^{12} x^{16}

1 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0(1) = 8408_{16}

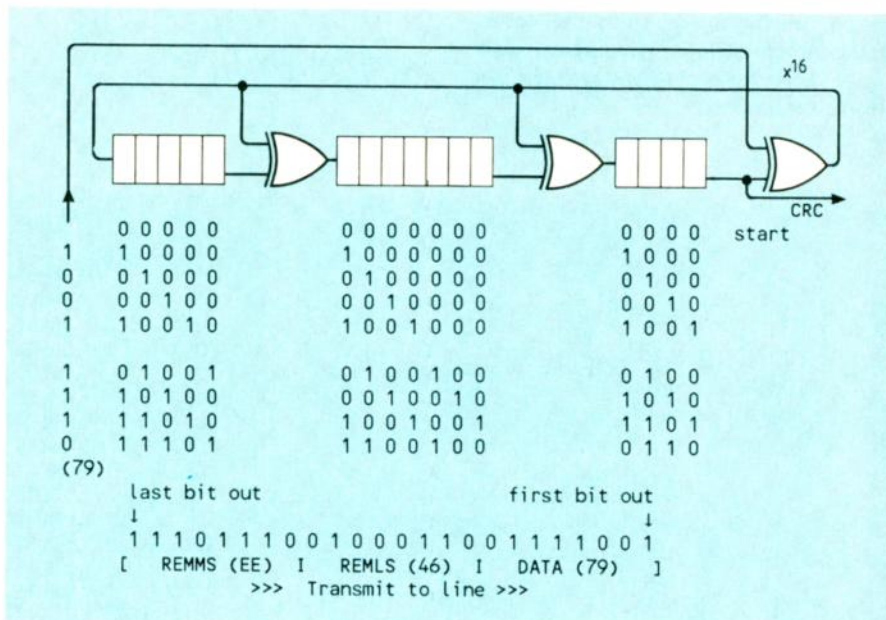


Fig. 6. Generating CCITT-CRCs.

Further observations

Although some of the following is obvious after a moment's thought, it may nevertheless suggest further study.

1. If the eight-bit byte is the same as the lower eight-bit remainder (remls) then the upper eight-bit remainder (remms) is 00 and remls becomes the previous remms.

2 (from 1). If the data string is the same as the remainder, then the new remainder is 0000. That's how it works, of course, but consider the implications!

3. If the remainder is 0000 and the data is 80_{16} then the remainder becomes the polynomial.

4. If the old remainder and data are interchanged, the new remainders are the same: for example, rem = ABCD data = 1234 gives the same remainder as rem = 1234, data = ABCD.

5. Pseudo-random pattern generators and simple scramblers may also be used with the general CRC model as decribed here if the hardware is re-drawn or the polynomial multiplied to lose any negative powers.

Don't be frightened...

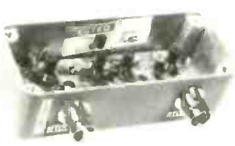
No-one should be frightened of CRCs, but they must not have powers attributed to them that they do not deserve. The general techniques described here are versatile, with applications beyond error detection. They are simple to implement in both hardware and software, and this choice depends upon the application and the best method of implementation. It is important to note that error control is rather like encryption in that it should be performed within the source and destination equipment and not left to some intermediate device or process. ■

Graham M. Stephens is with Datex Ltd.

RF EQUIPMENT

LOW NOISE GASFET PREAMPLIFERS

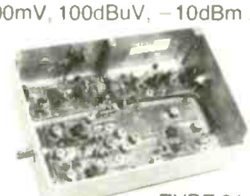
Aligned to your specified frequency in the range 30-1000MHz. Masthead or local use.
TYPE 9006. NF 0.6dB. Gain 10-40dB variable. In the range 30-250MHz £78
TYPE 9006FM. As above. Band II 88-108MHz £78
TYPE 9002. Two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Tuned to your specified channels in bands IV or V £102
TYPE 9004. UHF two stage Gasfet preamplifier. NF 0.7dB. Gain 25dB adjustable. High Q filter. Aligned to your specified frequency in the range 250-1000MHz £102
TYPE 9035. Mains power supply for above amplifiers £39
TYPE 9010. Masthead weatherproof unit for above amplifiers...... £12


TYPE 9006


TYPE 9002

WIDEBAND AMPLIFIERS

Monolithic microwave integrated circuits in a fully packaged microstrip module format. Full-wave shottky diode protected inputs. Temperature compensated bias circuitry. Voltage regulated local or remote operation.
TYPE 9007. 1-900MHz. NF 2.3dB at 500MHz. Gain 20dB.......... £150
TYPE 9008 Gasfet. 100MHz-2GHz. NF 2.5dB at 1GHz. Gain 10dB. Power output +18dBm, 65mW £150
TYPE 9009 Gasfet. 10MHz-2GHz. NF 3.8dB at 1GHz. Gain 20dB. Power output +20dBm, 100mW £150
TYPE 9253. 40-860MHz. NF 6dB. Gain 30dB. Voltage output 100mV, 100dBuV, −10dBm £94


