THE JOURNAL FOR PROFESSIONAL ENGINEERS

ELECTRONICS & WIRELESS WORLD

MARCH 1987 £1.95

Industrial soldering technology

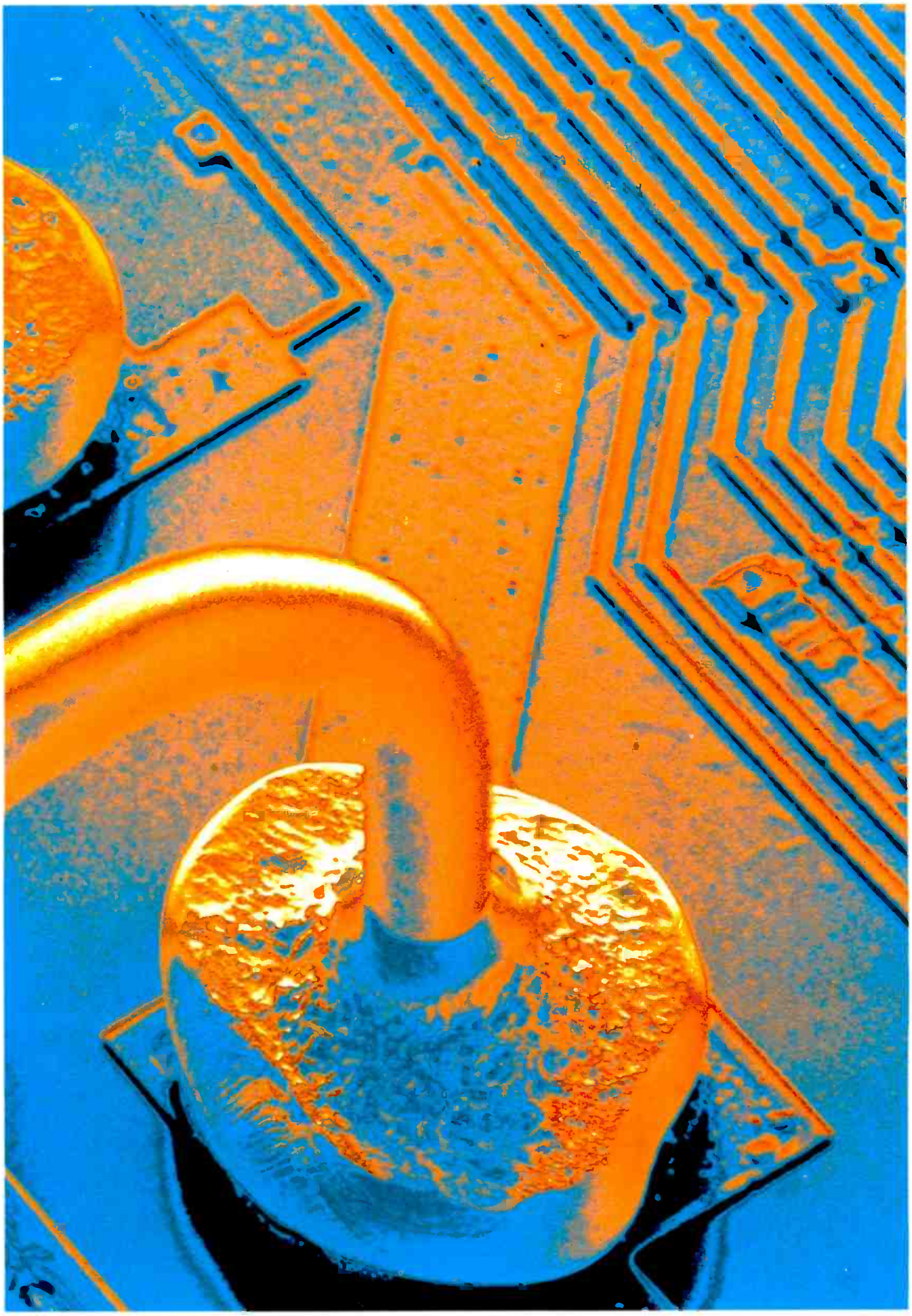
Orthogonality and Walsh functions

Testing surface-mounted devices

Measuring micro-ohms

Designing toroidal transformers

Scientific interface for PCW8256/8512



Australia A$ 9.35 Denmark DKr. 63.00 Germany DM 12.00 Greece Dra. 680.00 Holland DFl. 12.50 Italy L 6500 Spain Ptas. 700.000 Singapore S$ 11.25 Switzerland SFr. 9.50 USA $ 6.50.

MARCONI INSTRUMENTS
The last word in test instrumentation

2955 Radio Communications Test Set £5,750

- 11 test functions, including full duplex radio test
- Revolutionary design: fast and easy to use
- High clarity CRT shows all settings plus measurements in digital or analog forms
- Tones encode/decode facilities
- 38 instrument settings in non-volatile memory
- Spin-wheel frequency/level control in addition to front panel buttons
- Single and two-port operation.

2382/80 Spectrum Analyser £13,470 and Display £5,480

- Audio to UHF coverages: 100Hz-400MHz
- Outstanding resolution, with 3Hz minimum resolution filter bandwidth
- 0.025dB amplitude resolution
- Superb level accuracy ± 1dB, with auto calibration
- Frequency response better than ± 0.4dB
- Fully GPIB programmable capability
- Two steerable markers for levels and frequencies
- Self calibration for repeatability of measurements.

2022 AM/FM Signal Generator 10kHz to 1GHz £2,950

- Wide frequency cover: 10kHz to 1000MHz
- Compact, rugged and lightweight
- Comprehensive modulation: AM/FM/PhM
- Simple push-button operation, large LCD display
- Non-volatile memory for 100 settings
- The perfect service/maintenance tool.

2305 Modulation Meter 500kHz to 2GHz £5,418

- 500kHz to 2GHz frequency range
- Outstanding 0.5% basic accuracy
- Exceptionally fast auto-tuning, with low noise
- Modulation analysis including frequency and power
- Non-volatile memory to store user settings
- Excellent stereo separation
- Automatic self-calibration, advanced diagnostics.

6960 Option 001 Digital RF Power Meter £1,900

- Simple push-button or systems application
- Unparalleled accuracy, through sensor correction
- Non-volatile storage of frequently-used settings
- W or dB readings, plus offset capability
- Single-key auto-zero operation
- Average factor selection to reduce noise or improve resolution, advanced GPIB facilities.

2440 Microwave Counter 20GHz £3,650

- Wide frequency coverage: 10Hz to 20GHz
- High sensitivity and resolution
- Fast acquisition time: only 200ms typical
- High-stability oven-controlled crystal oscillator
- Overload capability up to 27dBm
- High AM/FM tolerance
- Built-in GPIB.

ENTER 1 ON REPLY CAR

through ELECTRONIC BROKERS

Electronic Brokers are now distributors for a full range of Marconi Test Instruments including Signal Generators, Microwave Counters, Power Meters, Modulation Meters, Spectrum Analysers, Radio Communication Test Sets and other general test and measuring equipment. For further information and a colour brochure please contact our Sales Office.

The first name in test equipment distribution

Electronic Brokers

Electronic Brokers 140-146 Camden Street, London, NW1 9PB
Fax: 01-2677363 Telex: 298694 Tel: 01-267 7070

All prices exclusive of VAT. Prices correct at time of going to press (UK only). Trading conditions available on request.

CONTENTS

MARCH 1987 VOLUME 93 NUMBER 1613

FEATURES

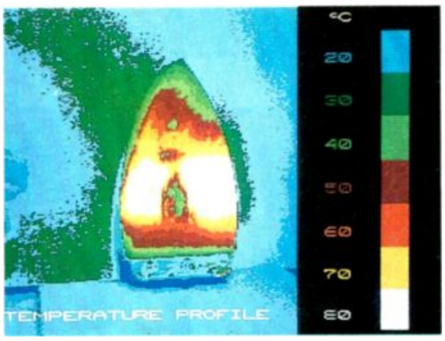


Image generated by the video frame store colour palette described on page 300.

For reasons totally outside our control, the article on the scientific interface for the PCW8256/8512 has had to be held over to the next issue. We apologise for this to the author and to readers.

REGULARS

COMMENT

Domestic Harmony

EDITOR
Philip Darrington

DEPUTY EDITOR
Geoffrey Shorter, B.Sc.
01-661 8639

TECHNICAL EDITOR
Martin Eccles
01-661 8638

PROJECTS EDITOR
Richard Lambley
01-661 3039 or 8637 (lab.)

NEWS EDITOR
David Scobie
01-661 8632

ART EDITOR
Alan Kerr

DRAWING OFFICE
Roger Goodman
01-661 8690

ADVERTISEMENT MANAGER
Ashley Wallis
01-661 3130

Michael Downing
01-661 8640

CLASSIFIED EXECUTIVE
Susan Platts
01-661 3033

ADVERTISING PRODUCTION
Brian Bannister
(Make-up and copy)
01-661 8648

PUBLISHING DIRECTOR
Clive Foskett
01-661 3151

REED BUSINESS PUBLISHING

It is encouraging to see that someone, somewhere is paying attention to compatibility. Traditionally, the emergency of a novel invention or development has been accompanied by a welter of alternative ways of going about it, with utter confusion reigning supreme.

One can think of hundreds of examples, from railway-line gauges to video recorders, in which companies have been determined to plough their own furrow, regardless of the rest of the world, so that a 110V, 60Hz sprocket dangler built in the US is held in place by a screw that is totally unknown in the rest of the 240V, 50Hz civilized world. Right-hand drive VHS video recorders won't play left-hand drive Betamax tapes and the problems of getting computers to talk to peripherals and to other computers are manifold. Any efforts to reduce this cacophony are greatly to be welcomed.

A report in the *Times* recently drew attention to a concerted effort by seven large manufacturers of domestic electronic goods to pave the way for the 'intelligent home' of the near future. Leaving aside the question of just how bright one wants a home to be in comparison with one's own mental capabilities, the business of ensuring compatibility between personal computers, television receivers and displays, telephones, sensors, actuators, heating, lighting, cooking, radio and anything else that comes to mind is an essential pre-requisite to the establishment of homes with any claim at all to intelligence, as opposed to the dumb kind which one simply lives in, periodically trekking wearily across the room to change a record (or compact disc, in this context).

The seven companies – G.E.C., Mullard, Siemens, Thomson, Philips, Thorn-EMI and Electrolux are spending, says the *Times*, £12 million on making sure that all the equipment will work happily together and that a British computer expressing a desire that the Swedish cooker should begin to think about dinner in a constructive manner shall not meet a sulky refusal to do anything of the sort. Thorn-EMI are leading the project and have built a test house at Hayes to investigate methods of communication between the equipment.

All this effort is, of course, later than it should be and much later than it could be. The Japanese, predictably, have had it well in mind for some time, and could be on the point of producing the hardware.

A funding of £12 million seems a great deal of money to devote to reaching an agreement to make equipment friendly, since all the techniques needed to do that are already there. But, at least, it is happening, and one must not be churlish about it. Let us hope that the Europeans and Japanese do not insist on having two different 'standards', when it would be so simple to set up a global one. If they can get computers to talk to washing machines, one might be permitted to hope that they will find it possible to talk to each other.

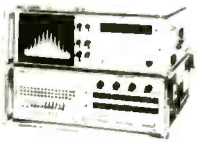
Electronics & Wireless World is published monthly USPS 687-540 Current issue price £1.95, back issues (if available) £2.10 at Retail and Trade Counter, Units 1&2, Bankside Industrial Centre, Hopton Street, London SE1 Telephone: 01-928 3567 By post, current issue £2.25, back issues (if available) £2.50 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 BISPRS G (EEP) Facsimile:** 01-661 2071 (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. **Subscription rates:** 1 year £18 UK and £23 outside UK. **Student rates:** 1 year £11.50 UK and £14.50 outside UK. **Distribution:** Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. Telephone 01-661 3248. **Subscriptions:** Oakfield House, Perrymount Road, Haywards Heath, Sussex RH16 3DH. Telephone 04444 59188. Please notify a change of address. **USA:** $49.40 surface mail, $102.60 airmail. Business Press International (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 Feinman, Business Press International 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 N.J. 07001. 2nd class postage paid. Postmaster – send address to the above. ISBN 0043 6062

RALFE · ELECTRONICS

10 CHAPEL STREET, LONDON, NW1 TEL: 01-723 8753

MARCONI INSTRUMENTS

MARCONI TF2371 200MHz SPECTRUM ANALYSER



30Hz–200MHz frequency range. 0.1db & 5Hz resolution. 100db displayed dynamic range. In-built tracking gen & counter. MINT condition with years certificate of calibration £8000

- **TF1245** Q-Meter with osc 1246 .... £575
- **TF2006** AM/FM Signal generator 10–1000MHz £1250
- **TF1313** ¼% RCL Bridge £375
- **TF2011** VHF FM Signal Generator 130–180MHz £325
- **TF1060/2** UHF Signal Generator 450–1200MHz £195
- **TF2604** Electronic multi-meter £175
- **TF893A** Audio power meter £75
- **TF2612** MF Attenuator 0–111db. 0.1db steps £100
- **TF1020A** 100W 250MHz power meter £75
- **TF2301** Programmable Modulation meter £125
- **TF2430** Frequency counter 80MHz
- **TF2305** Modulation meter £3000
- **TF2905/8** Sine Squared Pulse & Bar gen. 625 line £450
- **TF163S** Attenuator 1GHz £250
- **TF2304** Auto modulation meter £400
- **TF1245** Q-Meter with oscillator 1246 or 7 .... £550

★ ★ MULTI-RAIL POWER SUPPLIES ★ ★

Brand new 'Gresham-Lyon' Switch-mode power supplies giving outputs of +5V @ 6A. +12V @ 4.75A and −12V @ 0.5A. 240V AC. Input. Short/open circuit protected etc. etc. Bulk 'job-purchase' enables us to offer them at only £20 each including VAT. (Postage £2 each please). Quantity (10+) discounts available.

WE HAVE IN STOCK A WIDE RANGE OF POWER SUPPLY UNITS, AVO MULTI-METERS, INSULATION TESTERS, COMPUTER PERIPHERAL EQUIPMENT ETC. ETC. WE WOULD BE PLEASED TO RECEIVE YOUR ENQUIRY REGARDING ANYTHING ELECTRICAL OR ELECTRONIC

TEST & MEASUREMENT EQUIPMENT

- TEKTRONIX 576 Curve Tracer. Mint £4000
- TELEQUIPMENT D83 Oscilloscopes 50MHz £350
- TELEQUIPMENT D75 Oscilloscopes 50MHz £300
- TELEQUIPMENT DM64 Storage scopes .... from £250
- GOULD Digi-store scope 1425/125 20MHz £1500
- OSCILLOSCOPE – stock, phone for best quote.
- BRYANS 22020 XYT Plotter A3 .... £175
- BPL Wheatstone comparator bridge £150
- BRUEL & KJAER 1402 Random noise gen £250
- BRUEL & KJAER 2604 Microphone amplifier £100
- DYMAR 1525 VHF AM/FM Signal generator £395
- GR 1933 Sound level meter £275
- GPW 7620 Telegraph & Data generator £195
- AVO VCM163 Valve characteristic meter £400
- RACAL 9301 RF Voltmeter 1.5GHz £450
- RACAL 383 4-Trace display oscilloscope £175
- RADFORD LDO2 Low distortion oscillator £150
- STODDART Receiver RFI 375–1000MHz £350
- RADIOMETER FRA3 A.F. Wave analyser £250
- AVERY Electronic scales 1766. 25kgs £425
- TEKTRONIX 191 Signal generator £150
- TEKTRONIX 7B85 plug-in £650
- PHILIPS PM2454B Voltmeter £195
- FLUKE 871A Differential Voltmeter £250
- ENVIRONMENTAL CHAMBERS – Montford Instruments. Temperatures from −70 to +170C 3ø 15KW. p.o.a.

ALL OUR EQUIPMENT IS SOLD IN EXCELLENT, FULLY FUNCTIONAL CONDITION AND GUARANTEED FOR 90 DAYS. MAIL ORDERS AND EXPORT ENQUIRIES WELCOMED. PLEASE TELEPHONE FOR CARRIAGE QUOTE. ALL INSTRUMENTS ARE AVAILABLE EX-STOCK AS AT COPY DATE. GOOD QUALITY TEST EQUIPMENT ALWAYS **WANTED** FOR STOCK. PRICES QUOTED ARE SUBJECT TO ADDITIONAL VAT

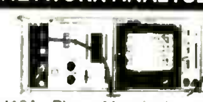
HEWLETT PACKARD

- **8007B** Pulse generator £500
- **8555A** Spectrum analyser unit to 40GHz £3950
- **400F** Voltmeter 100μV–300V 4MHz £225
- **741B** AC/DC Diff V.Meter/DC Standard £275
- **738BR** Calibrator £195
- **3330B** Automatic synthesizer 0.1Hz–13MHz £2950
- **331A** Distortion meter £350
- **4800A** Vector impedance meter £1950
- **11602B** Transistor fixture for 8745A £450
- **11600B** As above
- **7045A** XY Plotter Opt 001 (Time-base) £750
- **6600A/1** Sweep generator 26–40GHz 0–12db £3950
- **355E** Programmable attenuator 1GHz 0–12db £95
- **355F** As above but 0–120db in 10db steps £95
- **3490A** Digital Multi-meter £450
- **8733A** Pin modulator £450
- **202H** AM/FM Signal generator £150
- **8640B** Opt 001 & 2 Signal generator £2950
- **8701A/2A/3A** Microwave link analyser £450
- **431C** with **478A** Microwave power meter £250
- **8553B** Spectrum analyser plug-in 110MHz £1500

110MHz SPECTRUM ANALYSER

- **141S** Storage main-frame/8552A I.F. unit/8553L 110MHZ R.F. Unit £2,500
- **8554B** 1250MHz spectrum analyser plug-in £2,250
- **8004** Pulse generator £225

NETWORK ANALYSER



With types 8412A Phase-Magnitude and 8414A Polar display units. 110MHz. Recent calibration £2500

★ HP141T SPECTRUM ANALYSER SYSTEM to 40GHz ★

SYSTEM Comprises of type 141T Storage main-frame. 8552B I.F. plug-in unit and 8555A 10MHz–18GHz (40GHz with external mixers) R.F. plug-in £7500
Excellent throughout, calibration certified.

ENTER 6 ON REPLY CARD

EMS Power Systems

EMS manufactures DC Power Supplies and Battery Chargers both linear and switch mode in a range from 5 VA to 3.2 KVA.

Also a complete range of Standby, UPS and Mains Stabilizer Systems 35 VA to 1 KVA. EMS specialises in the manufacture of customised products and has a full design and development facility.

EMS (Manufacturing) Limited,
Chairborough Road,
High Wycombe,
Bucks HP12 3HH.
Tel: (0494) 448484

ENTER 21 ON REPLY CARD

SOWTER AUDIO FREQUENCY TRANSFORMERS

You name it! We make it!

For the past 45 years we have concentrated on the design and manufacture of high grade audio transformers during which period our total sold exceeds half a million. We continually take full advantage of all the improvements in magnetic and insulating materials and in measuring techniques utilising the most up to date instrumentation.

We have a very large number of original designs made for clients all over the world but naturally there are certain types of Sowter Transformers which are in constant demand. These have taken into account the tendency towards small size without sacrifice of performance, particularly for PCB mounting, and a few of these are listed below. They can be supplied with or without mumetal shielding cans. Performance requirements can be modified on request (utilising our readily available questionnaire) and generally without alteration in price.

We specialise in **LOW COST AND QUICK DELIVERY** which means a few days only or ex-stock.

TYPICAL PERFORMANCES

Sowter Type No	3575	4652	3678	6499	4079	6471	6469
Description	Miniature bridging transformer	Line output	Multi primary microphone transformer	Line output high level low distortion toroidal core	Splitter combiner transformer	Midget mic transformer for BT private systems	Very high quality microphone transformer
Impedances	10kΩ 10kΩ can be fed from 50 600Ω	600 or 150Ω inputs or outputs	Pys 60. 200 or 600Ω Sy 5KΩ down to 1k8Ω	600Ω 600Ω	200Ω Bal Py Two 200Ω Secondaries	Py 600Ω Sy 60kΩ	200Ω Py for 1kΩ loading (Bifilar) 8 1 step up
Frequency range	20Hz 20kHz	20Hz 20kHz	30Hz 20kHz	20Hz-20kHz	20Hz-20kHz	300Hz 3k4Hz	20Hz 20kHz
Performance	0 1dB over above range	0 25dB over above range	0 5dB over above range	0 3dB 40Hz-15kHz 0 5dB 20Hz 20kHz	0 5dB over above range	0 5dB over above range	0 2dB over above range
Maximum Level	7.75V r m s. on secondary	7 75V r m s on 600Ω	on 5kΩ load 3 4V r m s at 30Hz	26dBm at 30Hz	2 3V r m s at 30Hz	0 6V p-p on Primary	2 0V r m s on Py at 30Hz
Maximum Distortion	With 10V r m s at 40Hz only 0 12%	On 600Ω low source Z 0 1%	Less than 0 1% at 1kHz	0 1% at 30Hz at 26dBm	negligible 0 1% at 1kHz	negligible	0 1% at 20Hz
Shielding	Electrostatic screens and mumetal can	Mumetal can if desired at extra cost	Mumetal can	Toroidal can	Mumetal can rigid fixing bolts	PCB mounting	Mumetal can
Dimensions	33mm diam 22mm high	36mm high 43mm 33mm	33mm diam 22mm high	50mm diam 36mm high	33mm diam 37mm high	11 1mm high 19mm 17mm	33mm diam 22mm high
Prices each at works	1 £10 83 50 £9 77 100 £9 27	1 £9 67 50 £8 89 100 £8 69	1 £9 67 50 £8 67 100 £8 41	1 £17 12 50 £15 69 100 £15 35	1 £14 59 50 £13 37 100 £13 08	1 £3 89 50 £3 55 100 £3 29	1 £11 38 50 £10 12 100 £9 92

E. A. SOWTER LTD. (Established 1941) Reg. No. England 303990
The Boat Yard, Cullingham Road, Ipswich IP1 2EG, Suffolk. PO Box 36, Ipswich IP1 2EL. England. Phone: 0473 52794 & 0473 219390 – Telex: 987703G SOWTER

ENTER 33 ON REPLY CARD

TAYLOR

VESTIGIAL SIDEBAND
TELEVISION MODULATOR C.C.I.R/3

CRYSTAL CONTROLLED OSCILLATOR
19" RACK MOUNTING, 1u HIGH, 205mm DEEP

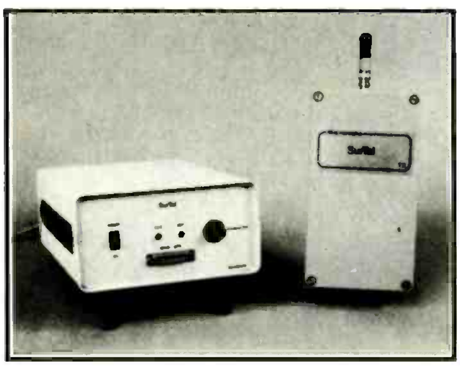
C.C.I.R/3 SPECIFICATION	
Power Requirement	– 240V 8 Watt (available in other voltages)
Video Input	– 1V Pk-Pk 75 Ohm
Audio Input	– .8V 600 Ohm
F.M. Sound Sub-Carrier	– 6MHz (available 5.5MHz)
Modulation	– Negative
I.F. Vision	– 38.9MHz
I.F. Sound	– 32.9MHz (available 33.4MHz)
Sound Pre-Emphasis	– 50us
Ripple on I.F. Saw Filter	– .6dB
Output (any channel 47-860MHz)	– +6dBmV (2mV) 75 Ohm
Vision to Sound Power Ratio	– 5 to 1
Intermodulation	– Equal or less than 60dB
Spurious Harmonic Output	– –40dB (80dB if fitted with TCFL1 Filter or combined via TCFL4 Combiner/Leveller

C.C.I.R./3.1	– Specification as above but output level 60dBmV 1000MV

CHANNEL COMBINER/FILTER/LEVELLER to combine outputs of modulators	
TCFL2	2 Channel Filter/Combiner/Leveller: Insertion Loss 3.5dB
TCFL4	4 Channel Filter/Combiner/Leveller. Insertion Loss 3.5dB
TSKO	Enables up to 4 x TCFL2 or TCFL4 to be combined.

TAYLOR BROS (OLDHAM) LTD
BISLEY STREET WORKS, LEE STREET, OLDHAM, ENGLAND.
TELEPHONE: 061 652 3221 TELEX: 669911

ENTER 12 ON REPLY CARD



SurTel
UHF VHF RADIO TELEMETRY

Scientific Instrumentation – Automatic Guided Vehicles – Machine Control Systems – Data Buoys – Plant Control – Mobile Terminals/ Displays – Environmental & Meteorological Systems – Strain Gauge – Monitoring – Survey Instrumentation

- **UHF** – Digital Communications at 1200 Baud over one or two way line of sight conditions (458 MHz nom.)
- **VHF** – As for UHF but available at 173 MHz working.
- **INTELLIGENCE** – Microprocessor based radio telemetry providing error checking and data formatting etc. Outputs for VDU's, Printers, Computers, Terminals.

Features: DTI Home Office approved to MPT 1309 – weatherproof housings (IP65) – portable – rugged – high/low power selectable – standby operation reduces battery drain – 12 volts D.C. – low power consumption – visual monitoring of operation.

Overseas customers may specify higher power options or alternative frequency of operation – OEM enquiries welcome

MICROMAKE ELECTRONICS
1 THE HOLT · HARE HATCH · UPPER WARGRAVE · READING · RG10 9TG
TEL: 073522 3255 TLX: 946240 Ref 19023890

ENTER 30 ON REPLY CARD

ADVANCED ACTIVE AERIAL

The aerial consists of an outdoor head unit with a control and power unit and offers exceptional intermodulation performances: SOIP +90dBm, TOIP +55dBm. For the first time this permits full use of an active system around the lf and mf broadcast bands where products found are only those radiated from transmitter sites.

- General purpose professional reception 4kHz – 30MHz.
- –10dB gain, field strength in volts/meter to 50 Ohms.
- Preselector and attenuators allow full dynamic range to be realised on practical receivers and spectrum analysers.
- Noise – 150dBm in 1Hz. Clipping 16 volts/metre. Also 50 volts/metre version.

SURREY ELECTRONICS LTD.,
The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG.
Tel: 0483 275997

LOW COST UNIVERSAL PROGRAMMER
EPROMS EEPROMS MICROS

- Completely self contained unit.
- No personality modules required.
- Controlled via RS232 serial interface.
- Supports Intel, Motorola and Ascii hex data formats.
- Easily controlled by most computers.
- Fast and standard programming modes.
- Low and high byte programming for 16 bit data.
- Byte, block and chip erase for Eeproms.

- Eproms: 2508/16/32/64 2758 2716/32/32A/64/64A/128/128A/256/512/513 27C16/32/64/128/256/512 68732/64/66
- Eeproms: 2816A/64A 52B13/23/33 48Z02
- Micros: 8748/48H/49/49H

Price uncased £295 plus VAT.

Micro Concepts

Tel: 0242 510525

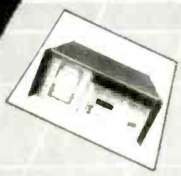
2 St. Stephens Road · Cheltenham · Glos · GL51 5AA

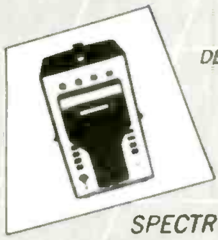
ENTER 55 ON REPLY CARD

Carston

USED TEST & COMPUTER EQUIPMENT

PHONE 01-943 4477 FOR OUR LATEST STOCKLISTS





GRAPHICS PLOTTERS
QUME
SCIENTIFIC COMPUTERS
APPLE
MAINS TEST EQUIPMENT
FLUKE
DESK TOP COMPUTERS
THORN EMI
VDU TERMINALS
GOULD
SPECTRUM ANALYSIS
IBM
SIGNAL GENERATORS
SOLARTRON
COMPUTER PERIPHERALS
HEWLETT PACKARD

★ SPECIAL OFFERS ★

HEWLETT PACKARD
1630G LOGIC ANALYSER **£6950**
1630D LOGIC ANALYSER **£5250**
4951A/100 PROTOCOL ANALYSER **£1990**
4953A PROTOCOL ANALYSER **£5000**

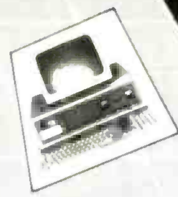
ATLANTIC RESEARCH
4600 PROTOCOL ANALYSER **£3950**

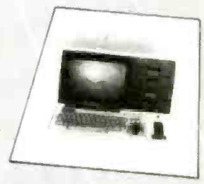
GOULD OS4020 DIGITAL OSCILLOSCOPE **£800**

HEWLETT PACKARD
141T SYSTEMS. DC TO 18GHz USING VARIOUS RF CONFIGURATIONS. SYSTEM PRICES FROM **£4500**
TYPICAL SYSTEM AS ABOVE
141T/8552B/8555A 18GHz SYSTEM **£7500**
AS ABOVE WITH PRE-SELECTOR **£9000**

WATANABE MC6601-6Z 6 PEN RECORDER **£795**

INTEL DEVELOPMENT SYSTEMS SERIES II, III AND IV AVAILABLE — RING FOR THE CONFIGURATION YOU REQUIRE
TYPICAL SYSTEM: — 225B + 721 DRIVE AND EXPANSION CHASSIS **£990**





STAG
DATA LOGGERS
HONEYWELL
PRINTERS/PLOTTERS
MARCONI
FREQUENCY COUNTERS
DRANETZ
NETWORK ANALYSIS
INTEL
OSCILLOSCOPES
DEC
LOGIC ANALYSERS
RACAL
CHART RECORDING
TEKTRONIX
μ DEVELOPMENT

A FEW EXAMPLES OF OUR CURRENT STOCK

LOGIC ANALYSERS AND DIGITAL TEST EQUIPMENT

TEKTRONIX
1240/D1/D2 Logic Analyser — **£2950**

FLUKE
9010A Micro-System Troubleshooter — **£2950**
9000A-Z80 Interface Pod — **£1050**

OSCILLOSCOPES

GOULD
OS300 15MHz Dual Trace — **£225**

HEWLETT PACKARD
1740A 100MHz Dual Trace — **£1050**

TEKTRONIX
2445 150MHz 4 Trace — **£2450**
2215 60MHz Dual Trace — **£550**
2335 100MHz Dual Trace — **£1250**

SPECTRUM ANALYSERS

HEWLETT PACKARD
3580A 5Hz to 50KHz Analyser — **£3250**

MARCONI
TF2370 110MHz Spectrum Analyser — **£6850**
TF2371 200MHz Spectrum Analyser — **£8500**

HEWLETT PACKARD
182C/8558B 1.5GHz System — **£5500**

COMPUTERS AND PERIPHERALS

HEWLETT PACKARD
86A — **£600**
85A — **£600**
9121D Drive — **£500**
9816S — **£2250**
9826S — **£2950**
7475A Plotter — **£1100**
98256 256K Memory Card — **£40**

LEAR SIEGLER
ADM42 Terminal (7 day warranty) — **£90**

SIGNAL SOURCES

HEWLETT PACKARD
8620C Sweeper Mainframe — **£1950**
86290B 2-18GHz Plug In — **£5500**
86222B .01-2.4GHz Plug In — **£3950**
8640B/001/002 AM/FM Generator — **£3950**

MARCONI
TF2019 AM/FM Generator — **£2950**

MISCELLANEOUS

NAGRA
IVS Tape Recorder — **£2250**

DRANETZ
606-3 Mains Analyser — **£2250**
626 + 3 Phase Plug In — **£3850**

HEWLETT PACKARD
9870A Noise Figure Meter — **£5500**
346A Noise Source — **£550**

S.E. LABS
6300 U.V. Recorder — **£800**

SOLARTRON
1200B Signal Processor — **£8000**

All prices exclude delivery and VAT

All items advertised are fully working and sold with a guarantee

Carston Electronics Ltd

01-943 4477

3 Park Road, Teddington, Middlesex TW11 0AF Telex: 938120

We specialise in the purchase and sale of top quality under utilised equipment. Every item sold by us has been thoroughly tested and calibrated to manufacturer's original specification — and carries a full guarantee.
If your requirement is not listed above, please phone. We have considerably more items in stock, plus a facility for locating rare equipment at short notice.