TYPE 9113

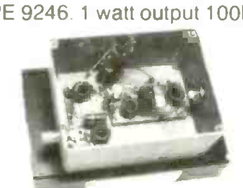

TYPE 9252

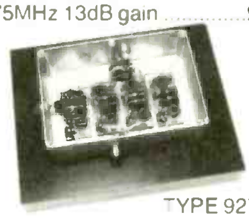
PHASE LOCKED LOOP FREQUENCY CONVERTERS

TYPE 9113 Transmitting. Converts your specified input channels in the range 20-1000MHz to your specified output channels in the range 20-1000MHz. 1mV input, 10mW output (+10dBm). AGC controlled. Gain 60dB adjustable −30dB. Will drive transmitting amplifiers directly £356
TYPE 9114 Receiving. Low noise Gasfet front-end. NF 0.7dB. Gain 25 dB variable £356

TMOS WIDEBAND LINEAR POWER AMPLIFIERS

TYPE 9246. 1 watt output 100KHz-175MHz 13dB gain £108


TYPE 9176


TYPE 9271

TYPE 9247. 4 watts output 1-50MHz 13dB gain £108
TYPE 9051. 4 watts output 20-200MHz 13dB gain £108
TYPE 9176. 4 watts output 1-50MHz 26dB gain £254
TYPE 9177. 4 watts output 20-200MHz 26dB gain £254
TYPE 9173. 20 watts output 1-50MHz 10dB gain £308
TYPE 9174. 20 watts output 20-200MHz 10dB gain £308
TYPE 9271. 40 watts output 1-50MHz 10dB gain £616
TYPE 9172. 40 watts output 20-200MHz 10dB gain £616
TYPE 9235. Mains power supply unit for above amplifiers.......... £164

PHASE LOCKED SIGNAL SOURCES

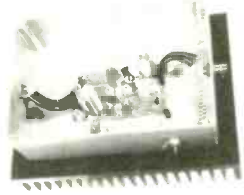
Very high stability phase-locked oscillators operating directly on the signal frequency using a low frequency reference crystal. Phase noise is typically equal to or better than synthesized signal generators. Output will drive the Types 9247 and 9051 wideband linear power amplifiers and the Types 9252 and 9105 tuned power amplifiers.
TYPE 8034. Frequency as specified in the range 20-250MHz. Output 10mW £120
TYPE 8036. Frequency as specified in the range 250-1000MHz. Ouput 10mW.......... £170
TYPE 9182. FM or FSK modulation. 20-1000MHz. Output 10mW £248

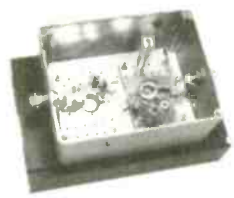
FM/FSK RECEIVERS

TYPE 9300 FSK data receiver single channel up to 200MHz...... £248
TYPE 9301 FSK data receiver single channel 200-1000MHz £398
TYPE 9302 FM receiver single channel up to 100MHz £248
TYPE 9303 FM receiver single channel 100-1000MHz £398

FM TRANSMITTERS 88-108MHz. 50 watts RF output

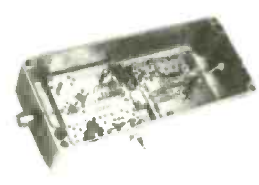
TYPE 9086. 24V + DC supply £945
TYPE 9087. Includes integral mains power supply £1,110
TYPE 9182FM exciter ±75KHz deviation. Output 10mW £248

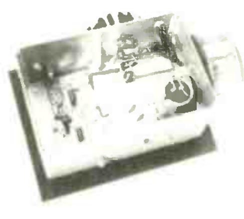

TYPE 9263


TYPE 9259

TELEVISION LINEAR POWER AMPLIFIERS

Tuned to your specified channels in bands IV or V. 24V + DC supply.
TYPE 9261. 100mV input, 10mW output.......... £218
TYPE 9252. 10mW input, 500mW output.......... £254
TYPE 9259. 500mW input. 3 watts output.......... £290
TYPE 9262 500mW input, 10 watts output.......... £530
TYPE 9263. 2-3 watts input, 15 watts output.......... £400
TYPE 9266 10 watts input, 50 watts output.......... £1,585
See below for Television Amplifiers in bands I & III.


TYPE 9105


TYPE 9158/9235

TMOS RF LINEAR POWER AMPLIFIERS

Tuned to your specified frequency in the range 20-250MHz. or your specified channels in bands I or III. 24V +DC supply.
TYPE 9105. 10mW input, 1 watt output.......... £230
TYPE 9106 500mW input. 10 watts output.......... £284
TYPE 9155. 1 watt input, 30 watts output.......... £327
TYPE 9158. 5 watts input, 70 watts output.......... £448

COMPLETE TELEVISION RETRANSMISSION SYSTEMS AVAILABLE

All prices exclude p&p and VAT.

RESEARCH COMMUNICATIONS LTD

Unit 1, Aerodrome Industrial Complex, Aerodrome Road, Hawkinge, Folkestone, Kent CT18 7AG.
Tel: 0303 893631. Fax: 0303 893838

ENTER 41 ON REPLY CARD

APPOINTMENTS

Advertisements accepted up to 12 noon 29th August for October issue.

DISPLAYED APPOINTMENTS VACANT: £27 per single col. centimetre (min. 3cm).
LINE ADVERTISEMENTS (run on): £6.00 per line, minimum £48 (prepayable).
(Please add on 15% V.A.T. for prepaid advertisements).
BOX NUMBERS: £15.00 extra. (Replies should be addressed to the Box Number in the advertisement, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS).
PHONE: CHRISTOPHER TERO on 01-661 8640 (Direct Line).
Cheques and Postal Orders payable to REED BUSINESS PUBLISHING and crossed.

RF PROJECT ENGINEER

NAD Electronics Ltd., the world-renowned producer of specialist hi-fi products is looking for an RF Project Engineer to take over the design of its range of state-of-the-art FM tuners.

You will be working on the design and development of FM and AM radio and TV tuners and all their associated circuitry. This will include front-end, FM demodulator, stereo decoder and frequency synthesiser design together with microprocessor control of the whole system.

Experience in RF design, up to at least 100MHz, is essential as is some experience with broadcast FM systems. Familiarity with microprocessor systems would also be useful. There will be ample opportunity to branch out into the other areas of electronics design offered by our wide range of products.

The candidate should be qualified to degree level and have three to four years' relevant experience. He/she should be self-motivated and able to work with the minimum of supervision.

A salary in excess of £20,000 is on offer to the candidate who has the right combination of experience, abilities and potential.

NAD

**Please send CV to:
Chris Evans,
Chief Engineer,
NAD Electronics Ltd.,
Adastra House,
401-405 Nether Street,
London N3 1QG
or telephone 01-349 4034 for further information**

767

Wanted urgently
Practical people for the Third World.

Many people want to help the Third World. But relatively few can offer the kind of help wanted most: the handing on of skills and professions which lead to self-reliance.

You could make this priceless contribution by working with VSO.

Current requests include:

- **Studio Electronics Engineer** ☐
- **Hospital Electronics Engineers** ☐
- **Lecturers in Power and Communication** ☐
- **Refrigeration/Radio/TV Engineers** ☐
- **Electrical Engineers for instruction/installation** ☐
- **Electronics Instructors** ☐
- **Maintenance and repair Technician** ☐

For more details, please complete and return to: Enquiries Unit, VSO, 317 Putney Bridge Road, London, SW15 2PN. Tel. 01-780 1331.

Conditions of work: • Pay based on local rates • Posts are for a minimum of 2 years • You should be without dependants • Many employers will grant leave of absence.

I'm interested. I have the following training/experience:

Name ______________________

Address ______________________

EWW/9/89

VSO

Helping the Third World help itself.

19p stamp appreciated Charity no. 313757.

AMANUENSIS

HARDWARE/SOFTWARE ENGINEERS

We have a large number of local and national clients requiring the following skills at all levels

HARDWARE: Contact David Dormany at the office or (0638) 741881 (home)
Microprocessors 68XX series (in particular 6809)
Design of analogue or digital circuitry
Radio/Data communications
CAD and multi/single layer pcb design
Image analysis and video A/D conversion
Networking, X25, DEC, ICL, HP, IBM mainfromes and PCs
Computer systems and peripheral maintenance
Project/Development Management
Sales/Marketing/Applications Engineers/Field Service or Test

SOFTWARE: Contact Anna Andrew at the office or (0536) 791141 (home)
Operating Systems: Unix, VMS, MS-DOS
Languages: C, Modula 2, Pascal, Fortran, BCPL
Applications: Oracle, DBaseIII +, CAD/CAM/CAE
Assemblers: 680×0, 80×86, 8085, Z80, 8086
Comms: WANS, LANS, Telecoms
Any combination of the above skills are in constant demand

AMANUENSIS RECRUITMENT
20 NEWMARKET ROAD CAMBRIDGE CB5 8DT ☎ 0223 354978

SALES PERSON

Sales person wanted, preferably with technical background or understanding of communication systems to sell communication products to both the commercial and government sectors

The applicant must have sales experience in landmobile radio communication products
The applicant need not be based in London as a large portion of the time will be spent on travelling

COMMUNIQUE

Salary plus commission and company car
Realistic earning potential up to £27,000+

Please write with CV to
Mrs C. Webster, Communique UK Ltd. Communications House, Purley Avenue, London NW2 1SB.