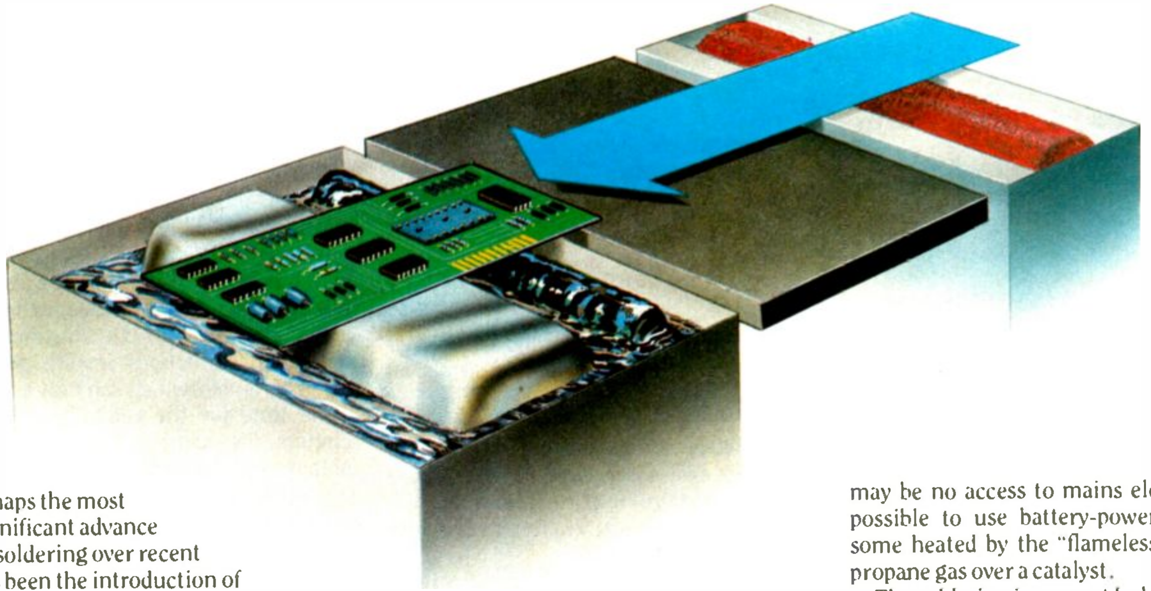
buy Carstonsell Carstonbuy Carstonsell Carstonbuy Carstonsell Carstonbuy

ENTER 46 ON REPLY CARD

ENTER 45 ON REPLY CARD

Soldering technology

Soldering methods have changed rapidly in recent years. This survey describes that techniques used and production practices.



Perhaps the most significant advance in soldering over recent years has been the introduction of machines to replace many of the manual assembly processes. Wave and reflow soldering are examples. Despite this, for many applications, manual soldering is still cost effective, depending on the volume of soldering to be completed. The production of greater than 400 p.c.bs a week is needed to make the purchase of a wave-soldering machine financially viable. Similarly more than 1000 boards a week would justify investing in pick-and-place machinery and reflow soldering for surface-mounted components.

HAND SOLDERING

Hand soldering is still the most widely used method for small to medium scale production and it is worth remembering some of the practical advice offered by solder manufacturers; not least because the same techniques apply to all methods of soldering.

Solder flows spontaneously into a joint if the correct conditions are provided. The joint must therefore be designed with a narrow gap between the parts to be joined, into which the solder can be drawn by capillary action. The gap should be open at the sides or the other end so that solder flow is not prevented by trapped air or flux. Maximum strength is obtained when the gap to be filled by the solder is between about 0.08 and 0.1mm wide. Where possible the joint should be designed so that the components interlock or support each other during soldering, thus avoiding the need for clamps close to the joint, which could take heat away, and providing extra strength in the finished joint. A good mechanical joint needs the solder to make it permanent but, ideally, should provide an adequate contact for current flow without the solder. All surfaces to be joined must be clean and free of grease.

Element	BS219	ITRI	Effect
Tin	59 to 60	—	
Arsenic	0.03	—	Decrease of spread area (1%)
Bismuth		0.1—	Discolouration/oxidation of solder coating (0.5%)
Iron	0.02	—	—
Copper	0.08	0.25	Grittiness (0.29%)
Aluminium	0.001	0.0005	Oxidation (0.0005%)
Silver	n.s.	2.0	
Cadmium	0.005	—	Decrease in spread area (0.15%)
Zinc	0.003	—	Oxidation
Gold	n.s.	0.1	
Antimony	0.2	—	Decrease in spread are (1.0%)
Phosphorous	n.s.	0.005	Dewetting/grittiness (0.01%)
Sulphur	n.s.	0.001	Grittiness (0.0015%)
Others	Total 0.08		
Lead	Balance		

The composition of KP grade solder as used in electronics. The percentages of maximum levels of impurities are specified in BS219. The next column lists the maxima recommended by the International Tin Research Institute where they differ from BS219. These result from tests carried out at ITRI, which showed the deterimental effects of the impurities caused by the proportion in brackets.

Many designs of soldering iron are available and some incorporate systems for feeding a length of soldering wire automatically, or to deposit molten solder from a reservoir within the iron. There are miniature soldering irons for hand-assembly of surface-mounted boards. For field work, where there may be no access to mains electricity, it is possible to use battery-powered irons, or some heated by the "flameless" burning of propane gas over a catalyst.

The soldering iron must be big enough for its working face to cover the width of the joint, and hot enough to heat the workpiece surfaces to a sufficiently high temperature for the solder to flow. The working surface of the iron must also be clean, free from charred flux and coated with a thin layer of molten solder so that heat can be conducted to the joint. Solder wire should be of a diameter thin enough to melt quickly but thick enough to supply sufficient solder for the joint without having to use too great a length of wire. The solder should be applied to the heated joint and not carried to the joint by the iron.

SOLDER

The combination of tin and lead used in solders is selected to give them a common melting temperature (eutectic mixture) as if they were a pure substance. The proportion also permits the lowest possible soldering temperatures (250 to 260°C) with less risk of damage to sensitive components, the standard mixture is 60 to 63% tin and 40 to 37% lead. There are various national standards for the permitted levels of inpurity. The British standard and the effects of the impurities, from research undertaken at the International Tin Research Institute (ITRI), are given in the table. This also includes maximum levels recommended by ITRI where they differ from BS 219 for KP grade solder.

Flux acts as a cleaner to remove oxides from the surfaces to be joined and also assists wetting, the reduction of the contact angle between the workpiece and the solder. For hand soldering of p.c.bs, it is convenient to use solder wire that incorporates the flux such as that provided by Multicore. Rosin flux leaves a deposit that usually has to be cleaned off after soldering but there have

A pick-and-place robotic system for assembling s.m.cs for hand soldering. The Weller station from Cooper Tools offers a choice of fine-tipped and shaped soldering irons, all temperature controlled.

been advances in this field too and Multicore has announced a synthetic flux, X32, which is virtually fume free and leaves no discernible residue, eliminating the need for cleaning a p.c.b. after soldering.

Depending on the components being used extra care may need to be taken: some components are sensitive to excessive temperature and others to static charges. It may be necessary to use temperature-controlled soldering irons and match the melting-point of the solder to the application. Several companies make such irons. One example is the 4710 soldering station made by Teleproduction tools. This uses a 100W element fitted into a lightweight pencil iron and offers a very fast heat recovery cycle. It is continuously variable between 100 and 400°C and is equally suitable for fine p.c.b. work as well as large solder tabs and other components which represent a considerable heatsink. The Stir-on 4710 has no moving parts: spiking or magnetic effects and leakage is negligible. It is completely safe for use on mos-fets and other 'sensitive' components. It has a range of 14 iron-clad tips from a 0.8mm conical tip to a 5mm screwdriver for heavy-duty soldering.

A number of suppliers offer static protection materials. When working with c-mos devices it is necessary to use conductive, earthed work surfaces, tools and packaging. The environment should be as static-free as possible. This involves, for example, not using nylon carpets. The operators should wear non-synthetic work-clothes to avoid generating static and should be provided with earthed wrist straps to conduct away any static that may have been generated. For the safety and comfort of the operator it is also necessary to provide extractor fans to remove the fumes generated by burning flux. Hand assembly can be partially automated by the provision of workstations which have, for example, rotating component trays to present the user with the next component or lights to indicate the container of the component to be inserted. This is often combined with a projection system which will focus an indicator light onto the position on the p.c.b. where the component is to be inserted. Such systems vary in complexity and are usually computer controlled.

DESOLDERING

Hand processes are often used in the reworking and repair of defective p.c.bs, which may have been hand or mass assembled. The joint is remelted with an iron and the solder extracted by suction. Often a iron with a hollow bit connected to a vacuum line and a solder-collecting reservoir is used for solder removal. Antex have produced an iron with a spring-loaded hollow bit which is pushed onto the joint and sucks the solder as it is withdrawn. There are of course also spring-loaded hand solder suckers and the capillary action of a woven braid of fine tinned copper wire. Other methods involve the use of shaped iron bits which can heat joints at the same time for the removal of integrated circuits, for example. It is also possible to obtain semi-automatic machines which are provided with heated solder baths small enough and shaped to reheat just the pins of

Multicore GS60 solder has added 0.17% copper to reduce drossing. Here used in a Zevatron wave machine.

Fry's Metals have been manufacturing solder for 75 years. They invented the wave soldering process and have developed a number of new fluxes for use in wave machines. Their low-dross solder, Super LDC, has a minimum of trace elements, but a new solder, as yet unnamed has been developed which ads to the high purity a special finishing process which provides a highly polished finish and keeps oxidation to a minimum. This will add to their ranges of solders, fluxes, solder creams and pastes.

one multi-joint component. In a single process the defective component can be replaced. The p.c.b. is positioned so that the component's leads can be immersed in the bath. A lever action brings the solder bath up to the component which can be withdrawn while its leads are immersed; a replacement is inserted and the bath removed, leaving the replacement in position and soldered.

SOLDERABILITY

Satisfactory wetting of a solder joint can only be obtained when the surfaces are completely free of oxide and foreign matter. Acid fluxes are available which are capable of cleaning the surfaces during the soldering operation itself, but the residues from these fluxes are usually highly corrosive. Electronic assemblies are especially vulnerable to this corrosion, and in our industry, nearly all soldering work involves the use of mild rosin fluxes of limited cleaning power. Therefore it is essential that the surfaces to be soldered are carefully selected and treated.

Clean copper is a highly solderable metal but oxidation films tarnish the surface and begin to form on copper immediately after cleaning, and these films are not easily removed by weak rosin fluxes. The copper tracks of a circuit board are therefore protected by a solderable coating during subsequent storage and handling. The soldering coat may also act as an etch resist during the manufacture of the p.c.b.

Solderable coating fall into two main categories: those that are wetted by the solder but not completely dissolved; and coatings that are displaced or dissolved by the molten solder at normal soldering temperatures (250° to 260°C). The first category usually implies the use of gold or silver plated onto the tracks. The plated layers need to be thick (and expensive) and gold/tin alloys form brittle joints with poor bond strength. Similarly thick silver deposits can lead to silver migration in the presence of moisture and direct current.

Thus the majority of solderable coatings fall into the second category and are dissolved or displaced by the solder. Rosin lacquers are widely used in the production of p.c.bs for domestic electronics. They offer protection for a few weeks. However, the lacquers are permeable to the atmosphere and allow oxidation of the underlying copper.

Thin precious metal coatings are dissolved by the solder. Silver coatings are prone to sulphide tarnishing which impairs its solderability and can be given a gold flash. This is turn is porous and so offers only a limited protection against tarnishing. It has a similar effect when used directly on the copper, and only prevents oxidation for a short period.

Good solderability and electrical contact properties are obtained from a tin/nickel coating with a gold flash covering, but the most convenient and widely used is thick pure tin or a tin/lead coating which has the same composition and properties as the solder to be used (60% Sn to 40% Pb). These coatings provide the best surface finish and retain solderability for long periods under good storage, i.e. clean and dry conditions.

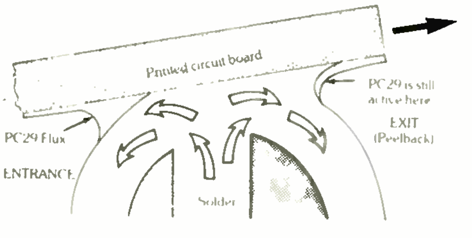
A reflow and curing oven for surface-mounted devices. Four heating zones can vary the heating cycle profile. – Zevatron GB, Dover.

There are several methods of applying such a coating. Hot methods involve dipping or roller tinning the p.c.b. but probably the most consistent, offering a uniform layer with longer protection (measured in years), is offered by electroplating. The advantages of hot coating and electroplating can be combined by the reflow soldering of electroplated coatings. This technique is often combined with the production of the p.c.b. tracks. The electroplated tin/lead coatings are widely used as etch resists. When the bare copper is removed by etching, the deposit then acts as a solderable coating. The fusing of the coating onto the tracks offers a number of advantages: A firm metallurgical bond is formed between the copper track and the tin/lead deposit; it leaves a bright, smooth surface which increases the shelf-life of the board; it reveals any soldering faults, and the shape and quality of the etched tracks; it covers the edges of tracks left bare by the etching process.

The same considerations apply to the solderability of component terminations which are to joined to the p.c.b. or indeed to each other. Tinned copper wires have the same characteristics as the copper on the board, but it must be stressed that the coating must be of sufficient thickness to retain solderability. Hot-dipped wire often displays very uneven coating when examined closely. When brass terminals are plated directly with tin/lead or tin coatings, zinc will diffuse rapidly to the surface of the coating and form zinc oxides which cannot be removed by rosin fluxes. It is therefore necessary that a barrier layer of matt copper or nickel is used as an undercoat to the coating. Kovar is a nickel-iron-colbalt alloy used in glass-to-metal seals and shows poor solderability and is difficult to clean chemically. It is often necessary to electroplate the Kovar with nickel to improve the adhesion of the solder.

Testing for solderability is by rotary-dip, which measures the time taken to give complete wetting of a surface. Round wires are dipped into a globule of molten solder and the time taken for the globule to join round the wire is measured. Another test is the area covered by a given quantity of solder over a surface. A wetting balance measures the force of the surface tension against the buoyancy of a component or wire immersed in molten solder. Visual inspection is also necessary. Tests should be carried out on p.c.bs and components before commencing a production run.

How wave soldering works.



WAVE SOLDERING

A wave soldering machine transports a p.c.b across a 'wave' of solder, produced by pumping molten solder up through a slot across the path of the feed and above the level of the surrounding solder bath. This forms a moving sheet of liquid solder. Machines vary in minor details; differences are mainly in the wave shape and size. For example, the provision of a deep wave for soldering extra-long terminations on boards, such as back-plane wire-wrapping pins. Other refinements include the injection of oil into the wave or onto the surface to improve wetting by the solder and eliminate solder dross. Oil injection has also been shown to reduce solder bridging as has the use of an inclined conveyor which assists the drainage of solder back down the circuit board.

Component leads can be formed or bent to anchor them to their locating holes but for economic reasons this is often omitted. Straight leads plugged into the board have a tendency to float while passing through the wave and this can lead to complete displacement of the component. Pressure pads or rollers can be applied to the upper, component, side of the board to prevent this. Re-useable, heat-resistant jigs can also be used to hold the components in their correct positions. Another solution is provided by passing the board with long, uncut leads over a deep wax wave. The projecting leads can then be cut by tungsten carbide slitting discs. The wax is melted off in an oven and the assembly is wave soldered. This process is an alternative to a double solder wave where the long leads are soldered, then cut and resoldered to cover the cut wires.

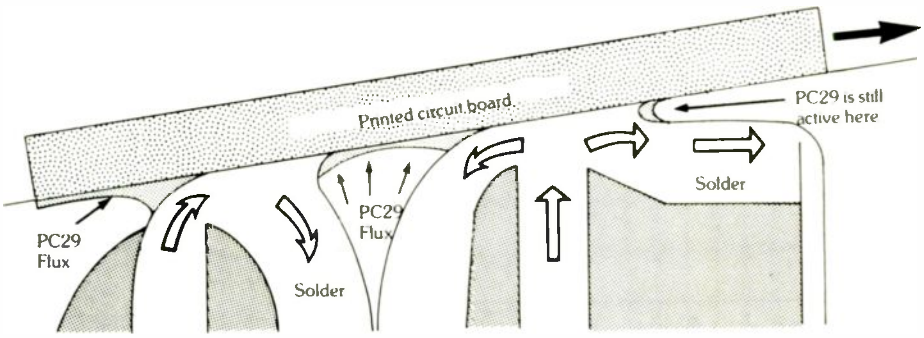
One recurring problem in some wave soldering processes is the formation of 'icicles' or stalactites of solder running down from the pins, which could cause short circuits. These can be removed by the use of a hot air jet or 'knife' to blow off the excess solder immediately after the soldering wave.

A new low-cost, compact wave soldering system for p.c.b. assembly comes from Hollis Europe. Prices for the new Europa machine, which is manufactured in the UK, start from as little as £4,000. This low price means that it is possible to buy a full wave soldering system for a cost typically associated with the less effective jet-wave soldering systems on the market. The cost of a new Europa is similar to that of many second hand machines currently available. The Europa features an ergonomically designed front panel to simplify operator control and monitoring while also being equipped with an efficient wave. In addition there is an oil-intermix capability that enables a user to select either dry soldering or oil-intermix operation if required.

The totally self-contained machine can fit either a customer-supplied bench or a rugged cabinet designed by Hollis for the purpose. The machine is designed to handle a maximum p.c.b. width of 305mm and features adjustable conveyor speeds from zero to 3m/min with a full Z-wave configuration and optional quartz pre-heaters. Either a pallet style (carrier type) conveyor or palletless (finger type) adjustable-width conveyor is available. All the conveyors are inclined to achieve optimum soldering results. Fluxing is carried out using a corrosion resistant polyethylene foam flux. The standing head of foam is adjustable to a maximum height of 15.9mm using either a rosin-based or water soluble foamable flux. Flux density control is an option. The wave is about 65mm wide to allow for longer component lead immersion at faster soldering speeds. The maximum wave depth is 12.77mm. The Europa is able to accept a dual-wave option if surface mount wave soldering is required. Hollis Europe is the UK offshoot of a US parent: Hollis Automation. They have set up a manufacturing and marketing centre in Chatham, Kent.

The best performance for wave-soldered p.c.bs is obtained when attention is paid to the design of the board itself. Studies have shown that the land and conductor geometry and size, and the pad shape and orientation with respect to the soldering direction can all have an effect on the quality of the product.

Some components not previously considered for wave soldering can now be assembled in this way. For example, leadless chip capacitors can be attached to the non-component side of a p.c.b. by heat-resistant adhesive. The solder-coated end pads can then be wave soldered to the board.



A double wave is used to solder s.m.cs.

There are areas of the board that do not require soldering and these can be protected by solder-resistant coatings or films. These help to reduce the percentage of defects and the solder consumption. Du Pont have recently announced a range of 'Vacrel' dry film solder masks. There are a number of solder resist films that can be cured by ultraviolet light.

REFLOW SOLDERING

Reflow soldering is the process of fusion of preplaced solder which may be printed on as a cream or paste, hot dipped onto the surface, or applied as an electroplated coating. The procedures can be applied to individual joints as well as being used for mass soldering a complete p.c.b.

The commonest forms of heating for this process are: immersion in a hot fluid, radiant, electrical conduction or induction heating. One of the widely used systems is the liquid which is usually a proprietary mixture of oils and waxes, or glycols and glycerols. To avoid thermal shock the board is preheated in a warm bath before the reflowing by brief immersion in the hot fluid. The trend is towards fully automated conveyorized systems. The other system most often used is heating provided by infrared radiation. The heating often takes place in an enclosed chamber or oven in an inert atmosphere which reduces oxidation and can remove the need for flux. Vapour phase soldering (also called condensation soldering) is a similar system which uses the vapour of a boiling heat-transfer organic fluid condensing on the surface of an electronic assembly containing solder preforms in such a manner that the heat from the condensing fluid melts the solder. The fluids are typically fluorinated compounds which boil at 20 or 30°C above the fusion point of tin/lead solder. Montedison UK produces the Galden range of perfluorpolyether fluids with boiling points between 165° and 265°C which in addition to their use in soldering can also be used for curing polymers and resins, and for thermal shock testing. The vapours from these fluids are inert and non-flammable.

SURFACE-MOUNTED COMPONENTS

Surface mounting offers the highest component density on a p.c.b. The components are designed to be as small as possible and consequently the leads are thin and offer very little surface area for soldering. Unlike through-hole boards, the solder joint must also provide the mechanical anchor to hold the component on to the board. The methods have already been described; wave and vapour-phase soldering are used. There are additional techniques to ensure that the joints are successful. In wave soldering, closely spaced s.m.cs may mask each other in the solder wave so some joints may be inadequately soldered; jets or two successive waves of different velocity/shape are used to overcome this. It is also necessary to control the stand-off, or gap beneath the component to allow solder to fill the joint space. This can be done by including stand-off bumps on the component.

Vapour-phase and infrared reflow processes use solder pastes or creams and it is possible to include, for example small glass spheres in the cream to ensure stand-off Surface tension of good solderable joints will pull the leads of a chip carrier on to the connecting pads, but leadless resistors and capacitors with only two connectors can suffer from lifting or twisting if the ends have different solderability. The non-metal body of the component is often glued to the board with a heat-resistant adhesive before soldering.

The major component of solder is tin and soldering is the principle use of tin. The International Tin Research Institute, in Uxbridge, Middlesex is therefore very interested in solder and has undertaken many research projects.

Our thanks are due to the Institute for the information included in this survey, and to the manufacturers who have sent us details of their products. Particularly Multicore whose Soldering Manual was a useful source of information.

Antex (Electronics) Ltd, Mayflower House, Armada Way, Plymouth, Devon PL1 1JX. Tel: 0752 667377
Hollis Europe, 109 Hopewell Drive, Chatham, Kent ME5 7NP. Tel: 0634 404677
Du Pont (UK) Ltd, 105 Wigmore Street, London W1H 0EL. Tel: 01-408 6362
Montedison UK Ltd, 7-8 Lygon Place, Edbury Street, London SW1W 0JR. Tel: 01-730 3405
Multicore Solders Ltd, Wood Lane End, Hemel Hampstead, Herts HP2 4RQ. Tel: 0442 233233
Fry's Metals Ltd, Tandem Works, Merton Abbey, London SW19 2PD. Tel: 01-648 7020
Zevatron GB Ltd, 1/3 Waterloo Crescent, Dover, Kent CT16 1LA

Soldering equipment will be featured in our New Products columns next month

Toroidal transformers

Low profile, low cost and efficiency make the toroid an attractive alternative to conventional transformer cores

TERRY MONAGHAN

Over recent years there has been a large increase in the production of toroidal transformers at the expense of laminated types. Toroidal cores have always been ideal for use in instrument transformers because of their superior magnetic characteristics, but they were not widely used for power transformers mainly because of the high cost of the finished product.

With the modern toroidal winding machines and materials currently available it is possible to produce high-quality toroidal transformers at a low cost. Not only has the price differential between toroidal and laminated transformers narrowed over the last few years, but in many cases it is possible to produce toroidal transformers for a lower cost than the laminated equivalent. However, cost is not the only criterion used when choosing a transformer: there are certain physical advantages to be gained from choosing a toroidal.

THE HISTORICAL ASPECT

In 1831 Michael Faraday invented the transformer. For his prototype Faraday wound the coils on a soft iron ring or toroid, as it provided a continuous magnetic circuit with a uniform cross sectional area per magnetic length.

There were several drawbacks with the construction of Faraday's ring transformer for practical a.c. use, including eddy current

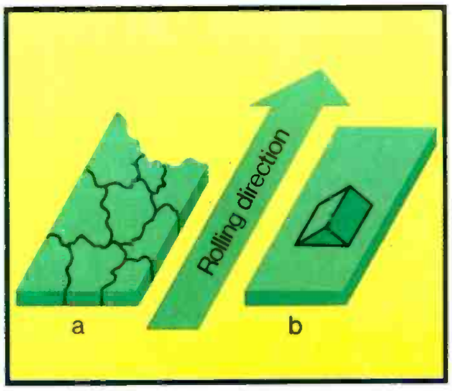


Fig.1(a). The steel sheet consists of grains which are joined together and arranged in a random manner. At (b), the grains are divided into small, cube-shaped domains less than a millimetre wide. The iron crystals are easiest to magnetize along the edge of the cube (domain axis). In g.o.s.s., most of the crystals align in the direction of rolling and act as one large crystal. In the unmagnetized condition, the crystals are magnetized in random directions, when an external magnetic field is applied the domain axes are brought in line to reinforce the field, making the flux far more intense.

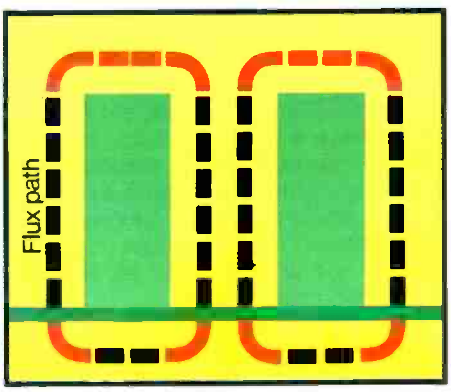


Fig.2. Flux path in E and I laminations. (Flux across the grain in red.) Approximately 40% of the flux is against the grain. As the magnetic properties of g.o.s.s. used across the grain are inferior to lower grade steels, flux censities as low as 1.3T are required to prevent high iron losses.

problems associated with a solid core. The shape of the core did not readily allow the use of mechanical winding techniques and the insulating materials (calico and twine) were not only bulky but were also hygroscopic and had to be impregnated.

To overcome the problems associated with high iron losses due to eddy currents, transformer cores were constructed from thin steel laminations, each insulated from one another. Initially, low-carbon steels were used; these not only suffered from high losses but they were also prone to ageing, (their magnetic properties deteriorated with time).

During the early 1900s silicon steel (4% silicon) was developed, which had certain improved magnetic characteristics and overcame the problem of ageing. Although iron losses decreased with increased silicon content, permeability and ductility also decreased, the latter causing problems with the punching out of laminations.

Further improvements were made to silicon steel's magnetic properties during the 1930s by cold rolling the sheets. As a result of the cold rolling process the grains (individual metal crystals) align in the direction of rolling. The resultant grain-oriented silicon steel (g.o.s.s.) has increased working flux density, increased permeability and reduced losses. However, the improvements in magnetic characteristics in g.o.s.s. are only realised when the magnetic flux is in the preferred direction, along the aligned grains (Fig.1).

To allow the use of mechanized coil winding and to avoid undue stress on the winding wires (which were originally textile wrapped), coils were wound on preformed bobbins, which were only suitable for use with stacked laminations such as E and I constructions. Unfortunately E and I and similar core assemblies have many drawbacks. Approximately 40% of the flux is at 90° to the preferred direction, allowing the use of relatively low flux densities in the order of 1.3 tesla (Fig.2); a large percentage of the core is only used as a return path of the flux; the stacking factor (percentage of steel per cross sectional area) is difficult to control; and the air gaps in the construction lead both to high reluctance (magnetic resistance) and fringing flux, where the flux leakage causes stray e.m.fs to be developed in adjacent leads, p.c.b. tracks and components.

To overcome some of the drawbacks of such constructions as E and I stacked laminates the C core was developed. The C cores are wound around a rectangular mandrel from strip g.o.s.s. (steel ribbon formed by slitting g.o.s.s. along the grain). The core is then stress-relief annealed for several hours in a special atmosphere, lightly impregnated and then cut in two to form two C shaped cores (Fig.3). To ensure that air gaps are kept to a minimum, the cut surfaces are ground, lapped and sometimes finally etched to form good mating surfaces. Because the winding tension is carefully controlled to give a stacking factor of 95%, excessive noise due to loose laminations or high iron losses due to excessive winding tension can be avoided.

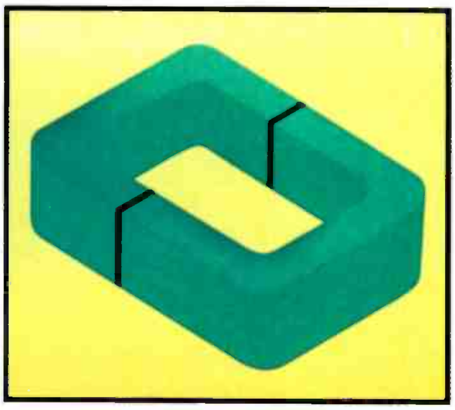
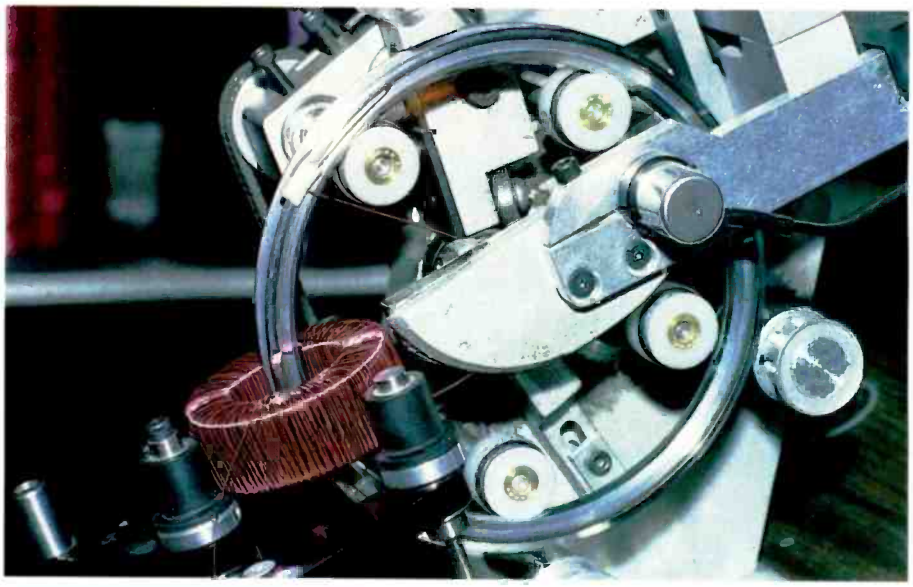
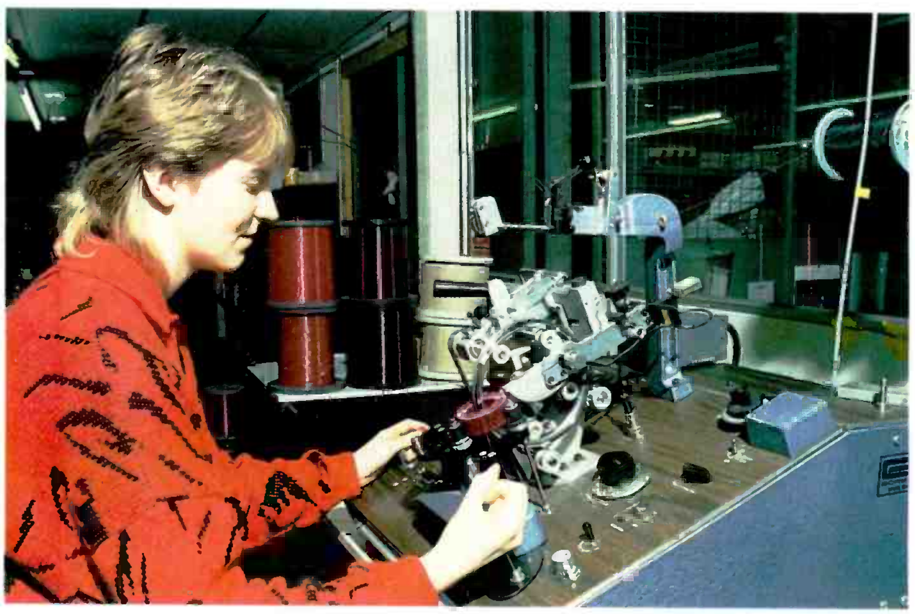


Fig.3. C Core. The C core allows the use of conventional bobbin winding and a performance that approaches that of a toroidal core. The finished transformer, however, is expensive to produce and magnetizing current is relatively high.

Fig.4. Random winding head. The use of random winding techniques allows the wires to be tightly packed, leading to more compact windings and better thermal conductivity than is offered by layer winding.

Fig.5. Winding machine. The winding process is labour intensive and dependent on the skills of trained operators.





The C core allows the use of conventional coil winding with a performance that approaches that of a toroidal core. However, the introduction of air gaps and bonding strains lead to higher magnetizing currents, and to a lesser extent higher iron losses than are achieved using toroidal cores. Because of the high labour content involved in producing the cores, the resultant high price rules out the use of C cores in all but very specialized applications.

The introduction of high-quality insulating materials has allowed a return to the toroidal core. Modern winding wires have polyster or polyurethane enamels which are extremely tough, flexible, high thermally rated and have excellent electrical properties. Not only is it possible to use random winding techniques, thus allowing more turns per square metre (Fig.4), but it is no longer necessary to impregnate coils to render insulation humidity resistant or to improve on thermal conductivity between turns.

Interwinding insulation based on polymeric materials is also tough, has high thermal and electrical properties and can easily be applied to the coils. Insulating

All you need to know about

TOROIDAL TRANSFORMERS

Why Avel? Ask any professional in this highly specialized business. When it comes to packaging power, we're the UK company with all the answers! We've supplied industrial leaders year in, year out, for over 30 years. Our experience is in a class of its own.

You want to know about our Toroidals? Right. They're made from high grade materials and conform to international standards. You are guaranteed: Low Profile; Low Weight; Low Radiated Field.

Primary voltage 120 + 120 for series or parallel connection. 50/60 Hz. Fixing Kit supplied with each Transformer. Types available in ratings from 15 to 1200 VA.

Any more questions? Just ask Avel!

ASK AVEL

LARGE STOCKS AVAILABLE OFF THE SHELF

AVEL-LINDBERG LTD

Arisdale Avenue, South Ockendon, Essex RM15 5TD England

0708 853444

ENTER 74 ON REPLY CARD

materials such as polyester film do not require impregnation and are readily available in tape form.

CONSTRUCTION OF TOROIDAL TRANSFORMERS

Toroidal core production is similar to C core production, except a circular mandrel is used; also, there is no need to fully bond and cut the core. If extremely low acoustic noise is required it is sometimes necessary to lightly bond the edges of the core to help damp any acoustic noise due to magnetostriction (the windings also help damp mechanical noise). The stress-relieved core is then covered with an insulating material such as expoxy or plastic to allow the use of direct winding. The finished core can be tested at this stage, and if it is not subjected to any undue knocks, it will retain its qualities through subsequent processes.

It was the introduction of high-speed toroidal winding machines (Fig.5) that helped reduce the labour costs involved in toroidal winding. Toroidal core winding is more dependent on the skill of the individual operator than conventional bobbin winding; the operator determines the correct winding tension, core rotation pitch and ensures the winding wires are not damaged in any way. The winding process is a mystery to most people until they see the operation, (after which some are still none the wiser). The winding process utilizes a ring-shaped shuttle which can be split to allow the core to be threaded on to it. The shuttle is first filled with the correct length of wire, the wire is then off-loaded on to the core whilst the core is rotated at the correct pitch to ensure complete core revolutions for the number of turns. Depending on the final application of the transformer, various winding techniques can be employed: for example, low stray field or low voltage between adjacent turns may be required. It is important that the correct quality of winding wire is used, as the winding speed is high and the wire follows a tortuous path.

When the correct number of turns has been wound onto the core, the shuttle is again split and the wound core removed.

Layers of interwinding and final insulation are applied on similar machines. Polyester films (Melinex, Mylar) have replaced cotton and other fabric tapes in most modern designs. They have a working temperature of 130°C, are extremely tough and have excellent electrical properties. For higher working temperatures, Nomex tape is used. With three layers of polyester film between primary and secondary windings, breakdown voltages in excess of 4kV are easily achievable as long as care is taken to avoid gaps in the insulation.

The finished transformers are suitable for use in most environments, but for high-humidity conditions, the transformers can be totally potted or varnish impregnated. Copper screening tape (consisting of copper strip encased in a Mylar envelope), is applied using the same machine (Fig.6).

Fig.6. Copper screening tape applied by machine as well as polyester film, is applied by machine in one operation.

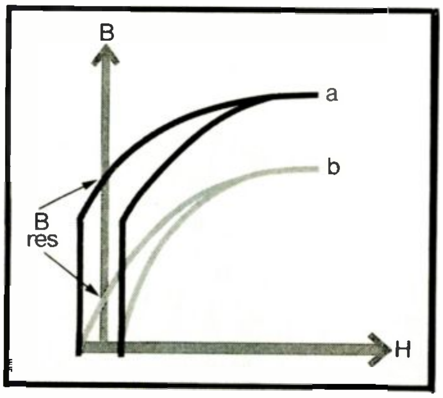


Fig.7. Effect of air gap. As air gap increases, residual flux (B_{res}) decreases: (a) without air gap; (b) with air gap. A high level of residual flux can result in momentary saturation (with resultant high inrush current) if energized in the same direction.

ADVANTAGES OF TOROIDS

It is easier to control the magnetic characteristics and the stacking factor of a toroidal core than it is for a conventional stacked core, which is assembled after coil winding. A low stacking factor would not only lead to mechanical vibration, but it could also lead to there being an insufficient cross sectional area of steel, causing increased flux density. A high stacking factor, on the other hand, would cause a mechanical stress on the material, which would not only lead to increased iron losses, but permeability would decrease and magnetizing current would increase. Because all of the g.o.s.s. is in the preferred direction it is possible to take full advantage of the material. Toroidal cores are usually run at the top of the knee on the B/H curve (1.6 to 1.7T) whereas laminated cores are usually run at 1.3T to avoid high iron losses. By referring to the transformer equation, $E = 4.44\hat{B}ANf$ (where E = induced voltage, $\hat{B}$ is peak flux density in tesla, N is number of turns and f is frequency in Hz), it can be shown that less turns per volt are required when operating a given cross-sectional area, A, at increased flux density. By using 1.6T as opposed to 1.3T, large savings can be made in the amount of copper used, leading not ony to large cost savings, but also space savings and reduced copper losses.

The missing air gap gives a lower-reluctance magnetic circuit than is possible using conventional and C cores, so that the magnetizing current tends to be extremely low on toroidal transformers. Iron losses also tend to low — typically 1.1W/kg, again due to the g.o.s.s. being used in the preferred direction.

As the windings are spread evenly over the entire core, the effective surface area for dissipating heat generated by copper losses is large. High current densities can be used to take full advantage of the insulating materials used. For a temperature rise of 60-70°C, a current density of 5A/mm^2 is used on low-power transformers and 3A/mm^2 on high-power transformers (although in many applications low regulation or low temperature rise is required).

Due to the virtual absence of fringing flux, stray field tends to be much lower on toroidal transformers than conventional and C core types, and by wrapping layers of g.o.s.s. around the circumference, stray flux can be further reduced.

Single-hole fixing simplifies mounting, (toroidal transformers are usually supplied with a mounting kit). The transformers can also be supplied with threaded inserts, studs and mounting frames.

The use of high flux and current densities accounts for toroidal transformers being approximately half the weight and volume of conventional transformers.

DISADVANTAGES

The missing air gap leads to a square hysteresis loop, which means that if the supply were to be removed when the flux is high, the core would be left with a high level of residual flux (Fig.7). If the core were energized in the same direction the core would saturate, causing a high current transient limited only by the primary impedance. By using anti-surge fuses (or soft-start circuitry on very large transformers) the high inrush current ceases to be a problem.

On a very distorted supply or if half-wave rectification is used, the core can become polarized and saturated in one direction. By using a symmetrical waveform in inverter designs, or by using full-wave rectification, the problem of core polarization is avoided.

APPLICATIONS

Toroidal transformers are very popular for use in low-profile equipment, such as racked audio systems. Another popular application for toroidal transformers is in tungsten halogen lighting, where both the efficiency and the shape of the transformer are prerequisites.

As it appears to be the norm to leave the transformer as one of the last components to be specified, the reduced volume of the toroid is the only option to be pursued in cases of very limited space.

The efficiency of toroidal transformers is extremely high, typically 90% at 120VA rising to 95% at higher powers, making them particularly useful in invertor applications.

Other applications include: 100V line systems, where good frequency response is required; use in monitors or preamplifiers where stray field is critical; use in medical equipment where high isolation is required and in any application where weight is to be kept to a minimum.

Terry Monaghan is a director of ILP Electronics Ltd, Canterbury.

Wide-range absolute-value circuit

Full-wave rectifier offers design trade-offs of its 75dB dynamic range and 20kHz bandwidth.

T.J. WILMSHURST

Many circuits to full-wave rectify or find the 'absolute value' of a signal have significant limitations in terms of signal amplitude or frequency. Especially critical in the design of precision rectifiers is the handling of low-amplitude signals, when the rectifying property of a diode is not directly available, and the provision of adequate bandwidth to accommodate the extended harmonics that may arise due to the rectification.

The circuits discussed recently in this journal and elsewhere (refs 1,2 and 3) have wide dynamic range at frequencies up to 1kHz and extended frequency response for largish input amplitudes. Their performance progressively deteriorates for smaller signal amplitudes (10mV) at higher frequencies.

The circuit described here was developed to operate over a bandwidth up to 20kHz, with peak-to-peak signal amplitudes of 4mV to 24V, a dynamic range of 75dB. Some trade-off between bandwidth and dynamic range exists, however, and component values can be modified to optimize performance over other operating conditions.

The design is based on the conditional inverter circuit of Fig.1, which inverts if the switch is closed, and buffers if it is open.

Alternatively, if the switch is solid-state with a finite on and off resistance,

$$\frac{V_0 R_2}{R_1+R_2}+\frac{V_1 R_1}{R_1+R_2}=\frac{V_1 R_s}{R_3+R_s}$$

and if $R_1=R_2$

$$V_0=V_1\left(\frac{2R_s}{R_3+R_s}-1\right) \qquad (1)$$

Normally R_s(on) is a few tens of ohms, R_s(off) is very high indeed, and it should be possible to choose a value for R_3 to give $V_0 = \pm V_1$. In this case however R_s(on) will be significant compared to R_3 (which must be kept low), so that with the switch on $|V_0|<|V|$ (slightly). A parallel resistor is added to modify R_s(off) so that a slight (and equal) attentuation also occurs with the switch open.

A further complication arises from the non-ideal behaviour of solid-state switches. When the control input changes state a

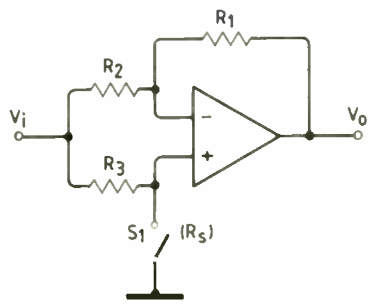
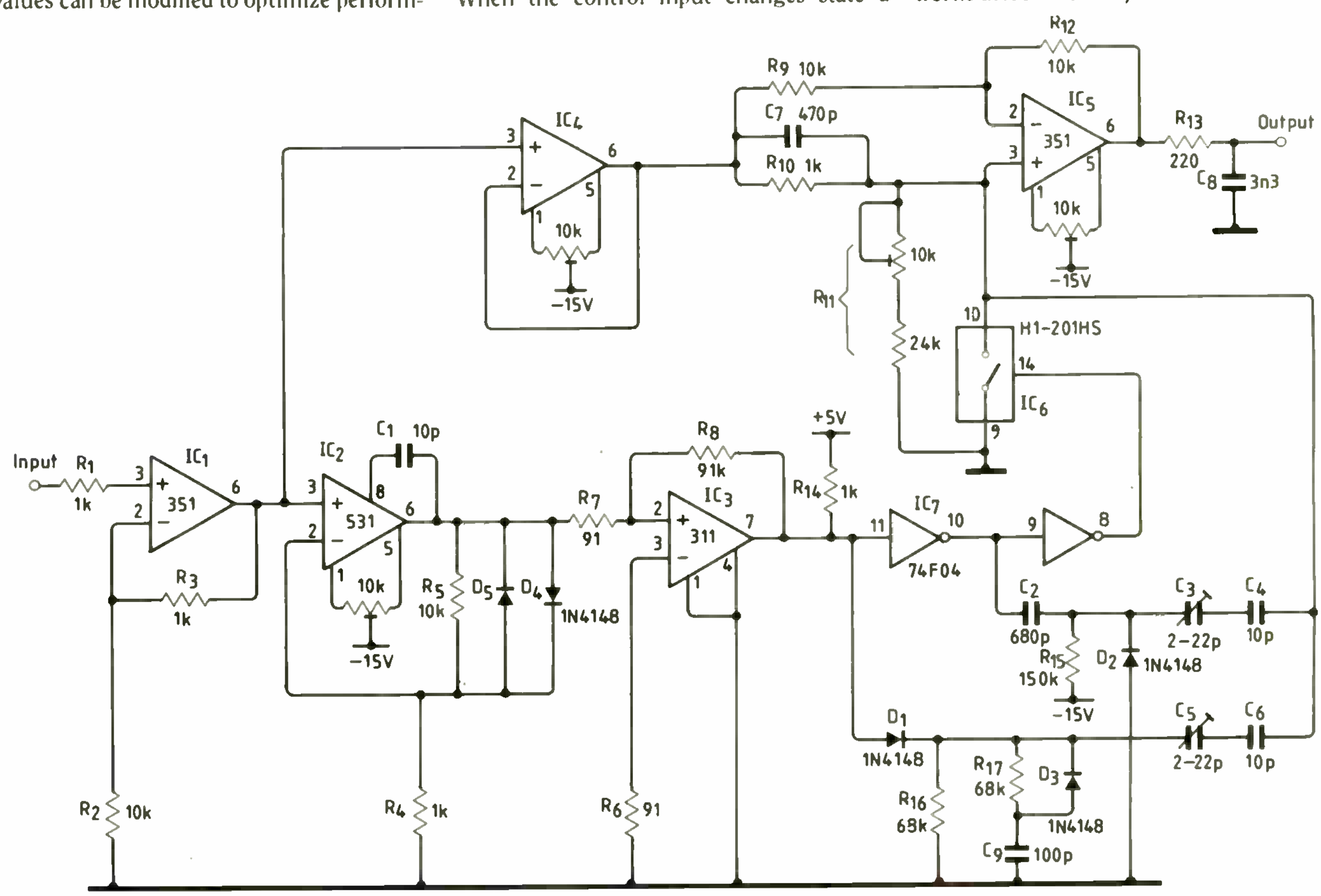


Fig.1. A 'conditional inverter' circuit inverts when S_1 is closed, and buffers when open. For unity inverting gain $R_1=R_2$, R_3 is non-critical.

Fig.2. Absolute value circuit in which ICs 5 and 6 form a 'conditional inverter', with polarity detection performed by ICs 2 and 3. Charge injection compensation is provided via the resistor-capacitor-diode networks driven from IC_7.



small charge is injected into the analogue circuit (due to the capacitive coupling between the two), and manifests itself as a voltage spike or step (depending on the associated circuitry) superposed on the analogue signal. If specified at all, the manufacturer either quotes the charge injected itself (ΔQ), or the voltage step (ΔV) induced in a specified load capacitance (C_L), where

$$\Delta Q = C_L \times \Delta V.$$

For the best complementary m.o.s. switches, $\Delta Q=10$pC, giving for a load capacitance of 10pF, a spike of 1V! And other switches will be far worse.

Three techniques available to alleviate this problem are used here, each contributing toward its reduction. These are minimization of source impedance, low-pass filtering (usually possible because spike widths are very narrow), and charge cancelling. In the latter a charge equal and opposite to that induced by the switch is simultaneously introduced into the appropriate node. The switch used (a Harris HI-201HS, obtainable from RR Electronics) is a low charge injection type, typically with $\Delta Q=10$pC.

In the final design (Fig.2) the conditional inverter is formed by op-amp IC_5 and switch IC_6. Polarity is determined by comparator IC_3, configured with a smaller amount of hysteresis, and preceded by a non-linear amplifier which provides necessary boost for low-level signals. The source impedance to the switch is effectively R_{10} in parallel with C_7. R_{10} is selected under the triple constraint of providing low source impedance (to allow rapid discharge of the injection charge), being large compared with R_s(on), and providing a sufficently high load resistance for IC_4 when the switch is on. With the value chosen the 351 is on the verge of current limiting for maximum negative-going voltage amplitudes. Substituting now into equation 1 for the switch-on, $R_s(on)=30\Omega$Y, gives

$$\frac{V_0}{V_I}=\frac{2\times 30}{1k+30}-1=-0.94$$

and to find R_{11} with the switch off:

$$\frac{V_0}{V_I}=0.94=\frac{2R_{11}}{1k+R_{11}}-1$$

$$R_{11}\approx 32k\Omega.$$

The small amount of gain introduced at IC_1 compensates for this attenuation.

With the HI-201HS the charge injection was negative for both transitions of switch control input, so each had to be cancelled by a positive charge packet, the compensating transition coinciding precisely with the one to be cancelled. Cancelling is obtained with the pulse-shaping networks associated with IC_7. The rising edges of the waveforms (Fig.3) provide the cancellation, in each case the decay occurring when the switch is closed, so that no coupling of this part of the waveform into the signal takes place. Cancellation is optimized by the adjustment of C_3 and C_5. Residual spikes are further attenuated by the R_{13}-C_8 filter section. Having a 3dB point at around 220kHz, this meets the circuit bandwidth requirement described in the first paragraph.

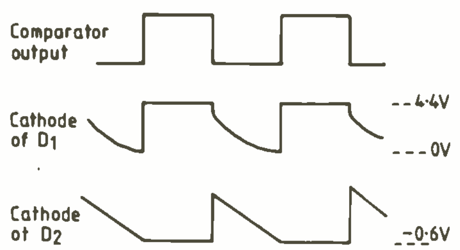


Fig.3. Waveforms that provide charge cancelling. Lower two waveforms are capacitatively coupled to the solid-state switch, the rising edges cancelling the charge induced by the switch. The decaying part of the waveform has no effect on the main signal as it occurs when the switch is closed, and the node in question effectively earthed.

RESULTS

The circuit as described has been constructed and tested using several samples of the HI-201HS switches. Some difference between these was found, but a reduction of charge injection to less than 1mV at output was obtainable. The circuit continues to operate with inputs of less than 1mV pk-pk, although here the charge injection, as well as distortion introduced by the comparator hysteresis and charge-cancelling circuits, renders the output of little use.

Four millivolts was reckoned to be the smallest input voltage leading to acceptable levels of output distortion, although this must depend on application. Frequency-dependent components, such as those governing decay time in the charge-cancelling circuits and those of the output filter, have been selected for the 20kHz bandwidth. If some increase in minimum signal amplitude is acceptable the bandwidth may be extended, bearing in mind also that the maximum output amplitude will not be available at higher frequencies.

References

1. Antoniou, 1974, Design of precision rectifiers using operational amplifiers. *Proc.IEE*, vol.121, no.10p.1041-1044.
2. Lewis, March 1986, Level-translating full-wave rectifiers. *WW* p.22-24.
3. Barker and Hart, June 1986, Transistor full-wave rectifier circuits. *WW* p.29.
4. Siliconix 1980, Analog Switches and their Applications.

T.J. Wilmshurst, M.Sc., M.I.E.E., is technical officer at the University of Cambridge engineering department.

Brunel given Siemens v.l.s.i. design tool

A v.l.s.i. design system recently donated to Brunel University provides graduate and post-graduate students with state-of-the-art facilities for education and research on current integrated circuit design techniques. The Venus system, developed by Siemens and already installed at numerous facilities within Siemens AG as well as at 18 German universities, is claimed to be the most extensive system available in Europe. The gift is a 7·530 mainframe computer with BS 2000 operating system, disc file storage, graphic workstations and various software from Siemens. It is of vital importance, according to Brunel's electrical engineering and electronics department, because funding of higher education being what it is, universities often have to make use of yesterday's technology, and it is through the generosity of such firms as Siemens and earnings from research contracts that it is possible to keep abreast of the latest facilities, say Brunel.

The gift goes beyond the provision of basic hardware and software, because the University will now be able to have designs manufactured on the 1.5-μm c-mos process and then have the chips returned to the researchers for evaluation. "These facilities are basic to modern electronic engineering" commented Prof. Gerald Musgrave, head of Brunel's department of electrical engineering and electronics and a director of Siemens Ltd, "as basic as having the latest microprocessor components, and play an essential role in the training of engineers for the next quinquennium".

Implementation of custom-designed circuit functions directly onto a v.l.s.i. chip has become of interest because of the sometimes costly programming associated with standard microprocessors, explained Dr E. Hoerbst, head of Siemens Venus project, and the combined advantages of higher processing speed, shorter development times, reduced component-count and improved design security all add to make application-specific circuits attractive.

It was to meet the shortage of trained circuit design specialists conversant with the use of c.a.d. tools that Siemens established the Venus design centres, said Prof. Schwaertzel, head of Siemens i.t. research, enabling industry-oriented design to be introduced into teaching courses and research programmes. Siemens is already manufacturing circuits designed by these universities on its Munich production lines.

The individual design steps for which c.a.d. support exists are development, simulation, construction, testing and the preparation of fabrication and test data. Development support begins with the logic synthesis, when a particular mathematical function is synthesized from basic logic elements, but the most vital part of c.a.d. support is the use of simulation to replace the costly and time-consuming testing of prototypes. Simulators and models are available for each level of chip design and there are tools for design analysis and evaluation at each level as well as the data-base holding the documentation – all necessary to ensure design security.

Conversion into a layout for the particular 'technology' employed is accomplished by cad-based chip construction procedures that place and route prefabricated or computer-generated circuit components; then a 'testability' analysis shows to what extent the subsequently produced v.l.s.i. chip has to be tested to guarantee fault-free working. The cad system provides fabrication test data ready to be passed on to the silicon foundry.

SATELLITE SYSTEMS

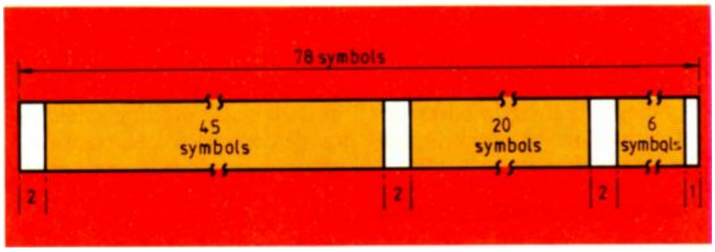
TOM IVALL

Bookie-MAC

The B-MAC television transmission system, as well as being used for satellite signal distribution in Australian broadcasting (December 1986 issue, p.65) is now appearing in a quite different role in the UK. Through a transponder of an Intelsat V comsat, it is sending live, private television coverage, including sound and teletext, of horse races and other betting-related events to thousands of betting shops throughout the country. The idea, of course, is to provide the punters in these shops with immediate information on which to base their bets. By the end of 1987 at least half of Britain's 10,000 betting shops are expected to be fitted up with the necessary t.v.r.o. receiving and display equipment.

B-MAC has been chosen for signal transmission because it was specifically designed to combine the advantages of the multiplexed analogue components (MAC) principle with means of encryption, scrambling and individual addressing of receivers. It was originally developed, in fact, for such private service use in a scrambled pay-tv system. British Telecom are supplying the satellite network, claimed to be the largest private one in Europe. For the signal transmission part they have chosen B-MAC equipment made by Digital Video Systems (now owned by Scientific Atlanta), who developed the B-MAC system in the first place. The hardware and software will be used to deliver a scrambled vision signal plus six separately addressed audio channels and a data channel for the teletext.

The whole network, valued at £70 million with £26 million going to BT, was ordered by a new company called Satellite Information Services Ltd (SIS). This is 45% owned by the big four UK betting groups, namely Ladbrokes, Coral, William Hill and Mecca, while the remaining 55% of the equity is held by the Racecourse Association, the Horse Totaliser Board and a number of independent directors. The system arrangement specified by the four betting groups was for a common television picture of an event but with an individual sound commentary from each group to be sent exclusively to the betting shops belonging to that group.



The private vision and sound signals from events are sent via BT's existing outside broadcast vision network to the Telecom Tower in London and from there to a nearby control centre operated by SIS Ltd. Here the programme material is edited and packaged for its recipients. The edited signals – vision, sound and data – then pass from the SIS control centre back to the Telecom Tower, which relays them via dedicated links to BTI's London Teleport in the docklands. At this earth station, an earth terminal transmits the encoded B-MAC signals to the Intelsat V comsat, in geostationary orbit at 27.5° W. Then the leased full transponder in the satellite broadcasts the signals to t.v.r.o. earth stations at betting shops throughout the country.

Each earth station has a 1.3-m receiving dish, an external frequency downconverter (jargon term 'low-noise block' or l.n.b.), a receiver, a B-MAC decoder with de-scrambling and decryption, and picture display equipment. Various display options are available, ranging from one tv screen with full sound and teletext services up to 12 screens continuously showing pictures or teletext with means for punters to select teletext pages not already on display.

The B-MAC system uses the same principle of time division multiplexing of time-compressed vision signal luminance and chrominance (analogue *Y*, *U* and *V*) as other MAC sytems. It is also similar to other MAC systems in the general sense of using the remaining time in the tv waveform to transmit digital data. This data carries digital audio and other information such as teletext and system control signals. But the B-MAC system differs, first in the way it organizes the digital data and secondly because it scrambles the vision part of the signal and encrypts the data in order to prevent unauthorised reception.

The time division multiplexer works in sample increments of about 47ns duration (1365 of them making up one tv line of the 625-line standard). In one B-MAC line, 750 samples are allocated to the luminance components and 375 samples to the chrominance component. These are separated by a transition period of six samples. The remaining 234 samples are allocated to data symbols (see below). Each data symbol is three sample periods in duration, making 78 symbols (234/3) in a 625 tv line. The instantaneous symbol rate is 455 + line frequency, or 7.11 Msymbols/s, and the average rate is 1.22 Msymbols/s.

Six digital audio channels and a clock reference burst (for recovering system clocks at the receiver) are transmitted during the line blanking interval of the television waveform. The time available, 11 μs in the 625-line waveform, is occupied by 78 symbols, as mentioned above. Each symbol is in fact a pair of bits in a four-level system. As shown in Fig.1, 20 symbols are reserved for the clock reference burst, which is generated as two-level data and consists of 10 cycles of 277.5 + line frequency. The average level of this reference burst defines zero chrominance level. The remainder of the time is filled with data proper and four short separation periods.

Dolby Deltalink encoders supply the digital audio data. Each audio channel contributes 13 samples and one control bit during a line period. The function of the control bit alternates from line to line, between step size and de-emphasis control. Two error concealment bits are added for each channel and a parity bit protects the six error concealment bits in each data stream. Two bits remain in each data stream and these are used to provide a utility data channel (RS-232 standard). The audio data may be reassigned to an auxiliary data port.

Teletext data is transmitted during the field (vertical) blanking interval – a period of 25 lines plus 1 line blanking interval in the 625-line standard. This available time is organized into packets, each of which contains 377 symbols and is allocated to a particular function. For example, teletext packets are transmitted on five tv lines (9 to 13) of the field. The other line periods are occupied by packets of data for clock recovery and synchronizing at the receiver, for system control purposes and for individual user data. This last-mentioned is addressed to individual receivers and used for sending them keys for de-scrambling.

Pictures are scrambled by varying the duration of the line blanking interval, in a random sequence of blanking times determined by the programme originator. This causes the tv lines to be randomly displaced in time. As there is no line sync information on a B-MAC tv line, an unauthorized receiver cannot easily restore the original line timing. To achieve maximum privacy the scrambling pattern is varied randomly and non-repetitively. The B-MAC encoder generates a scrambling pattern based on an arbitrary number called a 'seed', and a new, unpredictable seed is produced by a random number generator every 0.25 second. For de-scrambling at the receiver this seed is transmitted to it as data during the field blanking interval as mentioned above.

A similar principle is used for encrypting the digital audio and teletext data. The encryption process is determined by an algorithm, and this algorithm is based on an arbitrary number 'seed' which is changed randomly. Again, the seed, and hence the algorithm, is changed every 0.25 second. And, as with the vision scrambling, the seed is transmitted to the receiver as data during the field blanking interval and used there for decryption to recover the original digital audio and teletext.

Finally, to prevent technically

sophisticated pirates from breaking into this whole system, the seed numbers (and the rest of the sytem data) are themselves encrypted. This is done by a process similar to that used in the audio and teletext encryption, with an arbitrary number determining the encryption algorithm. The arbitrary number is known as the key, but is not fixed, as it could be discovered and revealed. So the key is changed by human choice at any time or frequency decided by the programme originator. He enters a new arbitrary number on a keyboard connected to the encoder. The changed key is distributed to all receivers by sending it to their decoders, one at a time, in data packets individually addressed.