731

ELECTRONICS TRAINER
at Camden ITEC

Camden Itec is one of 175 training schemes in Information Technology for young people aged between 16 and 18. It has European links especially with Denmark. We are looking for someone who has practical experience of Digital, Analog, and mechanical systems to work in our hardware department.

Applicants should preferably have an ONC/HNC or City and Guilds full technical certificate in electronics.

Hours 9.00am to 5.00pm five days a week. Holidays 6 weeks per year.

Salary on scale £10,162 – £14,344

Further information from Ross on 01-485 3324. Send C.V. to Camden Itec, 7 Leighton Place, London NW5 2QL.

773

CAPITAL RADIO 95·8 FM 1548 AM

CAPITAL RADIO ENGINEERING DEPARTMENT

MAINTENANCE ENGINEER

Capital Radio's Engineering Department has a vacancy for a suitably qualified maintenance engineer. Applicants should have a good working knowledge of microprocessor-based systems, particularly when applied to machine control in a broadcast environment. A working knowledge of the C programming language would be an advantage. In addition, applicants should have had previous experience of broadcast systems or be able to demonstrate an understanding of the operations of the components of a broadcast chain.

Applicants should be in possession of a full current UK driving licence and may be expected to work on a shift rota which includes weekends. Starting salary will be not less than £14,766 for a suitably qualified candidate.

Applications, in writing, should be addressed to Sue Davies, Head of Personnel, Capital Radio plc., Euston Tower, London NW1 3DR and should arrive not later than 4th September, 1989.

766

Sammy's

SAMUELSON FILM SERVICE LONDON LTD

Senior Service Engineer

required to work within our Samcinevision Hire Department. We are a major supplier to the motion picture film industry of video, sound and film editing equipment. The successful candidate should ideally have experience of servicing video equipment, basic computer hardware, and be educated to HND standard in electronic and electrical engineering.

The work also involves some R&D.

Please send CV to Steve Campbell, 21 Derby Road, Metropolitan Centre, Greenford, Middx UB6 8UJ

Closing date: 18th September, 1989.

781

FOR MORE INFORMATION CALL: CHRIS TERO ON 661-3033

A CAREER IN TECHNICAL AUTHORSHIP

There is a constant demand for technical authors throughout industry. If you have a technical background, a qualification in technical authorship can open up a prospect of a new and rewarding career. For details of a comprehensive Open Learning Course, leading to recognised qualifications in this field, send for free information pack to:

TUTORTEX SERVICES WW4
Freepost
ULVERSTON
Cumbria LA12 7BR
Telephone: 0229 56333

ST. LOYE'S COLLEGE FOR TRAINING THE DISABLED FOR COMMERCE AND INDUSTRY

ELECTRONICS SERVICING INSTRUCTOR

The College requires immediately a practising Electronics Service Engineer with broad training and recent field and/or workshop experience of micro-computers, to instruct on a highly skilled City and Guilds 224 course of training. The successful candidate will be required primarily to give practical bench training in fault diagnosis techniques and must be familiar with micro test equipment (eg. logic analysers). Previous instructor experience desirable but not essential.

Salary £10,363 to £11,469, currently under review.

Letters of application, together with a curriculum vitae and names and addresses of two referees should be submitted to **The Deptuy Principal, St. Loye's College, Topsham Road, Exeter, Devon, EX2 6EP.**

St. Loye's College is an Equal Opportunities Employer

772

RF DES ENGS

Extremely Competitive Salaries

Circuit and System design using leading edge radio architectures.

If you would like to hear about outstanding UK and European opportunities to work in satcoms, C³I radar, mobile radio and personal comms, call Ingineur on:

0926 817612

INGINEUR LTD (Agy), Pendicke Street, Southam, Warks CV33 0PN.

INGINEUR
ENGINEER • IN • EUROPE

PAPUA NEW GUINEA UNIVERSITY OF TECHNOLOGY

SENIOR/PRINCIPAL TECHNICAL OFFICER

Department of Electrical & Communication Engineering

The post requires expertise and experience on the maintenance and repair of a wide range of modern electronic communication and computer equipment and the ability to train local technical staff to a high level.