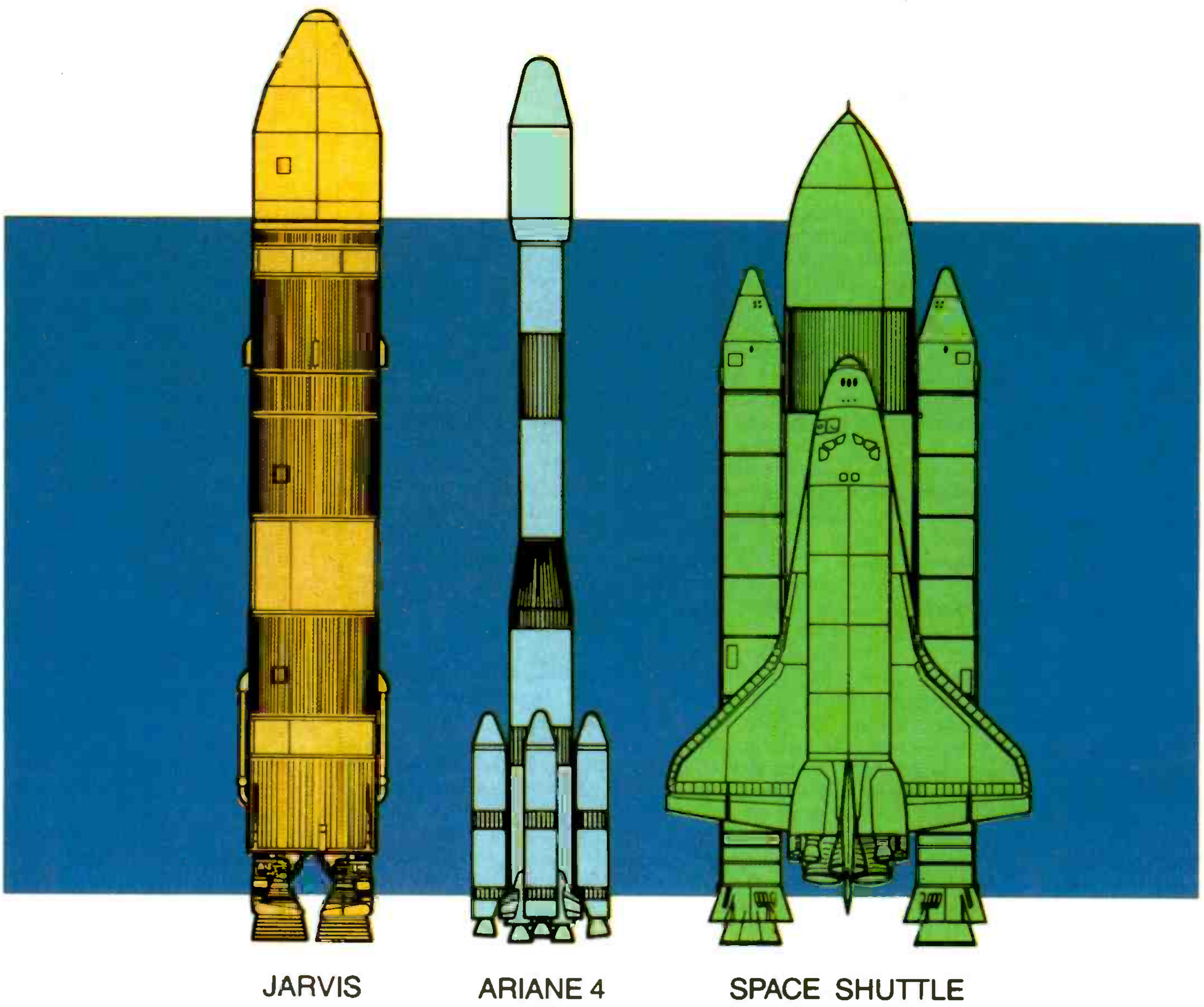
Rescue system consolidated

About 600 people have been rescued from marine, aeronautical and other accidents with the aid of an international satellite system operating since 1982. Called COSPAS-SARSAT, it uses low-altitude polar orbiting satellites to detect and locate transmissions from rescue beacons operating on the 121.5-MHz and 406-MHz allocated frequencies. As the earth revolves on its own axis the spacecraft, moving in their longitudinal paths, progressively scan the whole surface for beacons. A typical spacecraft altitude is 870km.

The system was founded by Canada, France, the USA and the USSR. Other participants are Bulgaria, Finland, Denmark, Norway and the UK. Now its organization is being strengthened by an administrative base and secretariat provided by INMARSAT at its London headquarters. This is making available technical, conference, administrative and international liaison services.

COSPAS is an acronym derived from the Russian words

The proposed satellite launcher on the left, compared in size with two current vehicles, is intended to place satellites in orbit at about half the price per kilogram of payload of that necessary with existing boosters. It would be capable of putting up several spacecraft on the same flight, to go into different orbits. Six Navstar satellites for the Global Positioning System could be launched together. Named after Gregory Jarvis, the Hughes engineer killed in the Challenger shuttle disaster, this expendable vehicle proposal is the subject of a study contract being undertaken jointly by Hughes and Boeing for the US Air Force. If it were constructed, Boeing would build the first two (lower) stages, designed to separate three minutes into the launch, while Hughes would build the third stage carrying the satellites.



SATELLITE SYSTEMS

'search and rescue' and in fact the system includes a Soviet satellite, COSPAS-1, which was launched as Cosmos 1383 in 1982. Similarly, SARSAT is an acronym for 'search and rescue satellite' and refers to a NASA spacecraft of that name launched in 1983. Also contributed by the USA is the services of the NOAA-9 weather satellite (of the National Oceanographic and Atmospheric Administration) launched in 1984. As well as transmitting weather pictures and other meteorological information, this spacecraft carries electronic equipment specifically for the rescue system.

Incidentally, INMARSAT recently increased its membership to 48 countries when Indonesia joined the organization late last year. Sea and air transport are particularly important to this country, geographically a group of islands.

Coming launches

After the loss of NASA's Challenger space shuttle and ESA's Ariane flight V18, both in 1986, there has been something of a hiatus in new satellite launchings while NASA and ESA investigate the causes of these disasters. It seems likely that Arianespace will be the first to start moving again, with a provisional schedule of launches for the ESA. Their flight V19, planned for February 1987, is intended to be an Ariane 3 launcher, carrying an ECS-4 comsat and the third multi-purpose satellite, K3, for the Australian Aussat system described last month. Alternatively Aussat-K3 could go up on flight V22 in July of the same year.

The next Arianespace flight, V20 in April 1987, is intended to launch Europe's first d.b.s. spacecraft, the West German TV-Sat 1. This is similar in technical design to the French TDF-1 d.b. satellite, which is also scheduled for a 1987 launch, in September on V24 or in November on V25, now that the French government has given its official go-ahead. A new meteorological satellite, Meteosat P2, is planned for launch in June by the latest ESA vehicle, Ariane 4.

NASA plans to resume space shuttle launches in February 1988, after a two-year gap. Ths US government has asked them not to take on any more commercial or foreign payloads except those designed specifically for the shuttle or those necessary to US national security or foreign policy.

So for about seven years after the resumption of operations, 41% of shuttle launches will be American military satellites, 47% will be for NASA's own activities – mainly scientific spacecraft – and the small remainder for commercial, foreign government and US government civil space projects. The first mission, flight 26 planned for 18 February 1988, will be to launch a tracking, data and relay satellite that will form part of NASA's own operational system for putting up spacecraft.

But from past experience of delays and accidents, all these dates and arrangements should be taken as highly provisional.

Launching satellites as a business activity is no longer confined to the nations of the West. The USSR with its Proton rocket and China with its Long March vehicle are also competing in this field. For example, there is an agreement for China's Long March 3 rocket to launch a comsat called Pan Am Pacific 1 in 1988. This spacecraft is owned by the American company Pan Am Pacific Satellite Corporation and is actually the Westar 6 satellite which went into a wrong orbit in 1984 and was later brought back by the space shuttle. Direct broadcast satellites owned by the US firm Dominion Satellites are also due to be launched by Long March rockets.

Space pioneer retires

Thirty years after Sputnik-1 startled the world, the space business has now existed long enought for a person to grow old in. One such person is Dr Fred P. Adler, who is on the point of retiring from the Hughes Aircraft Company. Dr Adler was head of a division in this company which developed Syncom, the first synchronous communications satellite. In 1963 Syncom II made history by providing a telephone link between the American president John F. Kennedy and the Nigerian prime minister Abubakar Balewa. This Hughes division also developed Early Bird, also known as Intelsat-1, which was the first commercial comsat. In operational service from the mid-1960s, it had a capacity of 240 telephone circuits or one television channel and kept going for four years.

Dr Adler's division also developed the unmanned Surveyor spacecraft, which performed five successful landings on the moon. In later years he became well known in the UK as president of the consortium which built NADGE, a computerised air defence system for NATO.

Following the death of Howard Hughes, who had become an eccentric recluse, the Hughes Aircraft Company went through a very complicated period as far as its ownership and financial affairs were concerned. But this major satellite manufacturer has now settled down as part of GM Hughes Electronic Corporation, a wholly-owned subsidiary of General Motors. It was bought by GM in December 1985.

Shoe-box size ship terminal

A cheap, compact earth terminal about the size of a shoe-box is likely to be available for use on ships some time during 1988. Intended for low-speed (600 bit/s) satellite data communications, it has been designed by engineers at INMARSAT (the International Maritime Satellite Organization) and will be undergoing trials in 1987. The prototype measures 12 × 8½ × 5 inches, including the antenna, and weighs only 6 kg (13 lb). Production models will be packaged for mounting on a mast or on the superstructure of a vessel.

INMARSAT sees this satellite system as an attractive alternative to standard h.f. marine communications. Estimated to cost the customer about £3500 – a sixth of the price of many existing ship terminals – the equipment is expected to find a market among the world's 175,000 or so commercial vessels and two million pleasure craft. Land mobile communications is another possible application to be tried out in 1987.

Signals are received and transmitted by a quad helix omni-directional, non-stabilized antenna. For reception (at 1.6 GHz) this has a minimum G/T of –24 dB/K. After amplification and demodulation the signals are decoded to the ASCII data transmission code and sent via a memory to the data terminal. Transmission, at 1.5 GHz, takes place through a 20W r.f. power amplifier.

A synthesizer tunes the transmitter and receiver in 5kHz steps. The equipment is controlled by a microprocessor – Motorola 68000 in the prototype – and integrated front ends and decoder chip sets are said to be under development by component manufcturers. Data transmission rate is actually 1200 bit/s to give bit-for-bit redundancy.

REED BUSINESS PUBLISHING

From February 1, 1987 Business Press International assume a new name – Reed Business Publishing Ltd. The new style is more descriptive of the Group's activities than the somewhat impersonal BPI.

RBP's range of publications is extremely comprehensive, covering such diverse interests as pub catering, classic cars, poultry and airlines, the most comprehensive category being in our own sector of electrical and electronics journals, and those devoted to computing. There are six publications on computing (*Practical Computing*, *Computer Weekly*, for example) and thirteen on electronics and electrical engineering; among them *Electronics Weekly*, the new *Semiconductor*, *Nuclear Engineering* and *Electrical Review*.

RBP is Britain's leading publisher of 'business-to-business' journals.

Mains equipment control

Following the recent article on signalling over over the mains wiring system, the author goes on to show how, with the use of the LM1893 and a microprocessor, remote control is achieved.

NIGEL GARDNER

Signalling over the mains wiring system was discussed in the October 1986 edition of *Electronics and Wireless World*. An enhancement of this concept is to the control of equipment and appliances via the same medium.

The system described uses the LM1893 Biline circuit for modulating and demodulating the mains-borne carrier, and together with a COP402 microprocessor handling all the handshake and signalling protocols, proves to be a very efficient package. The system comprises a master controller with a 1200 baud RS232 interface to the controlling computer and a number of slave modules distributed along the mains under its control (see Fig.1). Each slave unit has four input lines, four output lines and four i/o lines, the latter being programmed from the controlling word sent from the master unit.

MASTER

The master unit (Fig.2) is based around two main circuits. The first of these is the LM1893 carrier current transceiver and the second is a COP402 4-bit microprocessor. The software for the COP μP is implemented in a 27C16 eprom and incorporates all the necessary timing and handshaking functions needed to ensure a very low transmission-error rate. An interface to the host system is provided in the form of a conventional RS232 interface running at 1200 baud. This baud rate can be changed by anyone having a good understanding of COP μP software. A low-cost solution for generating the negative supply needed for the RS232 interface is provided by IC_6, an LM555 timer. The latch, IC_3, is needed to access data from the eprom, as multiplexed address and data lines are used by the COP.

SLAVE

The slave unit (Fig.3) is also based on the LM1893, COP402 and 27C16. Additional components are a +5V regulator and a DS3658 display driver. This latter device is capable of driving loads up to 600mA per output, but other driver circuits could be employed. As previously mentioned, there are 12 interface lines on the slave unit. The four inputs and four outputs are fixed in their function, but the four remaining lines can be defined as either input or output from commands sent from the master unit. Each slave unit has an address capacity from 00 to FF hex, giving a maximum number of 256 possibilities. Modification to the software can result in larger slave address capabilities and even grouping of subsections.

CONSTRUCTION

The construction of these circuits is straight forward enough. However, care must be taken around the mains section of the board and also when handling the c-mos circuits. Tuning up the circuits will require an oscilloscope to ensure correct adjustment and should take place before the COP is inserted into the board and with the two mains isolation capacitors removed.

The easiest way is as follows.

1) With the supply connected, attach a frequency meter or oscilloscope to pin 10 of IC_1 and adjust RO_2 to give a frequency of 125kHz.

2) Connect the oscilloscope to the output side of the isolation transformer – remembering to have removed the two isolation capacitors – and tune the output to a maximum.

3) Connect a jumper between the data-in pin, pin 17 of IC_1, and the 0V supply and observe the level change on the oscilloscope.

4) Adjust the tuning of T_1 to give equal amplitudes when the jumper is connected to 0V or floating.

5) Disconnect the power, remove the oscilloscope and jumpers, insert the COPs and replace the isolation capacitors.

Repeat the procedure for each subsequent slave unit to be aligned ensuring exactly the same trequency is set each time.

SYSTEM OPERATION

The master unit can be connected to either a v.d.u. style terminal or a microcomputer to enable correct operation. On power-up of the master unit, a ">" prompt will be displayed on the screen. This indicates that the master has correctly powered up. The next set of information you have to enter into your terminal is a control sequence of

TABLE 1

COMMAND	BIT/PORT ADDRESS	DESCRIPTION
W	0	1 BIT G0 OUTPUT
W	1	1 BIT G1 OUTPUT
W	2	1 BIT G2 OUTPUT
W	3	1 BIT G3 OUTPUT
R	0	1 BIT G0 INPUT
R	1	1 BIT G1 INPUT
R	2	1 BIT G2 INPUT
R	3	1 BIT G3 INPUT
W	7	4 BIT D OUTPUT
R	5	4 BIT IN INPUT
W	4	4 BIT G OUTPUT
R	4	4 BIT G INPUT
W	6	8 BIT D, G OUTPUT
R	6	8 BIT IN, G INPUT

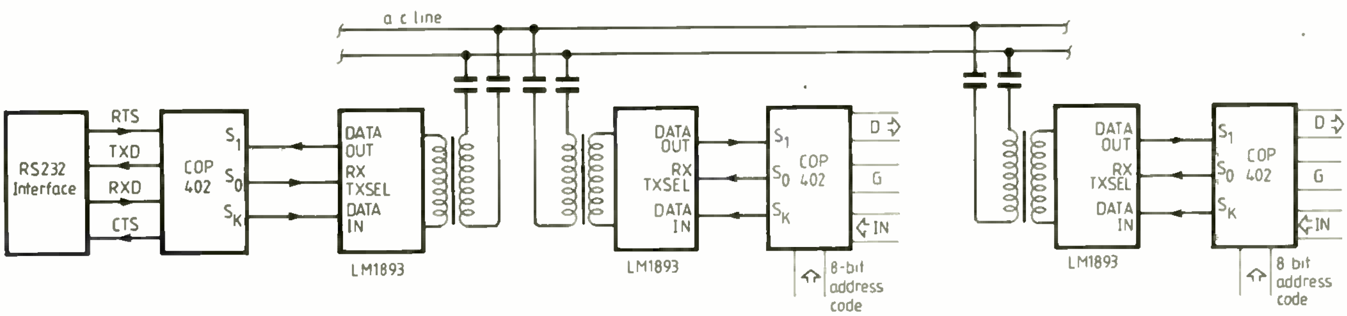


Fig.1 Block diagram of control system, showing master and two slaves.

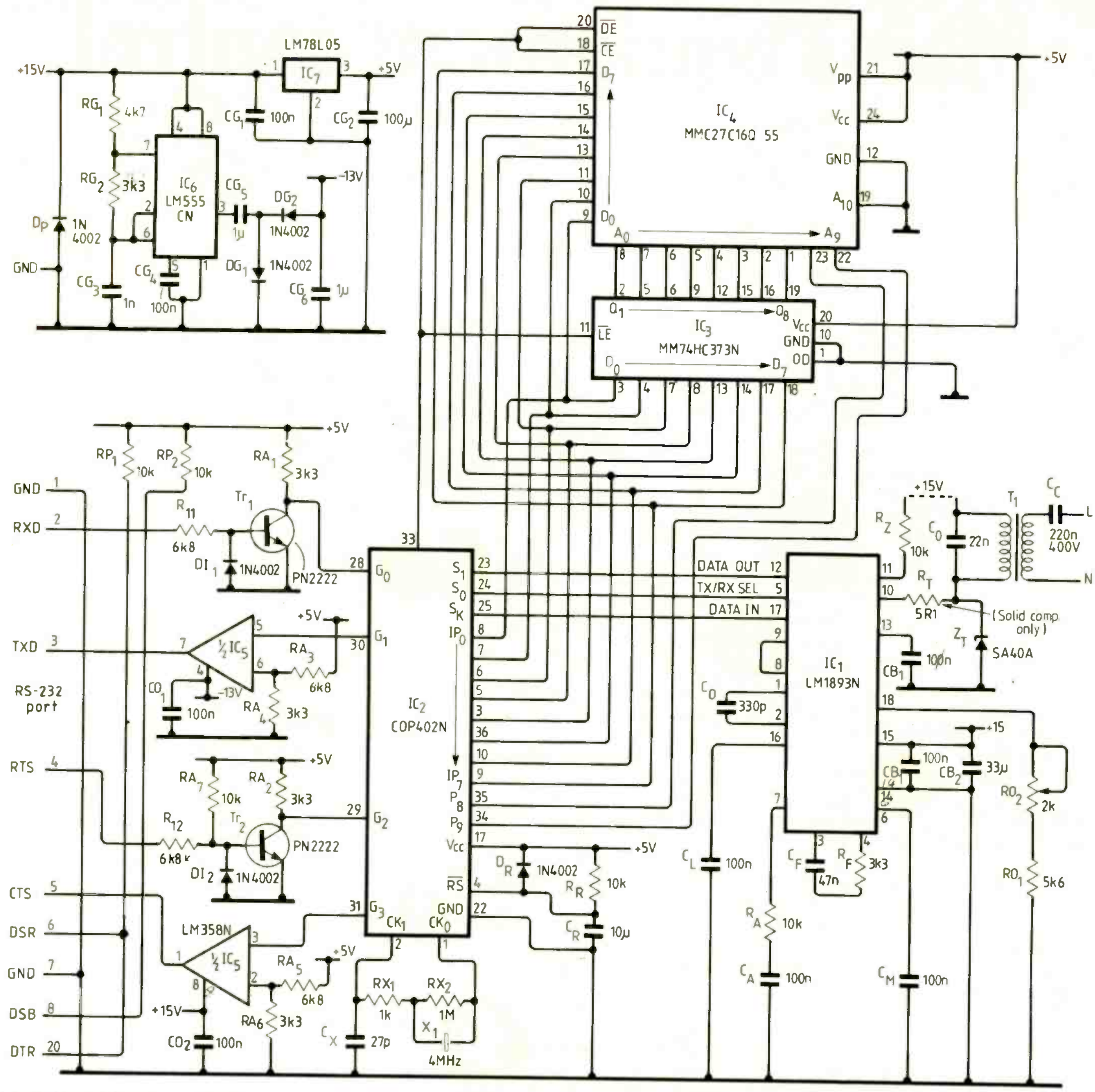
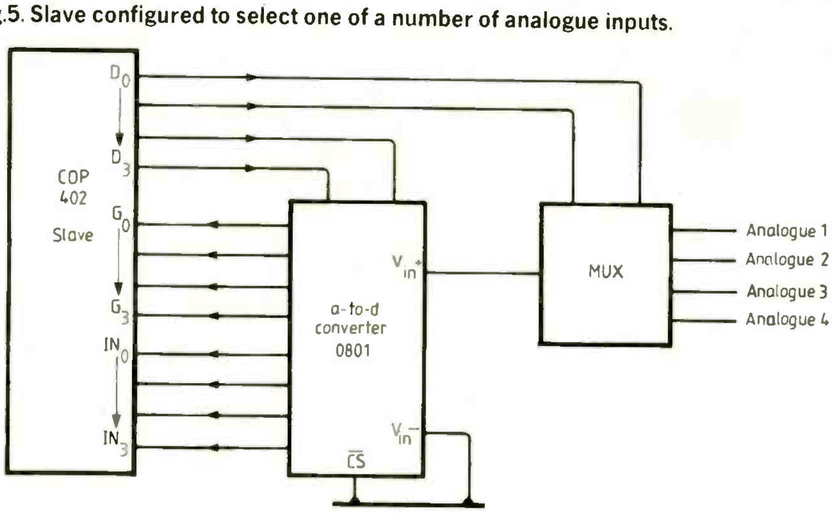


Fig.2. Circuit diagram of master unit.

Fig.5. Slave configured to select one of a number of analogue inputs.



characters, which is broken down as follows:

> command bit
(R/W)
[1 ASCII]
bit/port address
(0-7)
[1 ASCII]
data
(00-FFH)
[2 ASCII]
slave address
(00-FFH)
[2 ASCII]
CR
[1ASCII]

If, after transmission, a "?" prompt is returned, this indicates that the slave unit has been disconnected, the incorrect slave address was selected or an incorrect sequence was entered into the master unit. If the ">" prompt is returned, this indicates

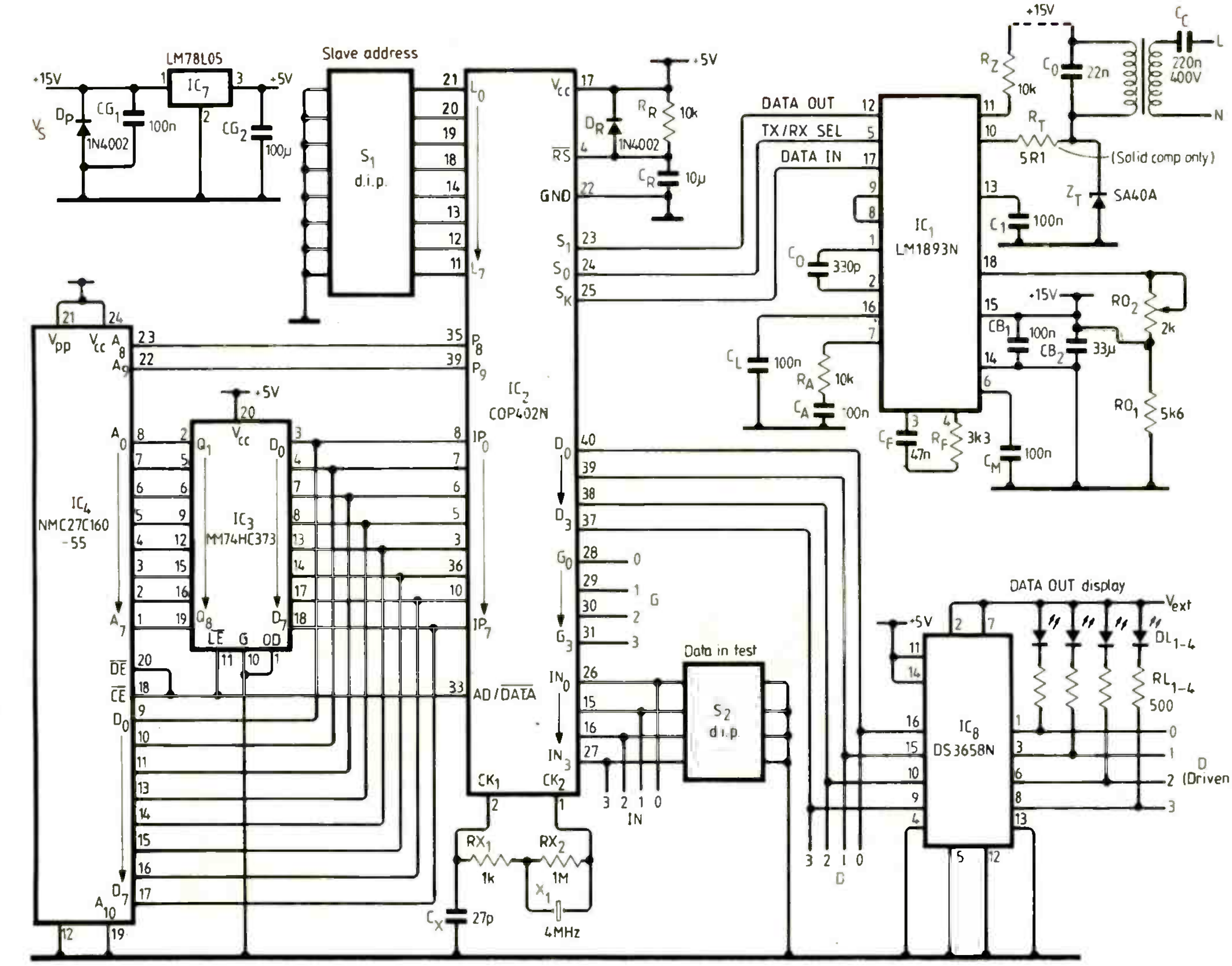


Fig.3. Circuit of a slave unit.

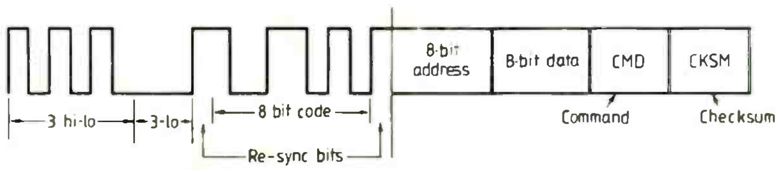


Fig.4. Transmission protocol from master to slaves.

correct reception at the slave unit addressed. Examples of typical messages are shown below:

W 1 01 56 (CR)

This changes the logic level of the G1 line on slave number 56 to logic 1.

R 5 00 E7 (CR)

This will read the logic inputs of the 4-bit input port of the slave addressed E7 and display them on the screen.

A further explanation of these commands and bit/port addresses is shown in Table 1. The command format sent along the mains is shown in Fig.4 and is made up of 3 high-to-low transitions, 3 low and 8 re-sync. bits. This preamble sets up the LM1893 in a mode ready to receive the important data which follows. The remaining data string is made up from 8 address, 8 data, a command byte and finally a checksum to ensure all data is in order. This format for the data-transmission string has proved to be the most efficient and least error free.

APPLICATIONS

Some suggested examples of the uses for this type of system are in the domestic and industrial lighting control environment where the output lines from the slave COP could drive opto-isolated triacs as outstations of an energy management installation; remote data-acquisition and control within a building for closed-loop heating systems and security monitoring in large premises.

An example of one of these applications is shown in Fig.5. The slave can be used to monitor analogue inputs selected by the multiplexer, fed to the ADC0801 a-to-d converter and then presented to the COP 402 input ports. The four output lines are used to control the multiplexer and hence select the input channel. If a slave module is required to have an analogue output, then Fig.6 might be the simplest solution. The slave provides eight lines to drive the d-to-a converter; the remaining four input lines can be given the function of digital feedback, if the analogue output is used in a servo application, or inputs from the limit switches.

Another application actually using the original version of these modules is for temperature monitoring and control on some sections of pipeline in the frozen north of America, and has been in operation for a number of months.

An important point should be noted about the use of large numbers of units within close proximity. As with all tuned circuits, there is some minor variation in tuning and when all these mistuned networks are lumped in one place the narrow bandwidth originally desired becomes almost a broadband matching. There are ways around this by ensuring the slave units are distributed by about 10 feet of cable – no real problem for 90% of applications, but it could result in excessive loading of the signal if a number of slaves are located adjacent to each other.

An additional device has been introduced to help designers in the other 10% of application areas, where slave units will be in close proximity. An example of this type of

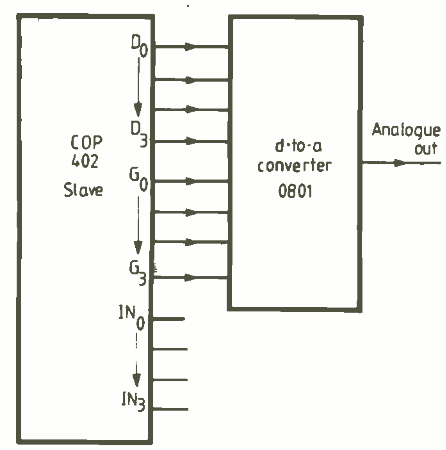
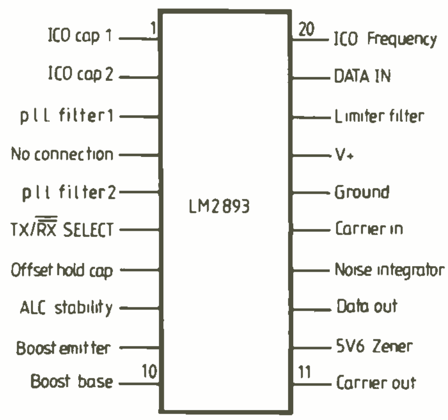


Fig.6. Analogue output from a slave.



Pinout for LM2893

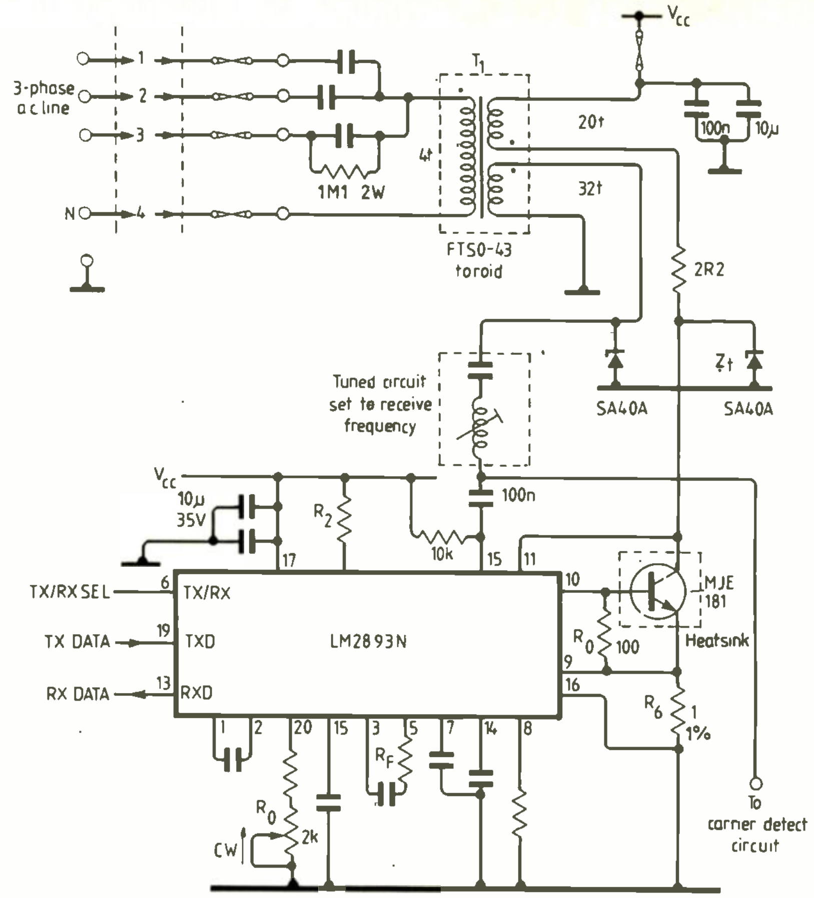


Fig.7. 'Last resort' method of avoiding trouble with groups of slaves, using the split-carrier mode of operation.

A software listing p.c.b. layouts are available, in return for a stamped and addressed envelope, from this office. Please mark your communication 'Mains control'.

One pair of master/slave eproms can be obtained from Nigel Gardner at 4 Magdalen Road, Warnborough, Swindon, Wilts. SN4 0BG. at an inclusive cost of £10.

application area is in electricity meters where a block of flats have all the units in the basement. In these areas, the LM2893 has the advantage over the LM1893 of having separate transmit and receive carrier paths. This enables the designer to use broadband matching for the transmit path and light loading in the receive direction, while still retaining narrow-band matching for greater noise immunity.

An application circuit for this type of interface is shown in Fig.7 and enables the same software to be used with the LM1893. The use of the LM2893 as a replacement to the LM1893 is only recommended as a last resort for those few percent of problem cases. The use of the LM2893 will add slightly to the cost due to the additional components required.

The use of these modules makes life a lot simpler for those who need an off-the-shelf solution for remote data-aquisition systems, where cabling is the major bugbear. This combination of low-cost microcontroller and a high-data-integrity modem working over the mains can form the basis of many remote measuring and control systems. The use within an office environment, for example, can reduce the cabling requirement to interface a selection of printers to a host of PCs. The software is well documented and allows the designer the maximum flexibility.

A software listing and p.c.b. layouts are available, in return for a stamped and addressed envelope, from this office. Please mark your communication 'Mains control'.

FILTERING

As the method of mains communications increases in popularity, there will come a limit to the number of independent systems which can be connected to the same mains feed. The obvious method of r.f. isolation is filtering, but conventional TT or T filtering circuits have to be physically large to cope with the mains currents.

This problem has now been solved by a non-invasive filter developed by Emlux Ltd, which can be clamped around the mains cable at the building entry point, without having to interrupt the supply. This filtering technique can also be used to enable neutral to earth communication to operate in addition to the normal Live-Neutral transmission path. This new filter is tunable to the operating frequency and will be a major advantage in simplifying the designer's task, when considering interference from adjacent co-channel systems.

BOOKS

Radio History Comes Alive The technical origins and development of broadcasting in this century make quite a romantic story, but not many of us know more than a few snippets of it. Of course it's all there in the learned society journals, but one would like to have it presented for more relaxing reading.

A new book has just been published which does this and more. "Radio! Radio!" by Jonathan Hill really covers the ground, from pre-Marconi times in the last century to the very end of the valve era in the 1960's. There are separate chapters for each decade from the 1920's onward detailing developments in broadcasting facilities, and in receiver design both technical and aesthetic. The author uses the "radio" of his title in the broader sense of broadcasting transmission and does not neglect television development, starting from Baird's first experiments in 1923.

What makes the book really special is the pictures. There are literally hundreds of photographs: some are of very early pre-broadcast equipment, but the great majority show domestic receivers from the "wirelesses" of the 1920's and on through each decade up to the 1960's.

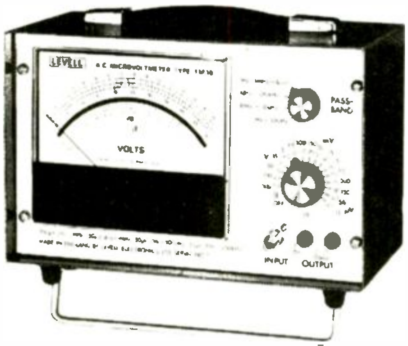
The book reflects the author's wide range of interests with well-researched technical history and good appreciation of the aesthetic aspects of receiver design. His talents as a photographer are evident; and he even writes well!

Such a well-produced work cannot be cheap, but you won't regret it if you give yourself an £18 treat. The publishers are Sunrise Press, 2-4 Brook Street, Bampton, Devon EX16 9LY. —DPL

LEVELL for INSTRUMENTS

ANALOGUE METERS

LEVELL AC MICROVOLTMETERS TM3A/B £159/179
16 ranges 15μVfs/500Vfs, accuracy 1% + 1%fs + 1μV − 20dB/ + 6dB scale. ±3dB 1Hz-3MHz. 150mVfs output. **TM3A:** 83mm scale. **TM3B:** 123mm scale and LF filter



LEVELL BROADBAND VOLTMETERS TM6A/B £249/279
16 LF ranges as TM3A/B + 8 HF ranges 1mVfs/3Vfs, accuracy 4% + 1%fs at 30MHz ±3dB 300kHz-400MHz.

LEVELL DC MICROVOLTMETER TM8 £135
28 linear ranges ±3μV/±300V and ±3pA/±300nA plus 2 log ranges for nulling. Output ±300mV at fs

LEVELL MULTITESTER TM11 £179
50μV/500Vfs ac, 50pA/500mAfs ac, 150μV 500Vfs dc, 150pA/500mAfs dc, 0.2Ω to 100GΩ, lin/log null Diode/LED test Optional RF, HV and Temperature

LEVELL TRANSISTOR TESTER TM12 £199
Transistor, diode and zener leakage to 0.5nA at 2V-150V Breakdown to 100V at 10μA, 100μA, 1mA Gain at 1μA-100mA Vsat and Vbe at 1mA 100mA

LEVELL INSULATION TESTER TM14 £210
Log scale covers 6 decades 10MΩ 10TΩ at 250V, 500V, 750V, 1kV, 1M 1TΩ at 25V 100V, 100k 100GΩ at 2 5V 10V, 10k 10GΩ at 1V Current 100pA 100μA

BENCH POWER SUPPLIES

THURLBY SINGLES PL154/310/320 £159/125/155
0.5" LED digit meters, acc 0.1%, resoln. 10mV, 1mA <0.01% change for 50% load change. Remote sense **154:** 0-15V 0-4A. **310:** 0-30V 0-1A. **320:** 0-30V 0-2A.

THURLBY DUALS PL310QMD/320QMD £269/339
Two 0-30V 0-1A (2A on 320) with isolated, series tracking, series or parallel modes of operation.

THURLBY TRIPLES PL310K/320K £275/345
310K: 0-30V at 0-1A, 0-30V at ½A & 4V-6V at 3½A. **320K:** 0-30V at 0-2A, 0-30V at 1A & 4V-6V at 7A.

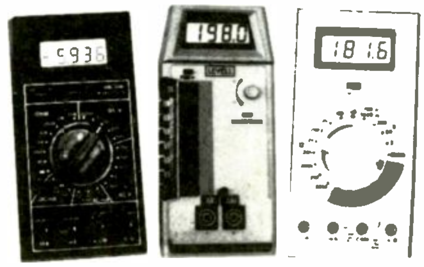
LEVELL DECADE BOXES

C410	: 10pF to 111, 110pF, acc 1%±2pF.	£49
R401/410	: 4 decs 1Ω or 10Ω steps, acc 1%, 2.5W	£49
R601/610	: 6 decs. 1Ω or 10Ω steps, acc 1%, 2.5W	£63
R601S	: 6 decades. 1Ω steps, acc 0.3%, 2.5W	£75
R701	: 7 decades. 1Ω steps, acc 1%, 2.5W	£72

DIGITAL METERS

LEVELL DIGITAL THERMOMETER DT1K £44
120°C/ + 820°C, acc 0.2%±1°C 3 digit 8 5mm LCD A standard Type K thermocouple socket is fitted Bead couple is supplied Battery life >3000 hrs

LEVELL DIGITAL CAPACITANCE METER 7705 £49
0 1pF 2000μF, acc 0 5% 3½ digit 12 7mm LCD



HC DIGITAL MULTIMETER HC4510 £69
4½ digit 11mm LCD Up to 1kVdc 750Vac, 10A 20MΩ Resoln. 10μV, 100nA, 10mΩ Buzzer dc V 0 05%

HC DIGITAL MULTIMETERS HC5040/5040T £37/39
3½ digit 12 7mm LCD Up to 1kVdc, 750Vac, 10A, 20MΩ Resolution 100μV, 100nA, 10mΩ (5040T: 100mΩ) Buzzer dcV 0 25% Battery life 2000hrs **5040T:** has a TR test

THURLBY DMMs 1503/1503HA/1504 £169/185/199
4¾ digit 9mm LCD Up to 1 2kVdc, 750Vac, 10A, 32MΩ, 4MHz. Resoln 10μV, 10nA, 10mΩ Mains battery **1503:** dcV 0 05% **1503HA:** 0.03% **1504:** True rms ac.

THURLBY INTELLIGENT MULTIMETER 1905a £349
5½ digit 13mm LED Up to 1 1kVdc, 750Vac, 5A, 21MΩ Resoln 1μV, 1nA, 1mΩ dcV 0.015% Computing and storage functions RS232/IEEE interface options

OTHER INSTRUMENTS AVAILABLE – FREE DELIVERY MAINLAND UK – QUANTITY DISCOUNTS – VAT EXTRA

LEVELL ELECTRONICS LTD. Moxon Street, Barnet, Herts., EN5 5SD, England
Telephone: 01-440 8686 & 01-449 5028

ENTER 37 ON REPLY CARD

Happy Memories

Part type	1 off	25–99	100 up
4164 150ns Not Texas	.95	.90	.87
41256 150ns	2.15	1.95	1.85
41464 150ns	3.35	2.99	2.79
2114 200ns Low Power	1.75	1.60	1.55
6116 150ns Low Power	1.40	1.25	1.20
6264 150ns Low Power	2.40	2.15	2.05
2716 450ns 5 volt	2.75	2.60	2.45
2532 450ns	5.40	4.85	4.50
2732 450ns	2.60	2.40	2.25
2732A 250ns	3.30	2.85	2.75
2764 250ns Suit BBC	2.45	2.20	2.05
27128 250ns Suit BBC	2.75	2.60	2.40
27256 250ns	3.70	3.45	3.30

Low profile IC sockets:								
Pins	8	14	16	18	20	24	28	40
Pence	5	9	10	11	12	15	17	24

Please ask for quote on higher quantities or items not shown.
Data free on memories purchased, enquire cost for other.

Write or 'phone for list of other items including our 74LS series and a DISCOUNT ORDER FORM.

Please add 50p post & packing to orders under £15 and VAT to total. Access orders by 'phone or mail welcome.

Non-Military Government & Educational orders welcome for minimum invoice value of £15 net.

HAPPY MEMORIES (WW),
FREEPOST, Kington,
Herefordshire HR5 3BR.
Tel: (054 422) 618
(No stamp required)

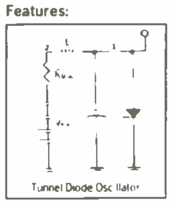
ENTER 38 ON REPLY CARD

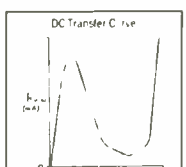
FOR THE BEST CIRCUIT SIMULATION C.A.D.

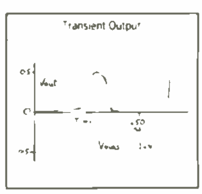
Designers are turning to 'THOSE ENGINEERS' software. They keep ahead by knowing what is going on while free to experiment without the costs, delays and uncertainties of physical testing. Those Engineers software which creates a net list removes the chores and errors in documenting. Ask us too for schematic layout software.

ECA–2 is an example of one of our circuit simulators

Features:





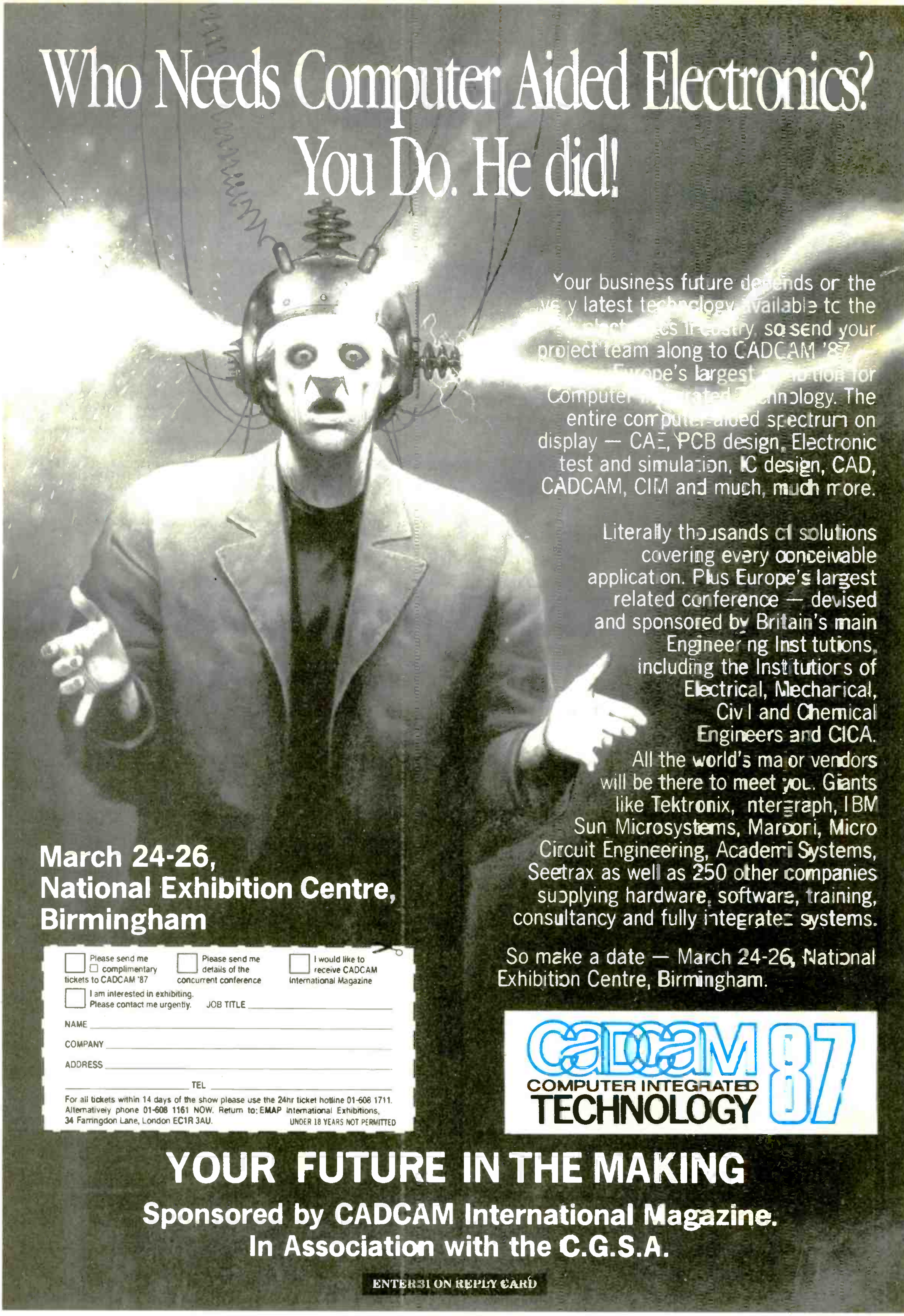


Transient analysis –	timing diagrams plotted
DC analysis –	DC transfer curves plotted
AC analysis –	Bode curves (gain and phase) plotted also phase and group delay output
Fourier analysis –	transients output in frequency domain
Tolerancing –	Monte Carlo and Worst Case
Temperature –	Components temperature effects supported
Non-linear simulation –	Breakpoints and polynominals supported
Full diode model –	I = Io' (exp((v'q) (n'k't)) − 1)
Complex components –	Resistors may have inductance etc etc
Variants –	Component characteristics can be made to vary with both time and frequency according to any function Offset currents may be imposed
Macro models –	Up to 64 connections per model to main circuit no limit on number or size
Probe –	Signals may be sampled or injected anywhere
Dual mode –	Interactive mode has powerful editing and interrupting facilities Batch mode for heavy work allows you to come back
High capacity –	Sparse matrix technique allows typically over 500 modes in 512K memory 8087 (or
High Speed –	80287) coprocessors supported
Reference Manual –	A ring-bound reference manual of over 200 pages is an integral part of ECA 2
No risk trial –	If you need more convincing, ring us for details of money back trial
Low price –	ECA-2 costs just £675 + VAT ECA 2 compares favourably with well known mainframe simulators and is more powerful than any other we know available on PC s

THOSE ENGINEERS software which is available from £99 supports IBM PC's and compatibles and the range of BBC microcomputers. As engineers in electronic and mechanical product and process design we welcome enquiries for other requirements.

THOSE ENGINEERS LTD, Sales: 106a Fortune Green Road, West Hampstead, London NW6 1DS.
Tel 01-435 2771, Telex 8950511 mark for mailbox 23332001.

ENTER 13 ON REPLY CARD


Who Needs Computer Aided Electronics?
You Do. He did!
Your business future depends on the very latest technology available to the industry, so send your project team along to CADCAM '87 Europe's largest for Computer Technology. The entire computer-aided spectrum on display — CAE, PCB design, Electronic test and simulation, IC design, CAD, CADCAM, CIM and much, much more.
Literally thousands of solutions covering every conceivable application. Plus Europe's largest related conference — devised and sponsored by Britain's main Engineering Institutions, including the Institutions of Electrical, Mechanical, Civil and Chemical Engineers and CICA.
All the world's major vendors will be there to meet you. Giants like Tektronix, Intergraph, IBM Sun Microsystems, Marconi, Micro Circuit Engineering, Academi Systems, Seetrax as well as 250 other companies supplying hardware, software, training, consultancy and fully integrated systems.
So make a date — March 24-26, National Exhibition Centre, Birmingham.
March 24-26,
National Exhibition Centre,
Birmingham
Please send me complimentary tickets to CADCAM '87
Please send me details of the concurrent conference
I would like to receive CADCAM International Magazine
I am interested in exhibiting. Please contact me urgently.
JOB TITLE
NAME
COMPANY
ADDRESS
TEL
For all tickets within 14 days of the show please use the 24hr ticket hotline 01-608 1711. Alternatively phone 01-608 1161 NOW. Return to: EMAP International Exhibitions, 34 Farringdon Lane, London EC1R 3AU.
UNDER 18 YEARS NOT PERMITTED
CADCAM 87
COMPUTER INTEGRATED
TECHNOLOGY
YOUR FUTURE IN THE MAKING
Sponsored by CADCAM International Magazine.
In Association with the C.G.S.A.
ENTER 31 ON REPLY CARD

Automatic testing of surface-mounted components

KLAUS BESELIN and HANS SCHAUFLINGER

This description of the automatic testing of printed-circuit boards with s.m.ds begins with the state-of-the-art in testing methods for p.c. boards with leaded components. Quality assurance starts with the selection of component manufacturers and the incoming inspection of their components, including the board connectors and the circuit boards (Fig.1).

When the individual components have been placed on the p.c. boards, the manufacture of the boards generally ends with soldering: the quality of the p.c. boards is decided during these few stages. The stages which follow — visual inspection, electrical test (possibly in several stages), system test in a set-up with other p.c. boards and firmware and finally power-up at the customer's premises — serve for checking the finished quality and, if necessary, the desired quality improvement. A simple go/no-go result is not sufficient here. As a precondition to economical repair, test methods using specific fault-finding to locate the fault or defective component must be applied (Fig.2).

SIEMENS QUALITY CONCEPT

In assessing the quality of p.c. boards, a quality concept (referred to as a *Q concept*) has been established at Siemens. This allows the effects on quality of the components, component placement method and soldering method to be summarized in one quality coefficient calculated by the formula

$$Q=100\cdot(1-dpm_c\cdot10^{-6})^{n_c}\cdot(1-dpm_p\cdot10^{-6})^{n_p}\cdot(1-dpm_s\cdot10^{-6})^{n_s}$$

where dpm = defects per million; n = number per p.c. board; subscript c = components; subscript p = component/placement; subscript s = soldered joints.

Q = 100 is achieved with completely fault-free manufacture.

If one considers, for example, a p.c. board with 170 components and a total of 800 soldered joints, the quality coefficient Q = 95 is obtained with the following dpm values:

component defect rate	100 dpm
placement error rate	100 dpm
soldering defect rate	20 dpm

This means that of 100 manufactured p.c. boards, 95 boards have no defects. With the remaining five boards the defects must be specifically eliminated. At the same time, quality-control loops must be used to ensure that series defects and quality impairments of the same type no longer occur, so that the quality of the component delivered and the manufacturing quality can be improved over the long term.

To achieve a component placement error rate of 100 dpm, an average of 10,000 components must be placed without errors. This means that with manual placement at 8s per component, the first error must not occur until 22 hours have elapsed! With automated component placement at a cycle time of 1s per component, an error must not occur on average until after 2 hours and 45 minutes of error-free operation.

These selected numerical examples show the enormous demands made on the manufacture of p.c. boards. An alternative to previous methods is given by the transition from analogue to digital techniques, which require fewer components, as well as the

Fig.1. Printed-circuit board testing as part of the manufacturing and quality system.

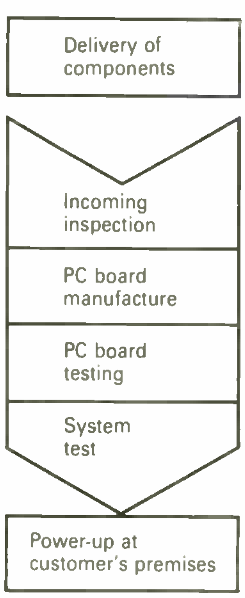


Fig.2. The seven stages in the quality assurance cf p.c. boards.

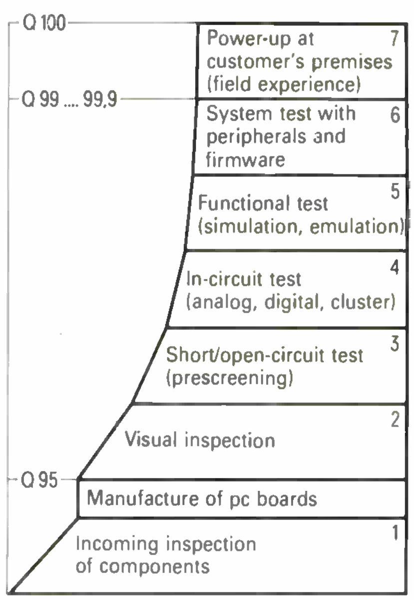
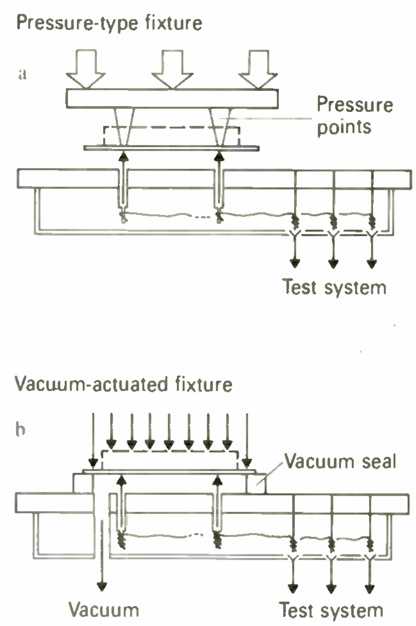


Fig.3. Test fixture principles:



ever-increasing integration of the individual components and, finally, the surface-mount technology, which simplifies component placement.

TESTING TECHNIQUE

In the case of p.c. boards with leaded components all the components are inserted into the board from one side – the component side – and connected to the tracks of the board on the other side – the soldering side – by wave soldering.

For the test, which primarily takes place via all connectors, contact is made with additional conductor paths from the soldering side; one contact is usually sufficient for each conductor path which is not connected to a point on the connector. In addition to component terminals, plated-through holes or special test pads which are best arranged in a test-point grid can be used for the purpose. This allows a complete short/open-circuit test of all conductor paths and an in-circuit test of all analogue and digital components. It is followed by a functional test of the p.c. board via the connector.

The first significant step towards surface-mount technology is the replacement of leaded components by surface-mounted devices (s.m.ds). These devices do not have leads which pass through the board and which are available for contacting during testing. Direct contact with the s.m.ds using test probes is not acceptable today for the following reasons:

- s.m.d. cases and packages can be damaged by the spring-loaded test probes, thus impairing the reliability.
- the contact areas on chips are sometimes so small and the positioning tolerances are so great that sufficient contact reliability is not ensured.
- with various designs, the component terminals in the vertical direction are concealed, and special contact elements such as clips for plastic leaded-chip carriers (p.l.c.cs) are not sufficiently reliable for use in bed-of-nails/fixtures.
- unsoldered connections with small-outline (s.o.) or flatpack devices can be closed by the contact force and may appear to be in order in the test.

To test the p.c. boards and for any specific fault locating that may be required, steps should still be taken to ensure that each conductor run is accessible to the automatic tester via the connector or from the soldering side. Test pads on the soldering side and plated-through holes can be provided for probing purposes during layout preparation for the p.c. board, either for a change of level or specifically for test purposes.

FIXTURES

A significant element in the testing is a reliable connection between the test system and the unit under test. Apart from the s.m.t., very high demands are made on the quality and wear resistance of the interface between the test system and the fixture, because the product range and production strategy may require a frequent change of test fixture. However, the resulting problems and the suitability of test-system interfaces to automatic fixture changing will not be discussed in detail here because they are not specific to the s.m.t. We are chiefly concerned with the individual fixture and the demands made on the unit under test, the p.c. board with s.m.ds.

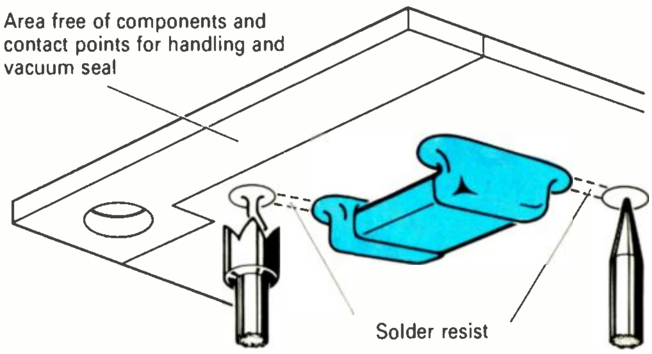


Fig.4. Contact points at an s.m.d. are needed for reliable contact.

TEST FIXTURE

Vacuum fixtures have established themselves in recent years for application to in-circuit testers. The simple principle has a number of advantages compared to manually or pneumatically actuated test fixtures. The vacuum principle is also suitable for p.c. boards with s.m.ds, unless the boards are exclusively reflow soldered and can no longer be held by vacuum because of a large number of open, plated-through holes. In any case, mechanical, pressure-type fixtures may play a greater part in future. These may facilitate the implementation of multistage probing and/or probing on both sides, as well as automatic p.c. board changing (Fig.3).

Probe plate, bed of nails. As already mentioned, it is generally not sufficient to achieve contact only via the connectors for fault locating; a test access point is needed on each conductor path. In the case of boards with leaded components, this test access point is generally the component lead itself, or is provided in the form of a plated-through hole or special test pad on the soldering side of the board.

Easily replaceable spring loaded test probes with a crown or coarse serrated head, or 30-degree tip have proved suitable as contact elements. Each probe should press down on the contact point with a force of at least 1.5N

Conditions and consequences for making contact with p.c. boards with s.m.ds via so-called bed-of-nails test fixtures as a function of size, shape and positions of the contact points.

Test pads ≥ 1.3mm dia. or component terminals (e.g. connector, i.c.) at a pitch of 2·5mm

- Probing on one side:

state-of-the-art for p.c. board and test fixture manufacture.

- Probing on both sides:

increased overheads in fixture manufacture (design, geometry, forces, wiring);
no contact problems should be expected with precise assembly and careful maintenance;
component side no longer accessible for fault-finding.

Test pads ≥ 0.7mm dia. 2·5mm pitch

- Contact on one side:

the use of rugged, standard spring-loaded test probes is possible;
need to improve the precision of the spring-loaded probes;
greater accuracy in position and angularity of the holes in the probe plate;
greater accuracy of locating pins in the fixture;
greater accuracy of the p.c. board relating to the positions of the test pads with respect to the tooling holes, as well as the hole diameters and positions of the tooling holes with respect to each other.

- Contact on both sides:

additional need for maximum precision in mating the lower and upper parts of fixtures.

Test pads ≥ 0.7mm dia. 1mm pitch

Contact can only be made with the p.c. board with miniature test probes;
need for very clean test pad because of the low contact force;
protective measures for the sensitive test probes;
great care in handling and servicing the fixtures;
demands on precision same as for 0.7mm dia. and 2.5mm spacing.

Guide values for p.c. boards and fixtures with very small test pads

Positions of the test pads with respect to holes: ± 0.1mm, on both sides if applicable.
Positioning of p.c. board via the locating pins: ± 0.07mm.
Position of the test probes tips including inclination: ± 0.1mm.