Salary per annum: Senior Technical Office K19 295 – K21 420 Principal Technical Officer K22 645 (level of appointment will depend upon qualifications and experience)

Initial contract perdiod is normally for three years but shorter periods can be negotiated. Other benefits include a gratuity of 24% taxed at 2%, support for approved research, appointment and repatriation fares, leave fares for staff member and family after 18 months of service, settling in and settling-out allowances, six weeks paid leave per year, education fares and assistance towards school fees, free housing, salary protection plan and medical benefit schemes are available. Staff members are also permitted to earn from consultancy up to 50% of earnings annually.

Detailed applications (two copies) with curriculum vitae and the names and addresses of three referees including telephone number and indication of earliest availability to take up appointment should be sent to The Registrar, Papua New Guinea University of Technology, Private Mail Bag, Lae, Papua New Guinea by **4 August 1989**. Applicants resident in the UK should also send one copy to Appointments (36571), Association of Commonwealth Universities, 36 Gordon Square, London WC1H 0PF, from whom further information may be obtained.

771

COURSES

IBA TRAINING

Short Course Programme

All dates are start dates. All fees exclusive of VAT.

☐ **Communications**

- *Introduction to X25 Protocol - 2 days, 18 Sept, £365*
- *Digital Communications 1 - 1 week, 27 Nov, £650*
- *Digital Communications 2 - 2 weeks, 27 Nov, £1200*

☐ **Television**

- *Video Distortion Measurements - 1½ days, 18 Oct, 28 Nov, £255*
- *Television Principles - 1 week, 4 Sept, 6 Nov, £650*
- *TV Principles & Measurements - 2 weeks, 4 Sept, 6 Nov, £1200*

☐ **Transmission**

- *TV Signals & Measurements (Video & RF) - 3 weeks, 6 Nov, £1800*
- *Radio & TV Transmission - 2 weeks, 25 Sept, £1200*
- *Radio Transmission (MF & VHF) - 2 weeks, 4 Sept, 23 Oct, 11 Dec, £1200*

☐ **Satellite Television**

- *Introduction to Satellite TV & MAC systems 20 min video (non-Technical) £48*
- *D/D2 MAC- Packet, Distance Learning & 23 min video, £522*

☐ **Engineering Publications Service**

For details call Stuart Webber on 0297-22051
Harman Engineering Training College (WW2)
Fore St Seaton Devon EX12 2NS Fax 0297 - 24419

ARTICLES FOR SALE

TO MANUFACTURERS, WHOLESALERS, BULK BUYERS, ETC.

LARGE QUANTITIES OF RADIO, TV AND ELECTRONIC COMPONENTS FOR DISPOSAL

SEMICONDUCTORS, all types, INTEGRATED CIRCUITS, TRANSISTORS, DIODES, RECTIFIERS, THYRISTORS, etc. RESISTORS, C/F, M/F, W/W, etc. CAPACITORS, SILVER MICA, POLYSTYRENE, C280, C296, DISC CERAMICS, PLATE CERAMICS, etc. ELECTROLYTIC CONDENSERS, SPEAKERS, CONNECTING WIRE, CABLES, SCREENED WIRE, SCREWS, NUTS, CHOKES, TRANSFORMERS, etc. **ALL AT KNOCKOUT PRICES**
– Come and pay us a visit ALADDIN'S CAVE

TELEPHONE: 445 0749/445 2713
R. HENSON LTD.
21 Lodge Lane, North Finchley, London N12.
(5 minutes from Tally Ho Corner)
1613

MANUFACTURERS SURPLUS STOCKS

Electronic Components, Test Gear, Radiotelephones, Computers, Photographic and Video Equipment. All at knockout prices.
Export and Trade Enquiries Welcomed.
Catalogues available from:
B. Bamber Electronics,
5 Station Road, Littleport, Cambs CB6 1QE
Telephone: Ely (0353) 860185
765

HAVING DIFFICULTY OBTAINING AN OBSOLETE VALVE/MAGNETRON/KLYSTRON?