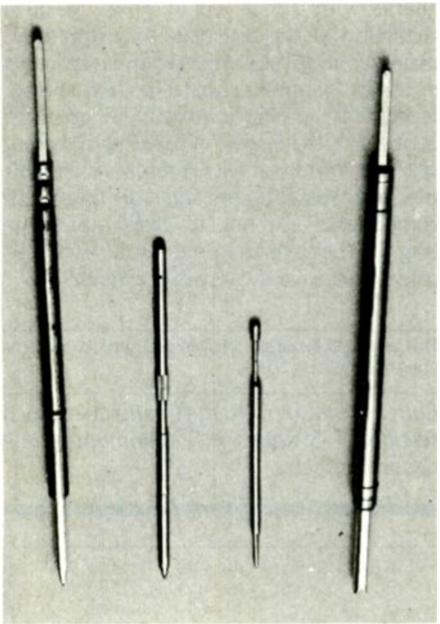
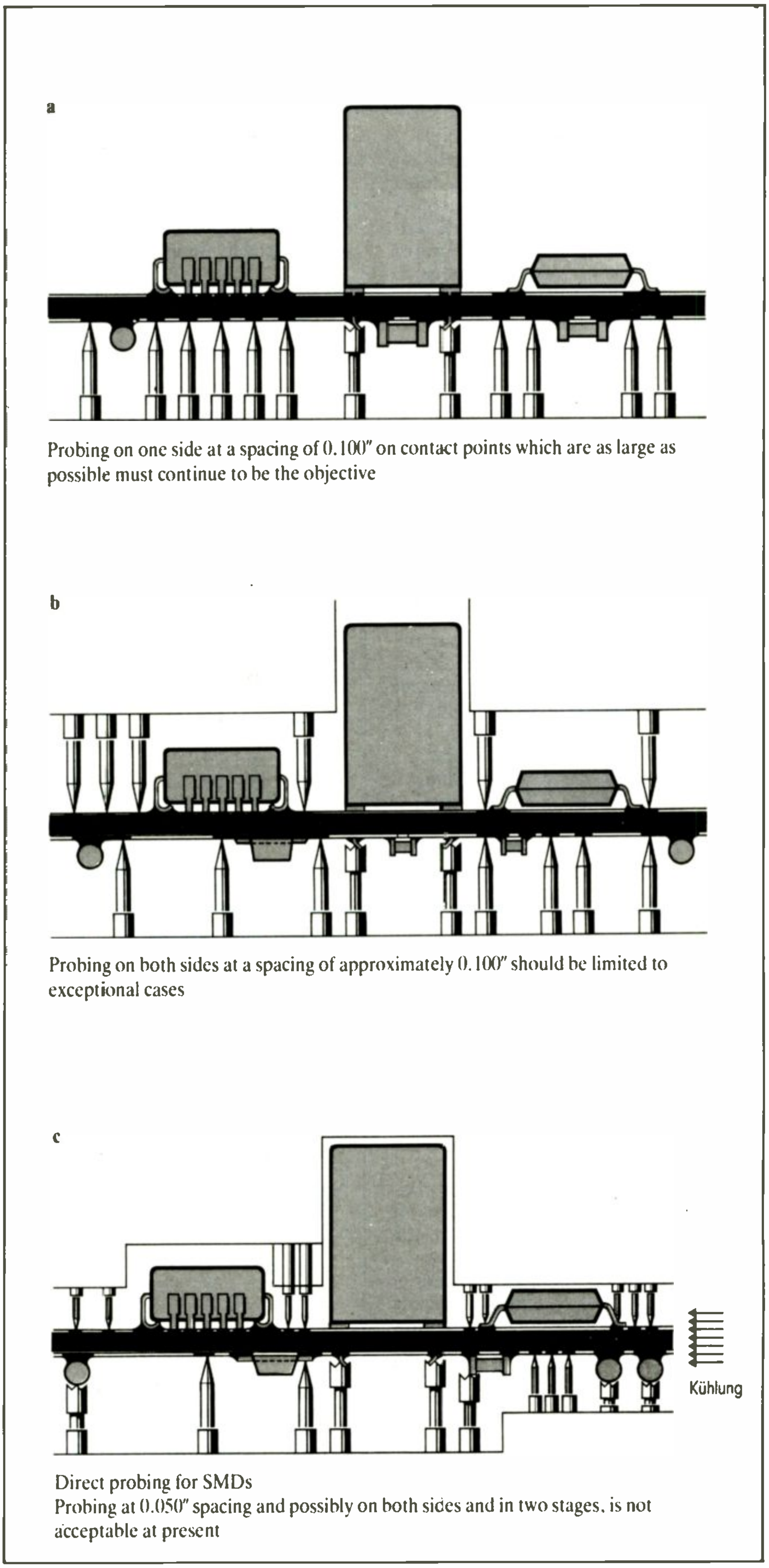


Fig.5. Spring-loaded test probes for 2.5mm and 1mm spacings, 1.5 times enlarged.

Fig.6. Principles of contacting for a.t.e.



to create a reliable contact. This contact force is also necessary for boards with s.m.ds.

Design for probe-ability. In the interest of simple, low-cost and reliable fixtures and of accessibility of the board component side for fault-finding, the following requirements apply to the testing of p.c. boards with s.m.ds:

- separate contact points should be provided for s.m.ds;
- contact points must be located on the soldering side;
- contact points should be arranged in 0·1 in. spacing.

Contact points can be soldering eyelets of plated-through holes ≧ 1.3 mm in diameter or, with mixed assembly, component leads (primarily connector terminals). The contact points must be free from solder resist or insulting coating; at a sufficient distance from the s.m.d terminal pads and edges; and at a sufficient distance from outer edges, tooling holes and other openings to allow contacting, handling and sealing in vacuum-activated fixtures where applicable (Fig.4).

Admittedly, some of these are severe requirements. For many products, they may create considerable friction between the development, production and quality assurance departments, because it appears that space saving – one of the significant advantages of s.m.ds. – is being defeated. This means that even with the application of s.m.ds, the manufacturing and process techniques must not be considered in isolation. The p.c. board as a product must obviously encompass the costs of fault locating and elimination from the overall economical aspects, and must therefore be of a design which lends itself to convenient testing. Fault elimination on p.c. boards with s.m.ds is still relatively difficult and the methods applied require optimization.

Although the decreasing size of components and higher levels of integration allow a further reduction in size of boards, the smaller lead or pad spacings (0.050 in, 0.040 in, etc.) create even greater problems for test fixtures. The spring-loaded test probes commercially available today are not yet suitable for extensive application. Their lack of stability, low contact force, short spring excursion, difficult and expensive assembly and wiring are only acceptable in exceptional cases. Fig. 5 shows a size comparison between the spring-loaded test probes for 0.100 in and 0.050 in spacings.

The second step towards surface-mount technology leads to an increasing number of components per board, because of the smaller size of the components. This means a correspondingly high number of conductor paths and, because of the grouping of functions on a board, a considerably higher degree of complexity. As long as the test-access points per conductor run are ensured and it is possible at the design stage to provide the required contacts, the test philosophy applied so far should be retained using test systems with higher numbers of pins. If restrictions are made, particularly at the design stage or in the p.c. board layout and design, a transition to the cluster test must take place for some areas, i.e. two or more components are tested as a single unit. This cluster test, as well as the functional test of the p.c. boards, requires a high programming overhead on account of the increased circuit complexity. Locating faults becomes increasingly difficult, as can be seen by taking the following example. Referring to the first example, assume that the components are doubled to 340 and the soldered joints to 1600. In the case of p.c. boards with s.m.ds, a quality coefficient of approximately Q = 97 can be achieved with the following dpm values:

component defect rate	50 dpm
placement defect rate	20 dpm
soldering defect rate	5 dpm

Having achieved this objective, the overhead involved in the testing technique must be reconsidered. There is clearly a need to promote the built-in test technique for p.c. boards and components of growing complexity.

In the transition period, in the case of boards fitted exclusively with s.m.ds and with a large number of conductor paths, a changeover to probing on both sides can be made. Fewer problems are expected here than with mixed construction of boards with leaded components and s.m.ds, for which fixtures can only be created at very high costs because of the widely differing component heights.

Increased integration and miniaturization through the use of s.m.ds must, of course, also be taken into account in the manufacture of the boards and in component placement. Of the large numbers of problem areas, however, only those points which are relevant to the use of test fixtures need be considered here: small track clearances and soldering pads; small plated-through holes; and high tolerance requirements. The intention is to meet these requirements, for example during component placement, by using special position-detection systems and appropriate control of the head of the automatic component-placement system.

In the case of bed-of-nails fixtures, with which several hundred spring-loaded test probes are to be applied simultaneously to the contact points, such position correction is not possible. With a board which is positioned in the fixture via two locating holes, it is necessary for all test probes to be applied reliably to the contact points, whilst no short-circuits with adjacent tracks are created. If there is therefore a desire or need to make contact with small contact points with a close pitch and/or on both sides, the relevant conditions must be provided for during p.c. board manufacture and in the construction of test fixtures.

With the present state of the art, contacts with a spacing of 0.05 in and possibly on both sides or in two stages should be rejected.

An acceptable solution for testing p.c. boards with s.m.ds could prove to be a reduction of the test pads to a minimum diameter of 0.7mm while retaining spacings of about 2·5mm, so that standard spring-loaded test probes can still be used. In contrast to the testing of bare boards where spacings of 1mm and less present no difficulties, the contact points of boards fitted with components are not so easily accessible (Fig.6). The fixtures would result in complicated, expensive and sensitive assemblies.

This article is based on a paper published in *Siemens Components* No. 6 (1986).

Both authors are with the Quality Assurance section of Siemens AG, Communications Group, Munich.

```
                                     : assume addr of data array in BX
                                     : and binary bit reversed
1$:     AX, II          MOV          : get current loop counter
        DX, NU          MOV          : and compare against the terminal
        AX, DX          CMP          : value of the number of passes
7$                      JA           : exit if all done
        AX, £ 1         MOV          :
        JJ , AX         MOV          : take opportunity to zero counter
        CX, II          MOV          : use the fact that II has the right
2$:     AX, 1           SHL          : number of shifts in it to
2$                      LOOP        .: calculate 2**II
        IA, AX          MOV          : and store result temporarily
        AX, 1           SHR          : calculate half of IA and also
        IB , AX         MOV          : store result temporarily
3$:     AX, JJ          MOV          : compare current loop contents
        DX, IB          MOV          : against terminal value of J loop
        AX, DX          CMP          : if IB iterations have been done,
6$                      JA           : go on to next outer loop
        KK , AX         MOV          : if not, put current J into K
4$:     AX, KK          MOV          :
        DX, N           MOV          : and compare it to the loops'
        AX, DX          CMP          : terminal value of N
5$                      JA           :
        SI, KK          MOV          : calculate the two pointers
        DI, IB          MOV          : into the data array
        DI, SI          ADD          :
        SI              DEC          : adjust to point to zeroth element
        SI, 1           SHL          : and for word addressing
        DI              DEC          :
        DI, 1           SHL          :
        AX, [BX+SI]     MOV          : get the corresponding array words
        DX, [BX+DI]     MOV          : from the matrix
        AX, DX          ADD          : first operation is addition...
        [BX+SI], AX     MOV          : restoring result in memory
        AX, DX          SUB          :
        AX, DX          SUB          : whilst the second is subtraction..
        [BX+DI], AX     MOV          : replacing each pair as we go
        DX, IA          MOV          : increment the inner loop K counter
        AX, KK          MOV          : by the step value in IA
        AX, DX          ADD          :
        KK , AX         MOV          : and replace the loop counter
4$                      JMP
5$:     JJ              INC
3$                      JMP
6$:     II              INC
1$                      JMP
7$:                                  : Gray code reordering goes next
```

Fast Hadamard transform

This assembly language version of the fast Hadamard transform was omitted from Mark Varney's article "Hadamard versus Fourier transformation" January issue, page 16. The listing uses FIG-Forth assembler, with Forth variables to hold current values of the loop counters. The binary-bit reverse routine is the same as for the fast Fourier transform, and Gray code re-ordering is not included for brevity. The 16bit data is assumed to be in two's complement.

1GHz millivoltmeter

Rectifier-input instrument for use between 1kHz and 1GHz in the range 2mV-2V

N. G. MICHAELIDES

Broadband voltmeters can be distinguished into the following groups:

- meters with rectifier input
- meters with amplifier input
- meters employing sampling techniques

As for all voltage measuring meters, a high input impedance is essential.

METERS WITH RECTIFIER INPUT

In the simplest case, a detector probe is used in conjunction with a high-impedance electronic d.c. voltmeter. A high-frequency detector located in the probe head is employed to obtain a d.c. output proportional to the measured r.f. Detectors use high-frequency diodes in half-wave (Fig.1(a), (b)) or voltage/doubler (Fig.1(c)) rectifier circuits. For voltages over 1V, diode rectifiers function as peak amplitude detectors in which d.c. output is equal to the peak value minus the forward bias voltage of the diode. For voltages higher than 3V, diode bias can be neglected and the d.c. output of the detector, scaled down by 1.41 or 2.82, serves as a measure of the r.m.s. value of a pure sinusoid. Readings can be taken on the linear scale of the d.c. meter. For voltages lower than 3V, diode bias becomes significant and special non-linear scales are needed. Calibration is accurate for sinusoids.

The voltage range of this combination is from 0.1-0.3V to 10-20V. The upper limit is imposed by the reverse voltage rating of the diode and can it be extended with a divider. The lower limit is imposed by measurement accuracy. Below 100mV, accuracy degradation renders the meter useless. Accuracy is affected by compression of the non-linear scale at low voltages; different volt-ampere characteristics among diodes, requiring a one to one meter-probe calibration; and temperature dependence of the diode volt/ampere characteristic.

Millivolt ranges are characterized by the change in detector behaviour. Peak response gradually gives way to 'square-law' detection, which results in a non-linear detector response. To overcome this problem, along with the temperature dependence, some instruments use thermostatically controlled probes and linearizing electronic circuits.

Another approach, used in the present meter, is through a comparison detector. In this, two similar detector circuits are used: one rectifies the unknown r.f., while the other, a known, instrument-generated, comparison a.f. The amplitude of the comparison a.f. voltage is automatically controlled to give the same d.c. output as the r.f. one. It is evident that if the responses of the two detectors are close enough, so will be the magnitudes of the two signals. It is assumed here that the two detectors have a flat frequency response from a.f. to r.f. and are under the same thermal conditions: error can be introduced by diode mismatch and detector frequency response.

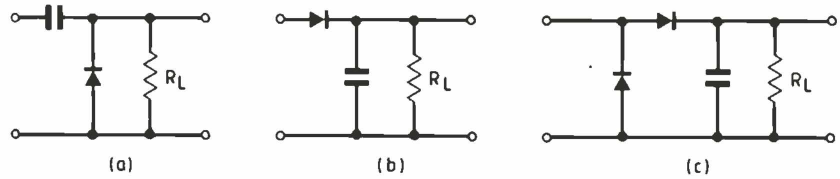


Fig.1. Forms of diode detector in half-wave, (a,b) or full-wave (c) circuits.

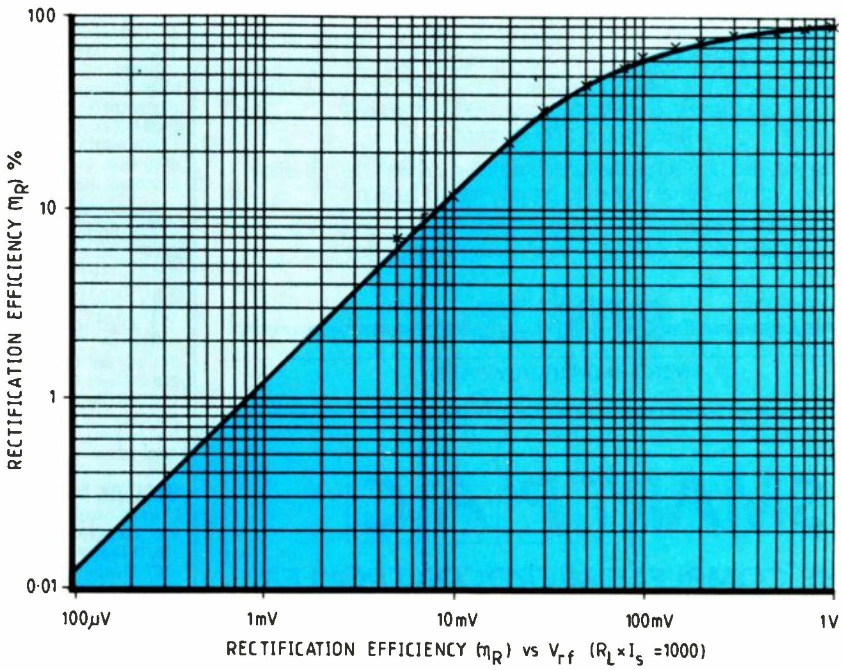


Fig.2. Computer plot of rectification efficiency of a half-wave circuit.

R.F. DETECTION

In a detection circuit (Fig.1) we can define for symmetrical waveforms the efficiency of rectification $n_R(v)$ as

$$\eta_R(v)=k\frac{V_{dc}}{V_{rfp}} \qquad (1)$$

where V_{dc} is the d.c. output of the detector,
V_{rfp} is the peak value of the detected r.f.,
k is a circuit factor, 1.0 for half-wave circuits and 0.5 for voltage-doubler circuits.

For sine waves $\eta_R(v)$ becomes

$$\eta_R(v)=k\frac{V_{dc}}{\sqrt{2}\,V_{rf}} \qquad (2)$$

where V_{rf} is the r.m.s. value of the detected r.f.

The output of a half-wave circuit (Fig.1(a), (b)) employing a diode that has a purely exponential characterisic defined by

$$I=I_S\left[\exp\left(\frac{V}{V_T}\right)-1\right] \qquad (3)$$

and provided that the internal resistance of the signal source is negligible, can be calculated[2] for the whole millivolt range from

$$I_0\left(\frac{\sqrt{2}\,V_{rf}}{V_T}\right)=\exp\left(\frac{V_{dc}}{V_T}\right)\left[1+\frac{V_{dc}}{R_L I_S}\right] \qquad (4)$$

where $I_0(x)$ is a modified Bessel function of the first kind and zero order,
V_T is the volt equivalent of temperature: for room temperature $V_T=25.5mV$,
I_s is the reverse saturation current of the diode,
R_L is the load resistance.

A computer plot of eq.(4) in the form $\eta_R(V_{rf})$ vs. V_{rf} is depicted in Fig.2. The Bessel integral.

$$I_0(x)=\frac{1}{2\pi}\int_0^{2\pi}\exp(x\cos\omega t)d\omega t \qquad (5)$$

was evaluated first using Simpson's rule for numeric integration. Then the two parts of eq.(4) were made equal by successive approximations. As can be seen, experimental results from a germanium diode detector are in excellent agreement with those theoretically predicted.

For small values of V_{rf}, the Bessel integral can be approximated by a series expansion

$$I_0(x)=1+\frac{x^2}{2^2}+\frac{x^4}{2^2 4^2}+\frac{x^6}{2^2 4^2 6^2}+\dots \qquad (6)$$

Also exp(x) can be expanded

$$\exp(x)=1+x+\frac{x^2}{2!}+\frac{x^3}{3!}+\dots \qquad (7)$$

Substituting the first two terms of the series expansions (6) and (7) and dropping V^2_{dc}, equation (4) becomes

$$V_{dc}=\frac{V^2_{rf}}{2V_T}\left[\frac{R_L I_S}{R_L I_S+V_T}\right] \qquad (8)$$

and for $R_L I_s \gg V_T$

$$V_{dc}=\frac{V^2_{rf}}{2V_T} \qquad (9)$$

V_{dc} calculated with eq. (8) has the following error over the exact solution of eq.(4):

+6.9% for $V_{rf}=20mV$
dropping to +2.0% for $V_{rf}=10mV$

Eq.(8), illustrated by the straight-line portion of the curve in Fig.2, indicates that for small V_{rf}, V_{dc} is proportional to the square of V_{rf}. For signals of V_{rf} = 30mV or less, the detector practically behaves as 'a square law' device. However, this square-law response offers both advantages and disadvantages.

The main advantage is that the detector has almost r.m.s. response regardless of the waveform of the measured signal. This is true only to a certain extent, depending on the voltage and the crest factor (ratio of peak to r.m.s.) of the waveform. Permissible crest factors for 2% and 5% error are given below:

V_{rf}	Crest factor
3mV	10/13
10mV	3/4
30mV	1.7/2

(source Rohde & Schwarz)

This property can be very useful in noise measurements. By insertion of a suitable attenuator or capacitive divider, higher voltages can be reduced to this level, thus extending upwards the almost true r.m.s. range.

On the other hand, the d.c. output of the detector falls/off rapidly with decreasing V_{rf}, becoming, below a certain value, unusable for further processing. For this reason, even the best professional meters have as their most sensitive subrange 3mV or 1mV f.s. To demonstrate this, a voltage-doubler detector will yield only 1.5 microvolt d.c. for 0.3mV r.f. In this low d.c. environment, the problems encountered are: noise (inherent and pick-up); thermocouple effects; short and long term thermal stability; electrostatically induced voltages; amplifier offsets; and printed-circuit leakage currents. The practice is to use a chopper-stabilized d.c. amplifier in the input stage. As an alternative a high-precision op-amp with comparable performance can be used.

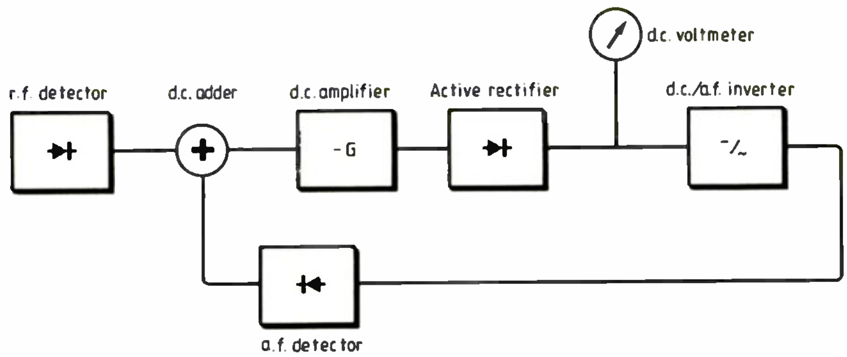


Fig.3. Block diagram of the millivoltmeter.

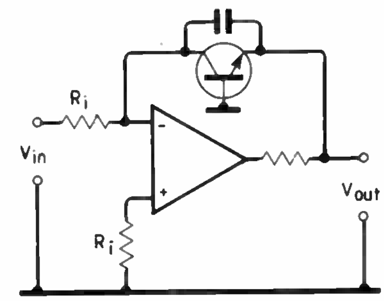


Fig.4. The use of log. amplifier obviates the need for elaborate switching. This is a basic circuit.

PRINCIPLE OF OPERATION

The principle of operation was used in a series of professional instruments manufactured by Rohde & Schwarz. During an attempt to re-design one such instrument[1], new circuits evolved that simplified circuitry astonishingly.

The r.f. to be measured and the comparison a.f. are rectified in the two similarly designed detector circuits (Fig.3, detectors 1,2) located in the probe head. The d.c. voltage difference of the two detector outputs is designated the error voltage

$$V_{err}=\frac{\sqrt{2}}{k}\left[\eta_R(V_{rf})V_{rf}-\eta_R(V_{af})V_{af}\right] \qquad (10)$$

The error voltage is then amplified by $-G$ and is ideally rectified, the rectified voltage being used for meter indication.

$$V_{ind}=G\,V_{err} \text{ for } V_{err}>0 \qquad (11)$$
$$V_{ind}=0 \quad \text{for } V_{err}<=0 \qquad (12)$$

The feedback loop closes with a d.c./a.f. inverter that generates a pure 5 kHz sine wave of V_{af} r.m.s. value, directly proportional to the absolute value of V_{ind}. Ratio of proportionally S is

$$S=\frac{V_{af}}{|V_{ind}|} \qquad (13)$$

Combining (10), (11), (13)

$$V_{ind}=\frac{G\eta_R(V_{rf})}{\frac{k}{\sqrt{2}}+GS\eta_R(S|V_{ind}|)}V_{rf} \qquad (14)$$

Examining eq.(14) one can see that it is a typical closed-loop transfer function of a control system. If $\eta_R(v)$ were constant, then the value of the fraction would have been constant and the relation between V_{ind} and V_{rf} linear throughout the meter range. The fraction contains $\eta_R(V_{rf})$ and $\eta_R(S|V_{ind}|)$ that are in general different by a small amount. In order to bring eq.(14) into common terms regarding $\eta_R(v)$ the following assumption is made:

$$\frac{\Delta\eta_R}{\Delta V}\approx\frac{d\eta_R(V_{rf})}{dV_{rf}} \qquad (15)$$

Eq.(15) is unconditionally true for V_{rf} <20mV (because $d\eta_R(V_{rf})/dV_{rf}$ is constant). For V_{rf}>20mV it is true for small ΔV. ΔV diminishes as G increases. Eq.(15) yields

$$\eta_R(S|V_{ind}|)=\eta_R(V_{rf})+a-a\frac{V_{rf}}{S|V_{ind}|} \qquad (16)$$

where

$$a=\frac{d\eta_R(V_{rf})}{dV_{rf}}S|V_{ind}| \qquad (17)$$

Rearranging, eq.(14) transforms to

$$V_{ind}=\frac{G[\eta_R(V_{rf})+a]}{\frac{k}{\sqrt{2}}+GS\left[\eta_R(V_{rf})+a\right]}V_{rf} \qquad (18)$$

The derivative $d\eta_R(V_{rf})/dV_{rf}$ in eq.(16) can be calculated analytically from

$$\frac{d\eta_R(V_{rf})}{dV_{rf}}=\frac{1}{\sqrt{2}V_{rf}}\left[\frac{dV_{dc}}{dV_{rf}}-\frac{V_{dc}}{V_{rf}}\right] \qquad (19)$$

$$\frac{dV_{dc}}{dV_{rf}}=\frac{\sqrt{2}\,I_1\left(\frac{\sqrt{2}V_{rf}}{V_T}\right)\left[R_L I_s+V_{dc}\right]}{I_0\left(\frac{\sqrt{2}V_{rf}}{V_T}\right)\left[R_L I_s+V_{dc}+V_T\right]} \qquad (20)$$

($I_1(x)$): is modified Bessel function of the first kind of first order.

A high degree of linearity can be achieved if $GS[\eta_R(V_{rf})+a] \gg k/\sqrt{2}$ throughout the

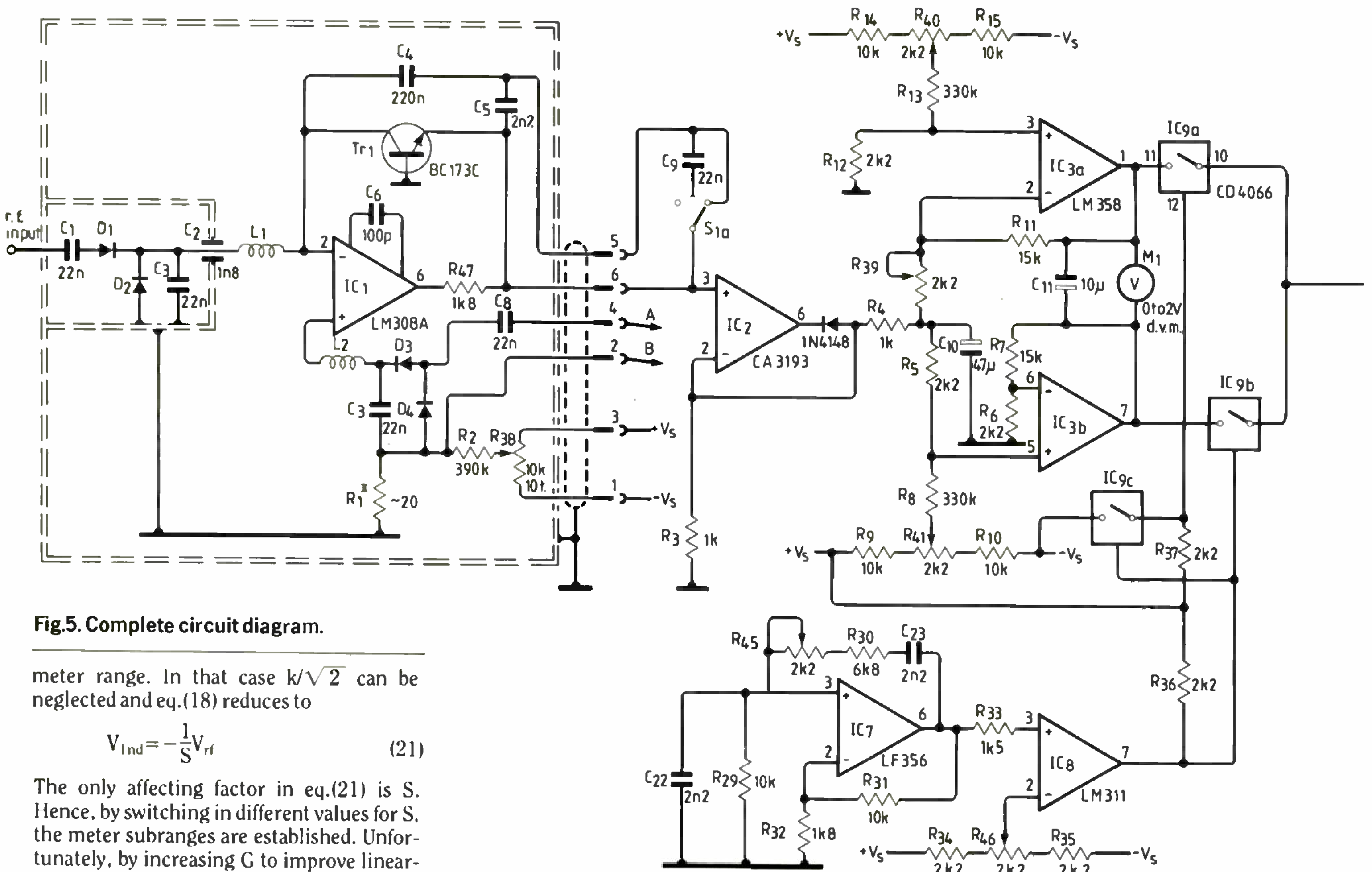


Fig.5. Complete circuit diagram.

meter range. In that case $k/\sqrt{2}$ can be neglected and eq.(18) reduces to

$$V_{Ind} = -\frac{1}{S}V_{rf} \qquad (21)$$

The only affecting factor in eq.(21) is S. Hence, by switching in different values for S, the meter subranges are established. Unfortunately, by increasing G to improve linearity, the tendency of the control loop to oscillate is increased. Stability can be maintained by giving G a frequency roll-off characteristic. For this reason, integrator capacitors are included in the d.c. path, but this prolongs response time.

A compromise between linearity, stability and response time can be reached. For this, in each subrange a suitable value for G is selected, such as to maintain $GS[\eta_R(V_e d2f)+a]$ within limits. The limits are determined by linearity imposing the lower limit ($GS[\eta_R(V_{rf})+a] \gg k/\sqrt{2}$), and control-loop stability imposing the upper limit. Hence, maximum G should be used for the minimum V_{rf} to be measured (where $[\eta_R(V_{rf})+a)$ and S are minimum) and vice-versas).

THE LOG. AMPLIFIER

The innovation of this design lies in the fact that the above goals are attained without the need for an elaborate switchable amplifier. Here a log. amplifier followed by a small-gain linear 'post amplifier' greatly simplify matters.

By this combination, as it will be shown, the dependence of V_{ind} on $[\eta_R(V_{rf})+a]$ is loosened and any desired degree of linearity between V_{ind} and V_{rf} can be achieved. A design requirement for 1:10 ratio subranges can thus be easily realised, in contrast with the switchable amplifier alternative.

Error voltage, eq.(10) modified by (15), (16), (17) becomes

$$V_{err} = \frac{\sqrt{2}}{k}\left[\eta_R(V_{rf})+a\right]\left[V_{rf}-S|V_{ind}|\right] \qquad (22)$$

Error voltage is applied in the input of the log. amplifier, (Fig.4) and its output, after being rectified (gain=1) and amplified by g is used as V_{ind}

$$V_{ind} = -gV_T \ln\left(\frac{V_{err}}{R_i I_t}+1\right) \qquad (23)$$

where R_i is the series input resistor,
I_t is the reverse saturation current of the transistor p-n junction,
g is the gain of the post amplifier.