(or transistor, I.c., CRT, trav wave tube etc)

- **RARE & OBSOLETE TYPES A SPECIALITY!**
- **ALL POPULAR TYPES STOCKED AT COMPETITIVE PRICES**
- **SPECIAL PRICES FOR WHOLESALE QUANTITIES**
- **OFFICIAL ORDERS FROM GVT DEPTS, MILITARY, PLCs, OVERSEAS ETC. WELCOME**
- **PHONE/FAX/TELEX FOR UP TO DATE PRICES ON YOUR REQUIREMENTS**

Visa – Barclaycard – Access accepted

BV **BILLINGTON VALVES**
Good quality – Low price – Rarities a speciality
39 Highlands Road, Horsham, Sussex, RH13 5LS, UK.
Phone: 0403 210729. Fax: 0403 40214. Telex: 87271
Office hours Mon-Fri 9am-5.30pm. Callers welcome by appointment only

WE BUY AND SELL TOP QUALITY TEST AND MEASUREMENT EQUIPMENT WE BUY AND SELL TOP QUALITY TEST AND MEASUREMENT EQUIPMENT WE BUY AND SELL TOP QUALITY

RALFE ELECTRONICS
36 Eastcote Lane,
S. HARROW, Middx HA2 8DB
Tel: 01-422 3593 · Fax: 01-423 4009

Please contact us for our latest stock lists of top-quality re-calibrated, test equipment. Good equipment also WANTED for stock and waiting customers for 'high-end' equipment. Stock examples: TEK 2213 60MHz o'scopes £395. HP8559A 21GHz analyser £4950. HP3582A audio analyser £3250.

80C552 SINGLE BOARD COMPUTER

ONLY £199 + p&p and VAT (minimum configuration)

A complete development system

This uses the latest Philips CMOS Microcontroller with the following features

32K RAM – 32K Eprom – buffered bus
Protected power supply for easier prototyping
Protected analogue inputs – 8 channel 10 bit ADC
2 pulse width modulated outputs – 3 × 8 bit i/o ports
Full duplex uart RS232C has shutdown capability
3 counter timers – watchdog timer – full pc link
prioritised 15 source interrupt handler
12MHz 8051 cpu core with powerdown
on board led array for indication purposes

ALSO AVAILABLE A FREE PC HOSTED CRDSS ASSEMBLER AND POWERFUL DEBUG MONITOR

For further details contact Bob Stewart at: BOBCAT LTD, Arboretum Lodge, Kilmun, By Dunoon, Argyll PA23 8SE
Telephone: 0369 84371

UNIQUE HIGH SPEED COMPUTER CONTROL SYSTEM

Are You Efficient? Do You Progress Jobs? Do You Carry Stock? Do You Have Answers for your Customers at your Fingertips?

We can offer you a totally tailored computer package which will revolutionise your business.

For information and prices, contact Martin at:

Dardsoft
25 The Auto Centre, Erica Road, Milton Keynes.
Tel: (0908) 310226

SUMMER SALE

OSCILLOSCOPES & GENERAL TEST EQUIPMENT
All items supplied in tested and working condition.
Calibration verified at no extra cost.

TEK 475 200MHz – D. Beam – DT. Base	£485
TEK 475A 250MHz	Phone for details
TEK 7603 c/w 7A16, 7A18, 7A26, 7B53A p/ins	£999
HP 1222A 15MHz Dual Beam	£165
Gould OS1100-S1 30MHz Dual Beam	£155
Philips PM3218 35MHz	£325
Philips PM3217 50MHz	£325
Cossor CDU150 35MHz	£149
SE LABS SM111 18MHz	£145

SPECIAL
MARCONI TF 2008 SIGNAL GENERATORS
10KHz – 510KHz · AM-FM SWEEP
£400
'Wooden Box' of accessories also available at £40
Also

Telequipment CT17 curve tracer – mint	£350
Marconi TF2015 Sig Gen's 10Mhz – 520Mhz AM-FM	£325
Marconi TF2002AS Sig Gen's 10Khz – 72Mhz AM-FM	£80
Marconi TF 2603 RF Millivolt 10 1·5Ghz	£99

Accessory kits available.

Racal Dana 9915M TXO 8 digit DFM 510MHz LED	£225
Advance DMM3 Mains/Batt Digital Multimeters incl. case/probes	£45
Megger Insulation testers 250v, 500v, V8, 9A	£35 – £50

MANY, MANY more items in stock and arriving daily at our three acre depot in Nottingham. We are open to callers 9am – 6pm weekdays – 8am – 4pm Saturday

Rob Taylor (Technical Manager)
Anchor Surplus Ltd., The Cattle Market Dept., off London Road, Nottingham NG2 3GY
Telephone (0602) 864041 or Fax (0602) 864667
742

G.W.M. RADIO LTD.,

40/42 PORTLAND ROAD, WORTHING, SUSSEX.
Tel: 0903 34897

Receivers. Racal RA17 MkII with handbook £180. Eddystone 730/4 £110 plus carriage. Interference measuring receiver manufactured by Eddystone for British Telecom 130Kcs to 33MHz Type No. 40A solid state mains or battery £140 inc. p&p. Racal 850 calibrators useful for netting VHF UHF Rx's and Tx's 12.5 25 50KHz channel spacing mains operation £27 inc. Oscilloscope SE Labs SM111 Twin Beam 18 Megs solid state £120 plus.
British made all brass quality marine carriage clocks eight day mechanical 14cm 5½in dial round brass case centre sweep seconds unused £70 inc. Mains isolation transformers 230/240v two secondaries each 230/240v at 100VA unused £4 each plus p&p £4 negotiable for quantity. Set of handbooks for Hewlett Packard 3585A 4 volumes weight 12 kilos unused offers. Secondhand ex-BT telephone equipment available and wanted. Many bargains for callers. Pye Lynx black and white security cameras from £65
788

TEST EQUIPMENT FOR SALE

contact
COOKE INTERNATIONAL
Unit 4, Fordingbridge Site, Main Road, Barnham, Bognor Regis, West Sussex PO22 0EB
Tel: 0243 54111
Fax: 0243 542457
Wide range of items available.
Send for lists.

ARTICLES WANTED

WANTED

Receivers, Transmitters, Test Equipment, Components, Cable and Electronic Scrap Boxes, PCB's, Plugs and Sockets, Computers, Edge Connectors

TOP PRICES PAID FOR ALL TYPES OF ELECTRONICS EQUIPMENT.

A. R. Sinclair, Electronics Stockholders, 2 Normans Lane, Rabley Heath, Welwyn, Herts AL6 9TQ
Telephone: 0438 812 193
Mobile ☎ 0860 214302
Fax 0438 812 387
780

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity.
Prompt service and cash.
M & B RADIO
86 Bishopgate Street, Leeds LS1 4BB.
Tel: 0532 435649
Fax: 0532 426881
9956

STEWART OF READING

110 WYKEHAM ROAD, READING RG6 1PL.
TEL: 0734 68041.
FAX: 0734 351696

TOP PRICES PAID FOR ALL TYPES OF SURPLUS TEST EQUIPMENT, COMPUTER EQUIPMENT, COMPONENTS etc. ANY QUANTITY.
103

PCB's DESIGNED AND DRAFTED

CAD/manual designs undertaken for single/double sided boards from initial idea to prototype. Testing and production service if required. Quality product to meet your deadline needs. Quality in design and rapid service guaranteed.

PCB DESIGN AND DRAFTING SERVICES
01-316 9571 day 01-552 2346 eve

ENTER 8 ON REPLY CARD

INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 932-935

Advertiser	PAGE
AEL Communications	849
Airlink Transformers	883
Audio Electronics	878
Carston Electronics	IFC
Cavendish Automation	902
Communique UK	901
Computer Appreciation	919
Display Electronics	915
Field Electric	926
Henrys Audio Electronics	844
Hitachi Denshi (UK)	846
Ian P Kinlock	911
ICOM (UK)	878
Johns Radio	883
Kestral Electronic Components	926
L J Technical Systems	883
Lab-Volt (UK)	849/OBC
Langrex Supplies	911
Laplace Instruments	865
Levell Electronics	865
M & B Radio (Leeds)	919/926
Natel Electronics	861
Number One Systems	893
Pineapple Software	861
R Henson	911
Research Communications	931
Rohde & Schwarz	889
Schlumberger Instruments	873
Sherwood Data Systems	897
Solex International	Insert
South Midlands Communications	919
Sowter Transformers	926
Stag Microsystems	878
Stewart of Reading	911
Taylor Bros (Oldham)	842/IBC
Thandar Electronics	865
Those Engineers	905
Thurlby Electronics	905
Triangle Digital Services	846

OVERSEAS ADVERTISEMENT AGENTS
France and Belgium: Pierre Mussard, 18-20 Place de la Madelaine, Paris 75008.
United States of America: Jay Feinman, Reed Business Ltd., 205 East 42nd Street, *New York*, NY 10017 – Telephone (212) 867 2080 – Telex 23827.

Printed in Great Britain by Carlisle Web Offset, Caxton Road, Newtown Trading Estate, Carlisle, Cumbria CA2 7NR, and typeset by Graphac Typesetting, 181 191 Garth Road, Morden, Surrey SM4 4LL, for the proprietors, Reed Business Publishing Ltd, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. *Electronics and Wireless World* can be obtained from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co. CANADA: The Wm Dawson Subscription Service Ltd., Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd: William Dawson & Sons (S.A.) Ltd. UNITED STATES: Worldwide Media Services Inc., 115 East 23rd Street, NEW YORK, N.Y. 10010, USA. *Electronic & Wireless World* $5.95 (74513).