Using the approximation exp(x) ~(1+x), for small x and after some algebraic manipulation, V_{ind} takes the form

$$V_{ind} = -\frac{V_{rf}}{S} + \frac{\exp\left(\frac{V_{rf}}{SgV_T}\right)-1}{\exp\left(\frac{V_{rf}}{SgV_T}\right)\frac{1}{gV_T} + \frac{\sqrt{2}\,S[\eta_R(V_{rf})+a]}{kR_iI_t}} \qquad (24)$$

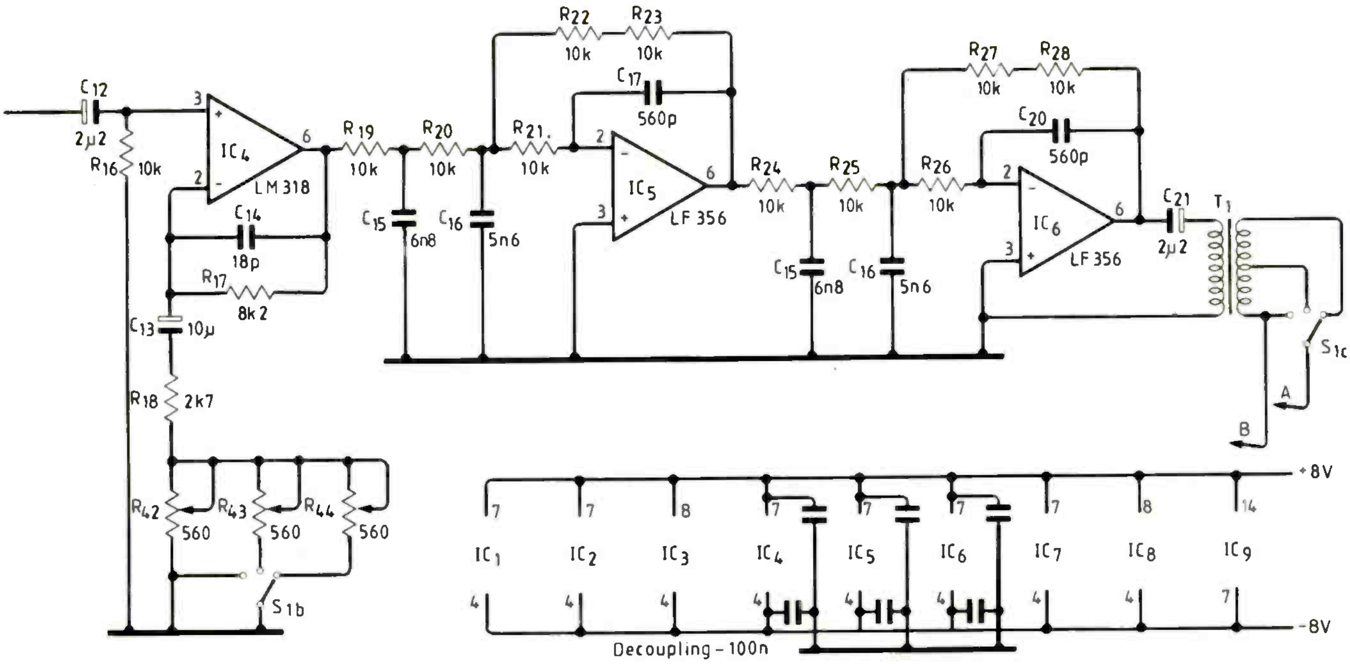
Eq.(24) is an improvement over eq.(18), since the expression containing $[\eta_R(V_{rf})+a]$ is no longer a multiplier of V_{rf} but a quantity to be subtracted, i.e. eq.(24) comprises two parts, a linear and a non-linear one. Also, $[\eta_R(V_{rf})+a]$ in the non-linear part is divided by an extremely small quanity, R_iI_t. the orders of magnitude of I_t and R_i are 10^{-14} A and 10^{+5} 214 respectively.

The magnitude of the non-linear factor, obviously affecting linearity, can be calculated by entering design values in eq.(24). The meter has three subranges: a) 2V-200mV, b) 200-20mV and c) 20-2mV. For compatibility with common d.v.ms, full-scale indication is 1.999V. Therefore, S values are: $S_a=1$, $S_b=0.1$ and $S_c=0.01$. In each subrange, the non-linear part has its highest value for the full-scale r.f. input. Among the three subranges maximum occurs for the 20mV r.f. input, where $[\eta_R(20mV)+a]$ = 0.47 is lowest. It is interesting to note that the non-linear factor can be trimmed to any desired value, by proper g selection. A design value of g=10 was chosen, resulting in a linearity error of the order of 10^{-4}. Thus, method error is far below the one anticipated from other sources. For the accuracy sought, the non-linear factor can be neglected and eq.(24) reduces once again to eq.(21). On the other hand, excessive g is not favourable, as it affects stability by increasing the overall open-loop gain.

Summarizing, the log. amplifier functions as a self-controlled, high-gain amplifier. It exhibits the highest gain in the vicinity of zero input. Maximum gain is only limited by the open-loop gain of the op. amp. (typ. 300 000).This property of the log. amplifier is particularly useful in the microvolt range, where ample gain is essential. However, this is not the only affecting factor. Lowest-value measuring capability (sensitivity) is determined by zero stability and noise.

ZERO STABILITY

Zero offset (meter indication with no input) is unilateral, i.e. it is displayed only on the side of zero where the control loop is effective. In the other side, '00.00' is displayed regardless of offset. This, a consequence



of the control function, can lead to erroneous measurements. It is therefore advisable to introduce deliberately an offset in the displayed side in order to avoid uncertainty.

If a zero offset exists (whether displayed or not), an input V_{rf} will be indicated as

$$V_{Ind}=-\frac{1}{S}\sqrt{V_{rf}^{2}\pm V_{offs}^{2}} \qquad (25)$$

where V_{offs} is the displayed zero or an equivalent amount on the other side. The positive sign refers to the displayed offset while the negative to the non-displayed.

In the case of the displayed offset, eq.(25) indicates that: for V_{rf} much greater than V_{offs}, the error introduced by V_{offs} is negligible; for V_{rf} of the same order as V_{offs} the value of V_{rf} must be calculated from eq.(25); and for V_{rf} much smaller than V_{offs} the contribution of V_{rf} to V_{ind} is too small for accurate interpretation.

It is evidence that V_{offs} must be kept as low as possible. Moreover, the stability of V_{offs} with temperature and time is of great importance. The origin of V_{offs} lies in the existence of parasitic microvolt voltages within the sensitive part of the meter, namely the two detectors and the log. amplifier inputs – the most critical part of the meter. The rest is more or less straightforward.

CIRCUIT DESCRIPTION

The circuit diagram of the meter is depicted in Fig.5. Error voltage is first log. amplified (IC_1 in the probe), then rectified (IC_2) and low-pass filtered (R_4, C_{10}). The following stage ($IC_{3a,3b}$) is a balanced-to-ground, low output-impedance d.c. amplifier. Potentiometers R_{40}, R_{41} null offsets (zero meter indication with zero rectifier input). Balance is adjusted by means of R_{39} although metering is balance-error free. The output of the

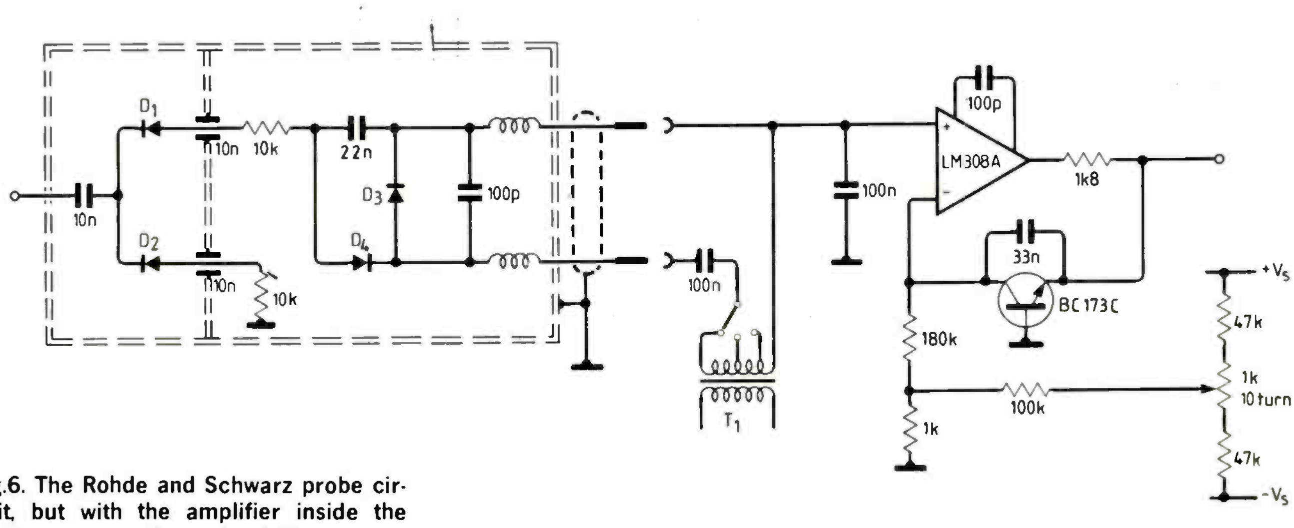


Fig.6. The Rohde and Schwarz probe circuit, but with the amplifier inside the meter, gave poor thermal stability.

succeeding chopper, a 5 kHz squarewave, is then amplified in meter calibration amplifier IC_4. This stage functions also as an impedance buffer between chopper and the first active filter. Separate calibration potentiometer, R_{42}, R_{43}, R_{44}, are provided for each subrange to compensate for minor discrepancies in transformer T_1 ratios. Two cascaded low-pass Butterworth active filters[3] (IC_5, IC_6) that follow, concert the squarewave into a sinusoidal voltage which, suitably divided by switchable ratio transformer T_1 (1:1, 10:1, 100:1), is finally delivered to the comparison detector in the probe. Auxiliary circuits to switch the chopper comprise, 5 kHz frequency oscillator IC_7, shaper-driver IC_8 and inverter-driver IC_{9c}, R_{45} and R_{46}.

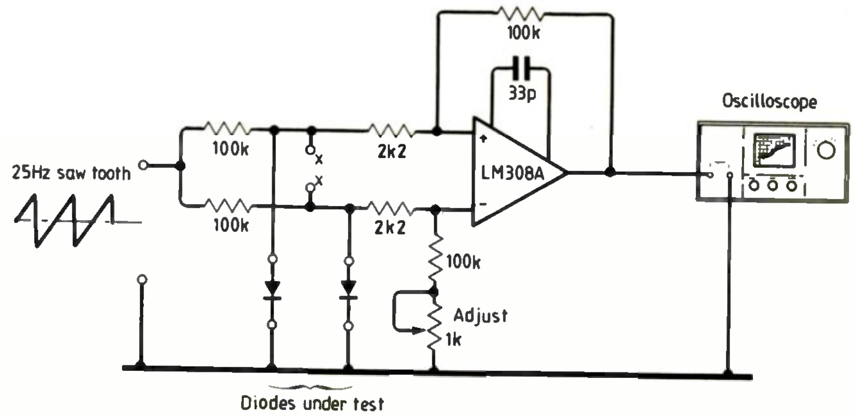
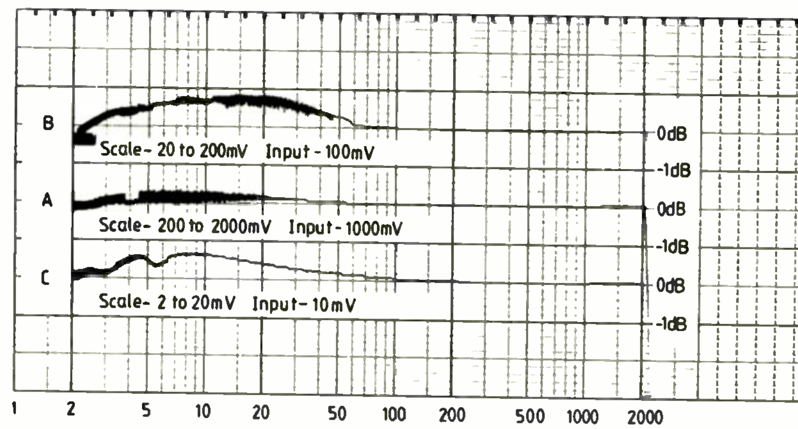


Fig.7. Circuit to assist diode pairing.



Audio frequency response of the instrument.

THE PROBE CIRCUIT

The incorporation of the log. amplifier (IC_1, Tr_1) in the probe was dictated by the need to suppress thermocouple voltages. As a first approach the Rohde & Schwarz probe circuit was tried with the log. amplifier located in the meter body (Fig.6). The former, implemented with ordinary components, gave the meter poor zero thermal stability.

Zero thermal stability was enhanced by increasing circuit compactness by placing IC_1 close to the two detectors ($D_{1,2,3,4}$), and limiting the number of components to an absolute minimum. The use of carbon or metal-film resistors should be avoided (R_1 inevitably used in the nulling circuit is an r.f. choke functioning as a copper wire-wound resistor.) R_2 is not a part of the sensitive circuitry. The input circuit is guarded and IC_1, selected for low input-voltage offset, low offset drift and low noise.

The need for a screen between the two detectors degrades the probe stability during thermal transients, but elimination of the screen affects the frequency response of the probe. Diodes are socket-mounted (not soldered). Gold plated i.c. pin sockets are recommended. Integration capacitors $C_{4,5,9}$ are subrange selectable for best stability/response time performance. The zeroing adjustment R_{38} is incorporated in the probe to facilitate switching between probes without need for re-zeroing. The value of R_2 indicated in Fig.5 may need adjustment depending on R_1, IC_1 offset and diode matching.

DETECTOR DIODES

As already mentioned, meter accuracy and thermal stability greatly depend on the degree to which the four diodes ($D_{1,2,3,4}$) are matched. Ideally, all diodes should have identical volt/ampere characteristics within a wide temperature range.

Among many types of r.f. germanium diodes that were tested, in lots of 10 to 40 per type, no pair of exactly identical diodes was found. Discrepancies were noticed in their characteristics in both the forward and reverse bias state, as well as in their temperature dependence. Fortunately, a reasonable amount of mismatch can be tolerated before its effects become noticeable. Also, instead of four matched units, two matched pairs, each split between the two detectors, suffice. Inevitable residual mismatch also affects meter zero. Nulling is easily accomplished, along with op-amp offset, via R_{38}. Furthermore, the drift of the meter zero caused by temperature change of this residual mismatch can be benefically used to compensate inverse drift of the op-amp offset. Thus, by proper arrangement of the four diodes in the two detector circuits, thermal stability can be improved.

For diodes available in quantities, a preselection was made by sorting them according to their forward-bias voltage measured with a multimeter. Various groups having closely similar values were formed, and preference was given to the most numerous group having the lowest voltage value. Although the latter is not of much importance, it is nevertheless a welcome property, because it indicates a high I_s (refer to eq.(8)). Pairing was assisted by the tester of Fig.7, in which the degree of match between two diodes is better as the oscilloscope travel approaches a straight line. Best matches were tested (in the same way) in other ambient temperatures.

This procedure, being almost a d.c. test, is a measure of the performance of the diodes in the l.f. and h.f. spectrum. V.h.f. and u.h.f. efficiency evaluation was performed in the actual meter. Here again, discrepancies were noticed among previously matched diodes. Thermal stability and frequency response optimization was the criterion for the final selection and positioning of the pairs.

Diodes of the types AA112, AA113 and AA119 were tested in quantities, with satisfactory results. Any of these types can be used. A smaller number of OA90, OA95 and AAY11 was also tested. A limited number of 'gold-bonded' type (1N270 and 1N995) showed better temperature behaviour. Unfortunately, this cannot take the form of a general rule due to the small number tested and the unavailability of other types of this variety for cross-checking. Manufacturer's pairs were also not available for testing.

OTHER CONSIDERATIONS

Other factors that, in a lesser degree, affect meter accuracy are, firstly, error due to temperature de-calibration. Meter calibration assumes a stable relation between oscillator frequency and filter frequency response. Uneven temperature drift in the corresponding circuits (IC_5, IC_6, IC_7) alters this relation and thus, meter calibration becomes temperature sensitive. By using temperature-stable capacitors, properly matched, the 5 kHz frequency oscillator and the two active filters can be made to drift evenly. In this way, de-calibration error on the prototype was limited to <0.2% from 0 to 50°C.

Secondly, there is a linearity error due to distortion of the 5 kHz sinewave. The meter measures the d.c. value of the a.f. envelope. Detection of low voltages is r.m.s. sensitive. Any change in the relation between the envelope d.c. and the a.f. r.m.s. affects linearity, mostly in the most sensitive subrange. Distortion, harmonics, line hum and modulation must be avoided. Measurements on the prototype showed <1% t.h.d. and harmonic levels <−47dB for the 2nd and <−50dB for the 3rd respectively. The transformer used is purpose wound on a ferrite core for low distortion. Primary and secondary have 2,000 turns, while the taps are on 200 and 20 turns. Transistor-radio audio transformers of suitable turns ratio can be used as an alternative. Modulation can occur from control-loop instability, but the specified capacitors $C_{4,5,9,10}$ ensure stable operation. The a.f. comparison voltage must be free from a.m. modulation with c.w. r.f. meter input. The r.m.s. value of a modulated signal is

$$V_{rms} = V_c\sqrt{1+\frac{m^2}{2}}$$

where V_c is the r.m.s. value of the carrier,
V_m is the r.m.s. value of the modulating signal
m is the degree of modulation V_m/V_c

PERFORMANCE

The meter was tested in conjunction with Rohde and Schwarz SMS-type r.f. signal generator. Linearity was tested throughout

subrange	V_{rf}	input impedance	frequency 10mHz	100MHz	250MHz	500MHz	1GHz
2V −200mV	1V	100kΩ/4pF	0dB	−0.4dB	−0.5dB	+0.5dB	+1.7dB
200mV− 20mV	100mV	45kΩ/5pF	0dB	−0.3dB	−0.6dB	−0.7dB	−2.1dB
20mV − 2mV	10mV	20k6pF	0dB	−0.3dB	−0.7dB	−1.0dB	−3.1dB

the meter range, at 10 MHz, with the generator terminated into 50 ohms. Composite generator-meter error (expressed as a percentage of the reading, not of the f.s. value) is

subrange	error
2V -200mV	+/−1.5%
200mV- 20mV	+/−0.7%
20mV - 2mV	+/−0.5%

The same results were obtained with the generator unterminated. For the frequency-response test, the generator was left unterminated in order to reduce to the minimum the components between generator and probe. One N-type-to-BNC adaptor was inevitably used. The frequency response of the generator-adaptor-probe combination for one of the prototype probes is given above. Among the above voltage levels a frequency-response disagreement can be noticed. It can be readily explained by the variance of the input impedance with V_{rf}. Indicated approximate impedance values are for <10 MHz. Input capacitance given includes shunt capacitance of the diodes, stray capacitance and that of the BNC connector. More moderate values of the order 3 to 4pF are possible.

Sensitivity at 10 MHz is 0.2mV for one stable digit, 0.5mV for two stable digits and 1.0mV for three stable digits.

References

1. Rohde & Schwarz: 'URV RF-DC Millivoltmeter' (operation and service manual).
2. R. W Landee, D. C. Davis, A. P. Albrecht, L. J. Giacolleto: 'Electronics designers' handbook', McGraw-Hill, New York, 1977, pp. 24-138, 24-142.
3. National Semiconductor: 'Audio handbook', 1976, pp. 5-3, 5-5.

Nicos Michaelides obtained his degree in electrical engineering, National Technical University of Athens, in 1973. He is currently working for the Greek Radio Television ERT.

Orthogonal functions — an introduction to Walsh functions

The use of Walsh functions reduces transforms to simple arithmetic, mainly addition, well suited to present-day processing methods. Only one set of functions – and therefore coefficients – is involved, instead of the two of Fourier analysis.

CHARLES H. LANGTON

Orthogonal functions are not new nor are they a special set of functions as trigonometrical or exponential functions are. Rather it is the property of orthogonality possessed by certain groups of already existing functions that is important.

The application of this mathematical concept has become more widespread in electronics in recent years because it has been found useful in analysing problems in communications such as modulation and multiplexing, computer switching networks, and pattern recognition systems. Perhaps the best known application of orthogonal functions is in the Fourier analysis of complex waveforms, although many textbooks on Fourier tend to play down, or not even mention orthogonality. Walsh functions are another group owing their prominence to orthogonality.

When testing a particular function for orthogonality it must be compared with another function having the same variable. The two functions are then orthogonal, or not orthogonal, according to the result of the test. For example, although the functions sin(at) and sin(bt) may be orthogonal, sin(at) and sin(bx) are certainly not because by definition any two functions are said to be orthogonal over a certain specified interval. Sin(at) is a function of time, and as such the interval must have the dimension of time. Sin(bx), on the other hand, is a function of some variable x and as such the interval must be of an appropriate dimension.

To determine whether two signals, f(i,t) and f(j,t) say, are orthogonal over a given interval T, it is necessary to integrate the product of the two signals with respect to t, over the range $0 \leq t \leq T$. Then, to be orthogonal, the result of this integration must be non-zero when the two functions are identical (that is when i equals j). Additionally, the result must be zero for all other cases (when the functions are not identical). This is written as

$$\int_0^T f(i,t).f(j,t)\,dt = \begin{cases} o \text{ for } i=j \\ k \text{ for } i=j \end{cases}$$

If the non-zero value k when the functions are equal is unity, the functions are described as orthonormal.

CIRCULAR FUNCTIONS

Since and cosine functions form the most widespread orthogonal system in use. The set of such functions is complete. Consider the set of circular functions in Fig. 1, harmonically related to the fundamental frequency ω radians per second, and observed over the interval $T=1/f=2\pi/\omega$ seconds.

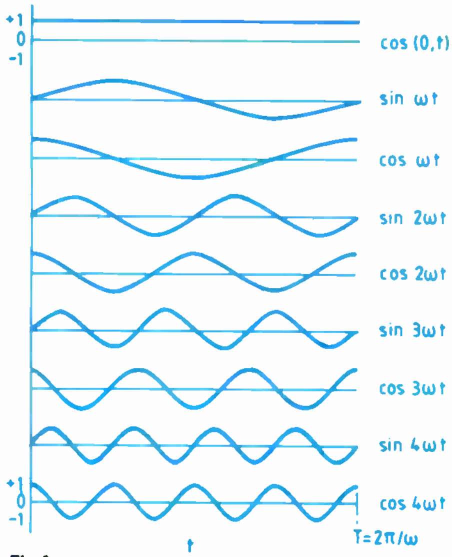


Fig.1.

We know, thanks to Fourier, that by choosing appropriate combinations of the eight waves shown, plus the d.c. level, at the correct amplitudes and then adding them together, an approximation to any single valued, repetitive complex waveform with period T may be synthesized. For a closer approximation extend the set to include higher order harmonics, 5ωt, 6ωt, etc.

The reverse process to synthesis, waveform analysis, is not easy, until we recall that harmonically related sine/cosine waves are orthogonal. Then it becomes a simple matter in principle to multiply each cosine wave (cosωt, cos2ωt, etc.) in turn with the function f(t) of the unknown waveform, and integrate this product for $0 \leqslant t \leqslant T$ where T is the period of f(t). Just like trying different keys in the lock.

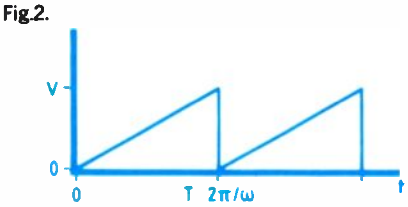
When the right key is chosen, the integral will not only have a non-zero value, but this value can be the coefficient of cos(rωt), telling not only that cos(rωt) is present in f(t), but also how much of it is present.

Unlike a good lock, it is possible that several cosine terms may 'click' when analysing a complex wave. The cosine coefficient are usually denoted by a_1, a_2, etc., and so a complete set of cosine terms will be $a_1\cos\omega t$, $a_2\cos 2\omega t$, $a_3\cos 3\omega t$, . . . $a_n\cos n\omega t$. Of course, if any of the terms do not exist in f(t), the corresponding coefficients will be zero.

Having tested each cosine wave against f(t) and obtained a set of cosine coefficients, the same procedure is repeated, this time testing the set of sine waves against f(t). Those that click will produce a non-zero integral, and this is given the letter b and appropriate suffix. The set of sine terms in f(t) will then be $b_1\sin\omega t$, $b_2\sin 2\omega t$, etc., up to $b_n\sin n\omega t$. Again, some of the coefficients will very likely be zero.

A partial example will exemplify this. Consider a repetitive sawtooth wave that rises linearly from zero to a maximum value V in a period T seconds, and having zero flyback time (Fig.2). The equation of this function is f(t) = Vt/T. To determine the amplitude of any term, say cos3ωt, that may possibly be present in this sawtooth, follow the directions indicated above. Thus:

Fig.2.



$$a_3 = \frac{2}{T}\int_0^T f(t)\cos(3\omega t)dt$$

$$= \frac{\omega}{\pi}\int_0^T \frac{V}{T}.t\cos(3\omega t)dt$$

$$= \frac{\omega V}{\pi T}\int_0^{2\pi/w} t\cos(3\omega t)dt = 0.$$

Thus there is no component cos3ωt present in the given waveform. If the calculation is performed with cosωt, cos2ωt, or any harmonic of this cosine series the result will be zero, i.e. $a_1 = a_2 = a_3 = \ldots = a_n = 0$.

Turn now to an investigation of the sine terms. Starting with sinωt:

$$b_1 = \frac{2}{T}\int_0^T f(t).\sin\omega t\,dt$$

$$= \frac{\omega}{\pi}\int_0^T \frac{V}{T}\ t.\sin\omega t\,dt$$

$$= \frac{\omega V}{\pi T}\int_0^{2\pi/\omega} f(t).\sin\omega t\,dt$$

$$= \frac{\omega V}{\pi T}\left[-\frac{2\pi}{\omega^2}\right] = -\frac{V}{\pi}\text{, as } T=2\pi/\omega.$$

In a similar way the coefficient of the second harmonic b_2 is $-V/2\pi$, that of the third harmonic $b_3 = -V/3\pi$, and the nth coefficient $b_n = -V/n\pi$. Hence all the sine terms are present in the ideal repetitive waveform represented by the equation f(t) = Vt/T.

WALSH FUNCTIONS

Sine/cosine waves are not the only ones that lend themselves in this way as building bricks in the assembly of complex waves. Sets of rectangular pulses may also be employed, and in digital processing this type of pulse is more readily available in a system than are sinusoidal waves.

Walsh functions are two-valued pulses, nominally +1 and −1. These can easily be translated into 0 and 1 levels, suitable for use in any normal two-state system. The mark-space ratio in general is non-uniform, which makes it difficult to define the frequency of such waves. Instead, the term sequency is used, defined as

$$\text{sequency} = \tfrac{1}{2}\left[\begin{array}{l}\text{average number of zero}\\ \text{crossings per second}\end{array}\right]$$

the unit being zs^{-1}.

Walsh waveforms are defined over an interval $0 \leqslant t \leqslant T$ and the wave will be sampled N times during this interval, where N is a binary number; less than 16 sample points would normally be too crude. When sampled it is usual to define the sample points as $\theta_0, \theta_1, \theta_2, \ldots \theta_{N-1}$.

Walsh functions must be used in sets. The number of functions in a set must be a binary number having the same value as N. The position of a particular function in the set is the order number n = 0, 1, 2, . . . N−1. It is usual for sets of Walsh functions to be drawn as a series of rectangular waves although as such waves are sampled it is more correct to indicate the sampled points θ_i only. Fig.3 shows a set of eight Walsh waves.

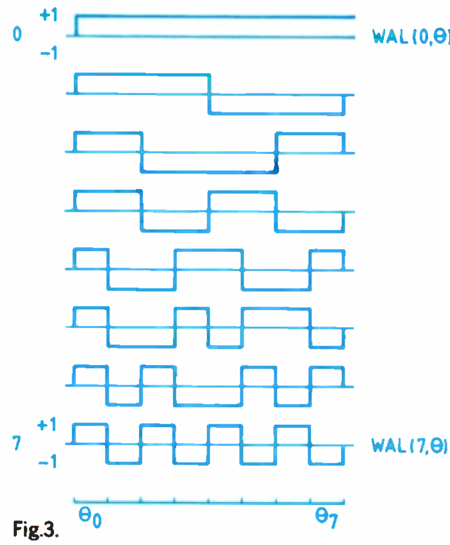
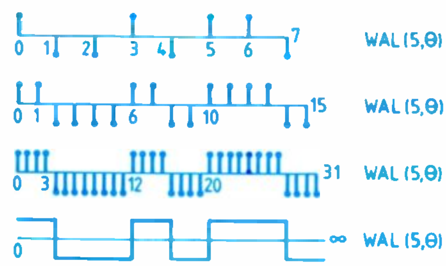


Fig.3.

The diagram above represents a complete set of WAL(n,θ) waveforms for N = 8.

It is interesting to note that for any value of N, the form of the i[th] (permissible) order is the same. To illustrate this point, WAL(5,θ) is drawn below for N = 8, 16, 32, and infinity.



As N increases, the definition improves. As $N \rightarrow 8$, the waveform approaches a rectangular shape.

The instantaneous value of any Walsh function can only be +1 or −1. To specify an instantaneous value, two arguments are required. First it is necessary to specify the order of the function, and secondly the instant θ at which the function is sampled. So the general way of expressing a Walsh function is WAL(n,θ). In Fig.3, for example, WAL(5,3) = −1.

DERIVATION

But how are these functions derived in the first place? There are two main routes. The first is to use a rather bulky formula which is tedious to perform. An oversimplified version of the formula could be:

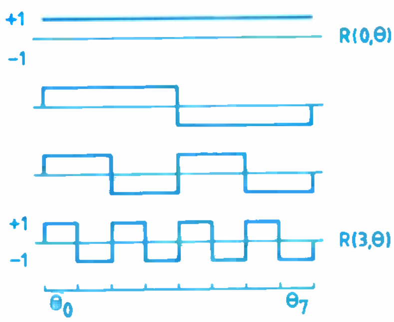
$$\text{WAL}(n,\theta) = \prod_{r=0}^{p-1}(-1)^{k_r}$$

where $2^P = n$. k_r always works out as an integer, therefore $(-1)^{k_r}$ will be (−1) or (+1) according to whether k_r is odd or even. The sign π stands for repetitive multiplication of $(-1)^{k_r}$ for all values of r from zero to p−1.

Hence, the final value of WAL(n,θ) can only be the result of several values of +1 or −1 multiplied together, hence WAL(n,θ) = ± 1 as stated. The table gives all the values of WAL(n,θ) for N = 8, n = 0 to 7, θ = 0 to 7.

Order n	Normalized discrete instant θ								
	0	1	2	3	4	5	6	7	
0	1	1	1	1	1	1	1	1	WAL(0,θ)
1	1	1	1	1	−1	−1	−1	−1	WAL(1,θ)
2	1	1	−1	−1	−1	−1	1	1	WAL(2,θ)
3	1	1	−1	−1	1	1	−1	−1	WAL(3,θ)
4	1	−1	−1	1	1	−1	−1	1	WAL(4,θ)
5	1	−1	−1	1	−1	1	1	−1	WAL(5,θ)
6	1	−1	1	−1	1	−1	1	−1	WAL(6,θ)
7	1	−1	1	−1	1	−1	1	−1	WAL(7,θ)

The second method is simpler and based on a set of harmonically related square waves described by Rademacher in 1922.* Walsh defined his own functions in 1923. Rademacher functions were later found to be a subset of Walsh functions. Here are the first four Rademacher functions:



Although Rademacher functions do not form a complete set, they are easy to remember and are useful because they enable Walsh functions to be determined more easily. The relation between the two is:

$$R(k,\theta) = WAL(2^k-1,\theta) \qquad (1)$$
$$k = 0,1,2,\ldots$$

Hence

$R(0,\theta) = WAL(0,\theta)$
$R(1,\theta) = WAL(1,\theta)$
$R(2,\theta) = WAL(3,\theta)$
$R(3,\theta) = WAL(7,\theta)$
etc.