Telecommunications Training

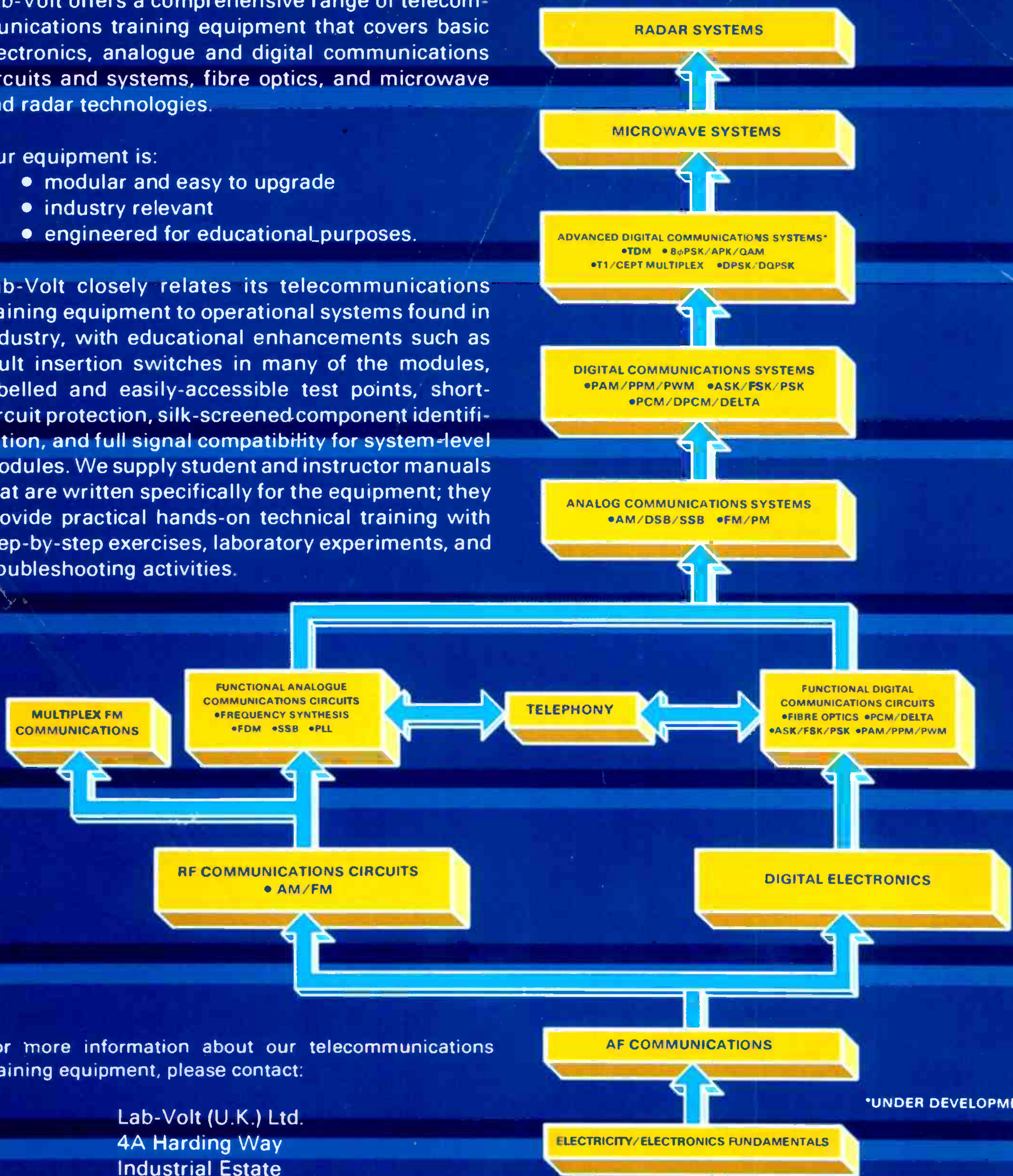
from fundamentals to state-of-the-art technology

Lab-Volt offers a comprehensive range of telecommunications training equipment that covers basic electronics, analogue and digital communications circuits and systems, fibre optics, and microwave and radar technologies.

Our equipment is:

- modular and easy to upgrade
- industry relevant
- engineered for educational purposes.

Lab-Volt closely relates its telecommunications training equipment to operational systems found in industry, with educational enhancements such as fault insertion switches in many of the modules, labelled and easily-accessible test points, short-circuit protection, silk-screened component identification, and full signal compatibility for system-level modules. We supply student and instructor manuals that are written specifically for the equipment; they provide practical hands-on technical training with step-by-step exercises, laboratory experiments, and troubleshooting activities.



*UNDER DEVELOPMENT

For more information about our telecommunications training equipment, please contact:

Lab-Volt (U.K.) Ltd.
4A Harding Way
Industrial Estate
St. Ives
Cambridgeshire
PE17 4WR
Or Call: 0480 300695

Lab-Volt®