The remaining Walsh functions that are Rademacher functions may be developed from the known Rademacher functions by the relationship:

$$WAL(i,\theta).WAL(j,\theta) = WAL(i\oplus j,\theta) \qquad (2)$$

where ⊕ is modulo-2 addition (exclusive-OR), and the dot signifies multiplication.

EXAMPLE

An example may be useful. Look for the Rademacher equivalent of WAL(2,θ). First express the order of WAL(2,θ) in binary. Thus

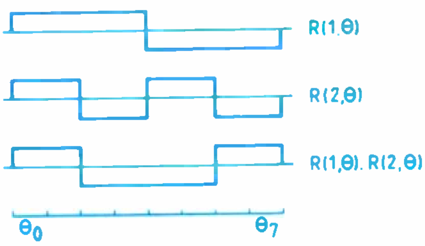
$$WAL(2,) = WAL(010_2,\theta).$$

Then find two binary numbers which, in modulo-2 addition add up to 010_2. Recall that in modulo-2 addition you never carry one.

$$010_2 = 001_2 \oplus 011_2$$

$\therefore WAL(2,\theta) = WAL(001_2 \oplus 011_2,\theta)$
$= WAL(1\oplus 3,\theta)$ reverting to decimal
$= WAL(1,\theta).WAL(3,\theta)$ from equation 2
$= R(1,\theta).R(2,\theta)$ from equation 1

The next diagram shows R(1,θ) and R(2,θ), and also their product. You can see this is identical to WAL(2,θ).



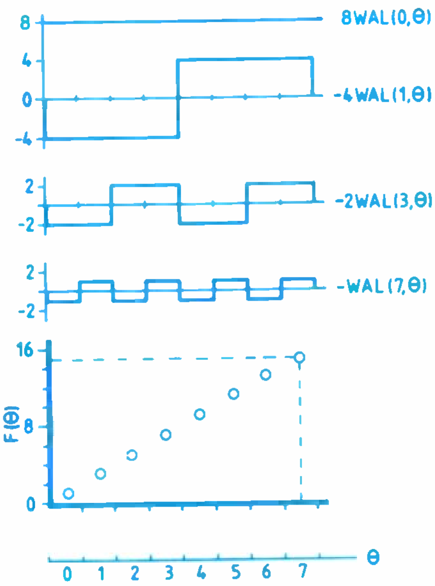
You may like to show that WAL(4,θ) = R(2,θ).R(3,θ).

WAVEFORM SYNTHESIS

Now take a number of Walsh waves and add them together algebraically so as to produce a complex waveform. As an example, let

$$F(\theta) = 8WAL(0,\theta) - 4WAL(1,\theta) - 2WAL(3,\theta) - WAL(7,\theta).$$

The four Walsh terms drawn to the same timebase, N being 8, are:



The sum of the samples taken at each instant is plotted on the lower axes. This shows a set of points F(θ). If the Walsh timebase was repetitive, F(θ) would have the form of a sawtooth, not unlike that shown in Fig.2.

WAVEFORM ANALYSIS

For a complex waveform f(t) it is possible to perform the reverse process of synthesis, that is analysis, and determine the content of the wave in terms of a series of Walsh functions:

$$a_0WAL(0,\theta), a_1WAL(1,\theta), \ldots a_rWAL(n,\theta).$$

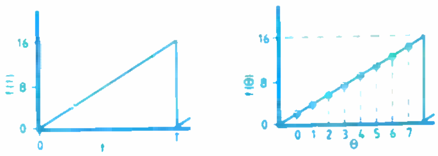
This is because Walsh functions form a complete orthogonal set, and a complex wave can be tested against each function in turn to see if the function is embedded in the wave. Very similar to Fourier analysis in fact.

The test for the magnitude of the nth Walsh coefficient a_n is to apply the following equation:

$$a_n = \frac{1}{N}\sum_{\theta=0}^{N-1} F(\theta).WAL(n,\theta) \qquad (3)$$

F(θ) is the original complex waveform sampled N times, N being as defined previously. Note that as f(θ) is a sampled function, i.e. not continuous, summation may be used instead of integration, as employed in the Fourier example.

Again, a worked example may be useful. Consider once again the sawtooth function f(t) shown and its sampled counterpart:



In this example we determine the value of the coefficient of the third order, $a_3WAL(3,\theta)$, assuming that N=8.

When θ =	0 1 2 3 4 5 6 7	
F(θ) =	1 3 5 7 9 11 13 15	from Fig.9
WAL(3,θ) =	1 1 −1 −1 1 1 −1 −1	from Table 1

Then, from equation 3,

$$a_3 = \tfrac{1}{8}[1(+1)+3(+1)+5(-1)+7(-1)+9(+1)+11(+1)+13(-1)+15(-1)]$$
$$= \tfrac{1}{8}[1+3-5-7+9+11-13-15]$$
$$= \tfrac{1}{8}[-16] = -2.$$

∴ third-order term = −2WAL(3,θ).

The other terms in the series may be obtained in the same way, so that if

$$f(t) = \frac{V}{T}.t = \frac{16}{8}.t = 2t,$$

the Walsh transform of f(t) is

$$F(\theta) = 8WAL(0,\theta) - 4WAL(1,\theta) - 2WAL(3,\theta) - WAL(7,\theta).$$

The rest of the terms are zero. Note that a_0 (eight in this case) represents the mean value of the wave.

This, of course, is the function we first thought of when considering the synthesis of a complex wave, so we have completed the cycle of transformation.

Many calculations using Walsh functions reduce to the product of (±1) and (±1). It is possible to replace the arithmetical operation of multiplication by the logical operation of exclusive-OR thereby speeding up the process. This is done by storing all data levels of +1 as zero, and all data levels of −1 as one as summarized in the table.

Arithmetical multiplication	Logical exclusive-OR
+1 . +1 = +1	0 ⊕ 0 = 0 converts to 1
+1 . −1 = −1	0 ⊕ 0 = 1 converts to −1
−1 . −1 = +1	1 ⊕ 1 = 0 converts to 1

Further reading

Beauchamp, K. G., Walsh functions and their applications Academic Press, New York (1975).
Harmuth, H. F., Transmission of information by orthogonal functions. Springer-Veriag (1972).
Roddam, T., Walsh functions, *Wireless World* Dec. 1981, Jan. 1982.

Charles Langton, M.Sc., M.I.E.R.E., is a chartered engineer operating as a freelance development engineer and technical author based at York.

*The same year in which the BBC was established – irrelevant, but it forges a link between Walsh functions and *Wireless World* readers.

Economical digital audio for broadcasting

Delta modulation codec provides an efficient and cost-effective means to convey a multiplicity of high quality audio and audio-with-video programming via satellite, cable tv and terrestrial broadcasting

STEVEN E. FORSHAY

Digital systems are attractive for signal delivery to consumers in that excellent audio performance is achieved in poor reception conditions, and effective scrambling algorithms are easily implemented without compromise in signal integrity. Digital broadcast systems proposals to date have employed both linear and companded forms of p.c.m.

Linear p.c.m. systems with the necessary dynamic range for high quality audio (e.g. 80 dB) offer excellent performance but are less desirable in consumer broadcast applications due to the high rate (500 to 700 kb/s per channel). The cost and implied manufacturing precision in d.a.cs (0.01% for 80dB dynamic range) and anti-aliasing filters is also of concern.

Good performance and a bit-rate reduction to perhaps 330kb/s can be achieved using fixed emphasis, simplified error protection, and a suitable digital companding algorithm around a p.c.m. codec of at least 10-bit full-scale resolution. The Nicam codec system[1] developed by the British Broadcasting Corporation is an example of such a system. Companded p.c.m. systems offer a reduction in transmission bandwidth requirements, but the cost of precision converters and anti-aliasing filters necessarily remains.

Efficient digital transmission implies a low sampling rate while high quality implies audio bandwidth to at least 15kHz; these conflicting goals place tighter restrictions on anti-aliasing filter design and ultimately limit the extent to which filter cost can be reduced. In addition, viable p.c.m. systems require error concealment or correction which adds significantly to consumer hardware complexity and cost.

There is no doubt that well designed p.c.m. systems can satisfy consumer demand for quality service but the inherent cost of precision d.a.cs, multi-pole anti-aliasing filters, and error-correction circuitry may continue to be a deterrent to large-scale consumer acceptance.

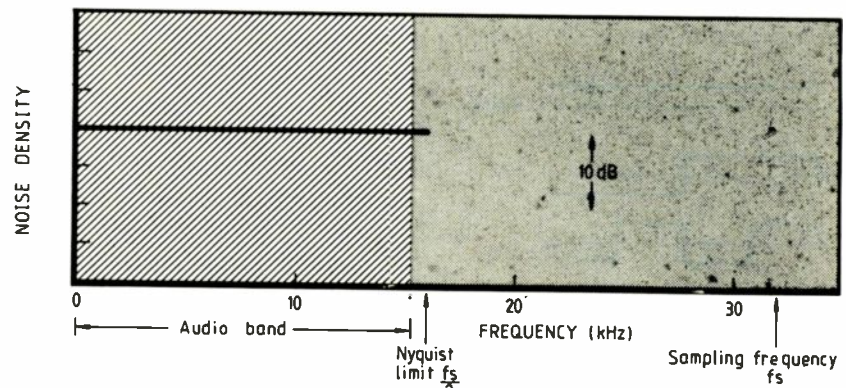


Fig.1. In a pulse-code modulation codec quantization noise is uniformly distributed over the Nyquist bandwidth.

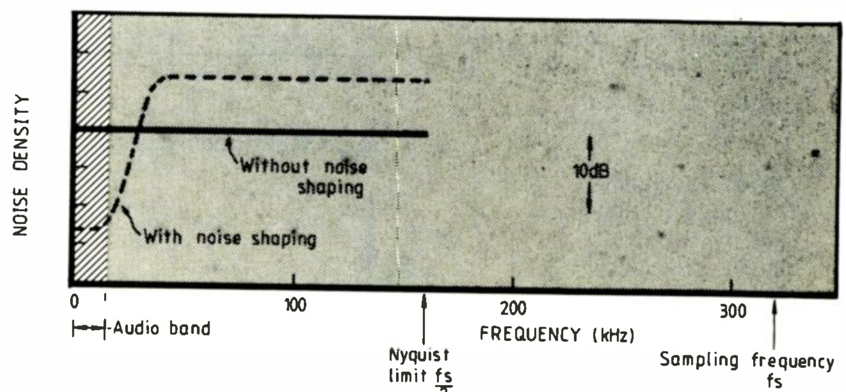


Fig.2. In a delta modulation codec noise shaping can be used to reduce the amount of in-band quantization noise.

DESIGN OBJECTIVES

In development of an efficient and cost-effective transmission coding scheme several important goals must be achieved in a balanced approach:

- The codec system must be faithful in reproduction of high quality source program and be fully complementary in its signal processing. The system should provide high quality transmission means consistent with present day technology and likely future expectations.
- The system must be economically viable and practical in operation in order to ensure long-term acceptance. Hardware costs, especially consumer hardware, and transmission efficiency must be well-balanced with performance and future flexibility.
- The system should offer robust performance and minimal audible degradation in the presence of worst-case errors.

DELTA MODULATION

Prior research work in development of a digital audio recording system based on delta modulation[2] led us to consider a variation on the technique for consumer broadcast media, where delta modulation has the following significant advantages over p.c.m:

- The delta demodulator (a passive integrator) is inherently simple and can be manufactured with much less precision than a multi-level p.c.m. d-to-a converter.
- The audio signal is highly oversampled, thereby eliminating the need for complex anti-aliasing filters.

● All bits are of equal weight so that isolated bit errors have minimal audible effect (in contrast to m.s.b. errors in p.c.m.). Good error performance can be achieved with a low overhead error concealment technique (discussed later).

ADAPTIVE DETLA MODULATION

Delta modulation can be used to achieve significant advantages in bit-rate and cost. However, linear delta modulation at the rates under consideration (200 to 300 kb/s) has insufficient dynamic range for high quality reproduction. An adaptive delta modulation scheme therefore seemed desirable.

Quantization noise in any properly dithered, sampled and quantized codec system appears approximately uniformly distributed over the Nyquist bandwidth. In any companded codec, noise modulation (program modulated quantization noise) must be considered.

In digitally companded p.c.m. systems quantizing accuracy (number of bits per sample) decreases according to the companding law with increasing signal level. Noise modulation is produced as a result of quantization accuracy varying from fine at low signal levels, to coarse with signals approaching full scale. High-level l.f. signals can produce audible h.f. noise modulation as only minimal noise masking is provided by the signal spectrum. Fixed high frequency pre-emphasis can reduce noise audibility with a commensurate compromise in high frequency headroom. Such a system may work well if low frequency noise is sufficiently low and the compromise in high frequency headroom, is acceptable. In contrast to straight p.c.m., noise modulation in a differential system such as a.d.m. is produced by high slope signals (i.e. signals of high frequency and level). This charateristic is quite acceptable and possibly preferable to that of companded p.c.m. in that high frequency signals are more effective at masking high frequency noise.

Conventional a.d.m. schemes code the audio signal and step-size scaling information into a single bit-stream. Step-size adaptation information is derived by monitoring the output data stream; such systems are referred to as being output-controlled, with the significance of individual output bits varying according to the particular adaption algorithm chosen. These are inherently sensitive to errors occuring in critical gain control bits which produce annoying impulsive changes in signal amplitude. The magnitude of this effect can be reduced by slowing the adaption rate but transient response is then degraded. System design becomes a compromise between acceptable error performance which requires a slowly varying scaling signal, and good transient performance which requires fast adaption.

Use of fixed pre-emphasis can yield a good compromise between audible noise modulation and low to middle frequency headroom. However, even if the reduction in high frequency headroom is acceptable, the de-emphasis characteristic only serves to increase the audibility of low frequency noise components which may not be masked by signal.

Output-controlled a.d.m. is therefore unlikely to meet the requirements of a high quality codec system.

Quantization noise in a properly designed codec is approximately uniformly distributed over the Nyquist bandwidth. In over-sampled systems such as delta modulation much of the noise power is outside the audio band and noise shaping[3] can be employed to redistribute the quantization error energy so as to reduce the in-band noise level at the expense of out-of-band noise. Figure 1 illustrates the noise distribution for a 32kHz sampled p.c.m. system. Figure 2 illustrates the benefit of noise shaping in an over-sampled system. The delta modulation system under consideration here operates at a minimum of six times over-sampling; noise shaping is employed to reduce the otherwise flat in-band noise spectrum at a 6dB/octave rate with decreasing frequency below about 15 kHz. Noise in the region of 1kHz is suppressed approximately 15dB.

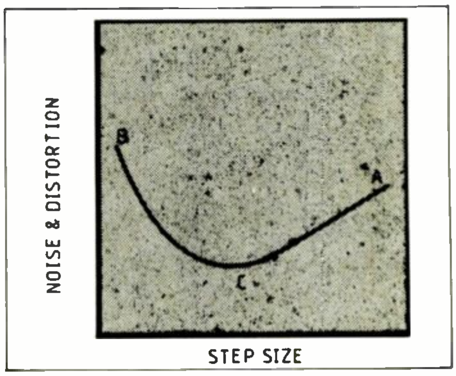


Fig.3. Small step size B introduces distortion due to slope overload, large step size A introduces excessive quantization noise. Optimum step size C minimizes noise and distortion.

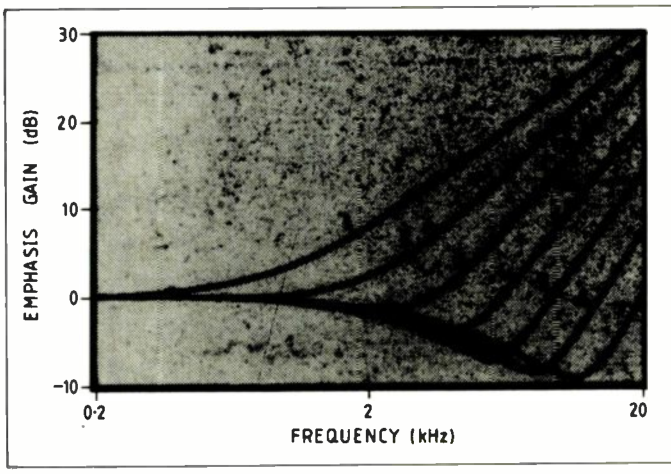


Fig.4. Examples of the continuously variable pre-emphasis curves.

OPTIMIZED DELTA MODULATION

Quantization error and distortion products at an a.d.m. codec output are functions of two varying parameters; step size and the audio signal itself. Consider the codec operating on a single sine wave. Output noise and distortion will vary qualitatively with step size as shown in Fig.3. In region A the step size is too large resulting in excess quantization noise. In region B step size is too small resulting in excess distortion and noise due to delta modulator slew-rate limiting. In region C step size is optimized so as to fully load the delta modulator and produce minimum quantization noise. Delta modulator performance can be optimized in a similar way for each short segment of audio if the step-size control signal is continuously variable.

Conventional output-controlled a.d.m. codecs operate in region A most of the time and move into region B on signal transients; codec performance is never quite optimized. In our system, delta modulator step size is input-controlled thereby achieving continuous optimum operation in region C.

VARIABLE EMPHASIS

Noise in an optimized a.d.m. system depends on the program signal. In the presence of a fixed-amplitude sine wave for example, codec noise is directly proportional to signal frequency. Conventional fixed emphasis can be effective in reducing quantization noise if the spectral components of the desired signal are predominantly low frequency in nature. However, h.f. signals boosted by the emphasis require greater step size and therefore produce more broadband quantization noise.

De-emphasis will restore the overall frequency balance and maintain the noise level in the region of the signal components at its original level before emphasis, but will increase the audibility of low-frequency noise components not masked by the program signal. For this reason conventional fixed emphasis alone is insufficient to provide high quality performance with a.d.m.

In studying the resultant quantization noise spectra in an optimized a.d.m. codec operating at 200 to 300kb/s there are three distinct operating modes to be considered if noise suppression via emphasis is to be optimized. The conclusions listed over are drawn on the basis that the predominant signal spectral components are confined to a narrow region of the audio band on a short-term basis. In fact, such a signal (sine wave) is the most critical case.

● When the dominant spectral components

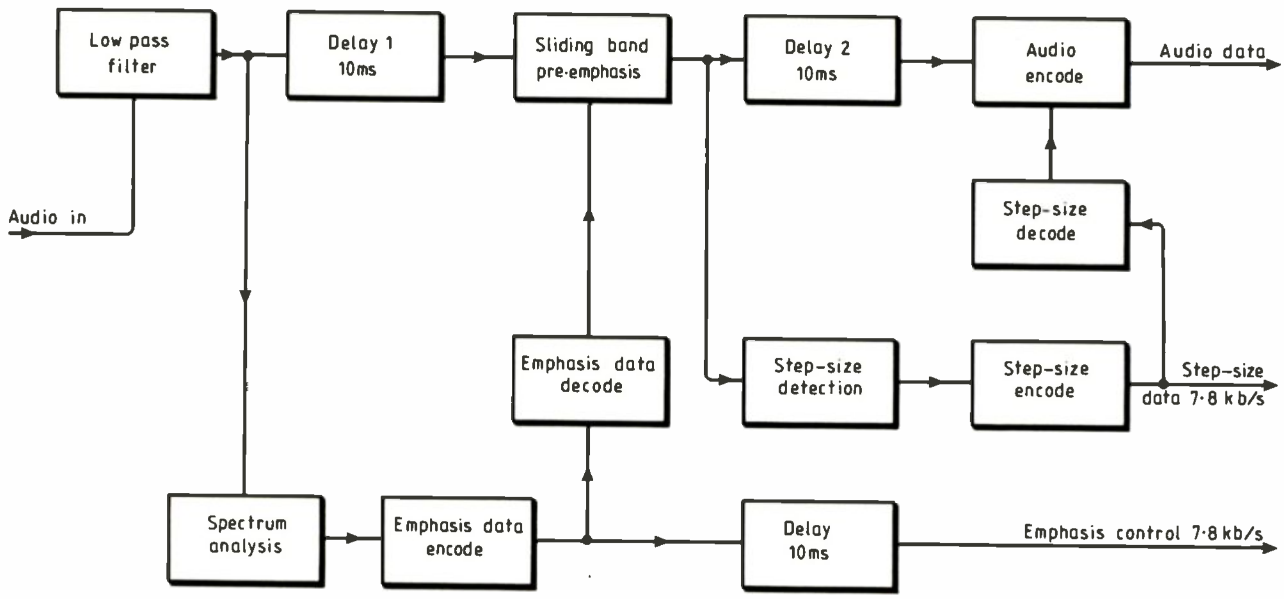


Fig.5. Simplified schematic of the adaptive delta modulation digital to analogue converter.

of the signal lie below 500 Hz substantial high frequency pre- and de-emphasis is desirable to eliminate noise audibility. Low frequency noise is masked by the signal.

- Dominant middle frequency signal components (i.e. 1 to 3kHz) still provide some low-frequency noise masking, but it is desirable to slide the emphasis up in frequency so as to maintain the benefit of high-frequency noise suppression without increasing the quantization noise by boosting the audio signal.
- Dominant signals above 3kHz can effectively mask noise in the region of the signal spectrum but noise at either end of the audible spectrum (particularly l.f. noise) will not be as well masked. A pre-emphasis curve with a notch in the region of the dominant signal spectrum will decrease the required step size and result in reduced quantization noise. Complementary de-emphasis will then pick out the signal components while suppressing both low and high-frequency noise not masked by the signal spectrum.

A family of pre-emphasis curves achieving the desired variable response is shown in Fig.4. Curve 1 is most appropriate for signals of predominant low frequency content. Response curve 3 is more desirable for signals with predominant middle frequency components. If the predominant signal components are in the 6kHz region, curve 5 would be the desired emphasis response.

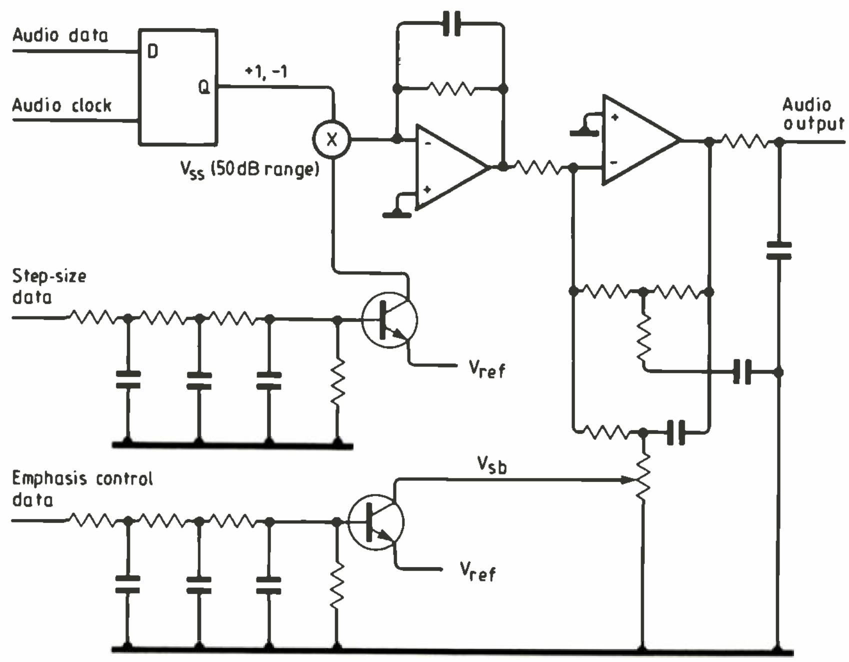


Fig.6. Adaptive delta-modulated encoder including generation of two low bit-rate control signals.

NARROW BANDWIDTH CONTROL SIGNALS

The adaptive operation of system frequency response or gain control via a control signal is a waveform multiplication process whereby control signal sidebands are superimposed on the spectral components of the audio signal. Depending on the extent of sideband spread and the nature of the program signal the audibility of such sidebands may become objectional.*

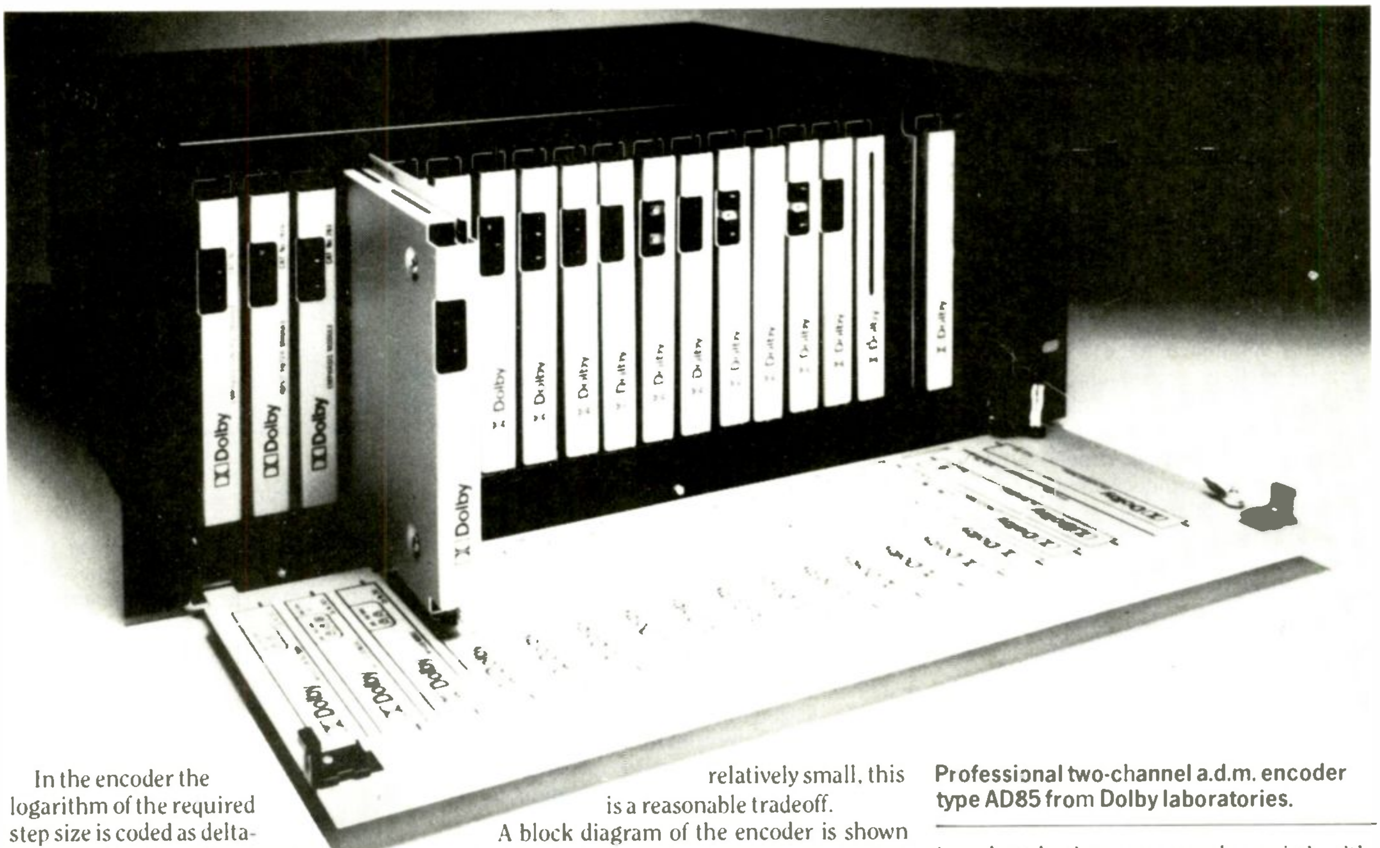
In the input-controlled codec system under consideration, control signals are generated in the encoder and conveyed to the decoder in separate 8kb/s data streams. The audio signal is analysed in advance through use of delay lines in the encoder; thus narrow band (50Hz) control signals can be used with no compromise in transient performance. The fact that the control signal is of narrow bandwidth and is greatly oversampled, leads to a robustness in performance in the presence of transmission bit errors, and with decoder parts of wide tolerance.

*In theory, complementary noise reduction systems introduce antiphase control sidebands during expansion. However, due to parts tolerances in practical circuit implementations, control sidebands may not be completely cancelled. To minimize the audibility of those components that remain taking advantage of the masking effects of large signals on closely spaced sidebands) it is desirable to reduce control-signal bandwidth as much as possible while maintaining system dynamic performance. The slower the control signal can be made, the more tolerant the system will be to control signal mistracking.

CONSUMER DECODER

In developing this new codec we realised that the complexity of the decoder circuitry appearing in the consumer's home could be greatly reduced at the expense of some additional complexity in the encoder; this is a fundamental aspect of our approach.

A conceptual diagram of the consumer decoder is shown in Fig.5. Each single channel decoder receives three data streams; audio data, step-size control data, and emphasis control data. The audio data-rate is typically in the range of 200 to 350kb/s, while the step size and emphasis control data are at much lower data rates, typically around 8kb/s each. In audio-with-video applications a convenient data rate is half the horizontal line rate.



Professional two-channel a.d.m. encoder type AD85 from Dolby laboratories.

In the encoder the logarithm of the required step size is coded as delta-sigma modulation. The step size control signal is decoded by low-pass filtering the step-size data stream to recover its average value and exponentiating the resultant voltage. The emphasis control signal is decoded in an identical fashion, and is used to control the variation in pole frequency in the adaptive de-emphasis network.

Wide dynamic range audio is recovered by multiplying the incoming audio data by the decoded step-size control signal, and integrating the resultant signal in a leaky integrator. The recovered audio is then dynamically de-emphasized; a final single de-emphasis pole provides sufficient attenuation of spurious out-of-band components that no further output filtering is required.

The decoder is relatively simple and does not require components of extraordinary precision. Performance degradations produced as a result of component tolerances produce errors in gain and frequency response similar to analogue systems; no mechanism exists for creation of high-order non-linearities such as those produced by non-monotonic p.c.m. converters.

Decoder cost is low. The original decoder design using available discrete components – at a cost of about £4 for a two-channel circuit – has been superseded by a specially designed integrated circuit from Signetics. This 28-pin two-channel device requires only a few external components to achieve the low-pass filtering of the two control signals and a simple low-pass audio output filter.

PROFESSIONAL ENCODER

The fundamental requirement of the system encoder is to produce the necessary bit streams for high quality reproduction via the cost-effective decoder. The encoder is significantly more complex than the decoder, but as the number of encoders required is relatively small, this is a reasonable tradeoff.

A block diagram of the encoder is shown in Fig.6. The audio input signal is first low-pass filtered to remove any spurious components. The spectrum of the band-limited audio is then analysed to determine the optimum emphasis characteristic to minimize the audibility of quantization noise in the presence of that particular signal spectrum. An emphasis control signal is generated and encoded in a low data-rate bit-stream, and locally decoded for control of the encode variable emphasis. By definition, the control signal decode operation limits the recovered control signal bandwidth to approximately 50 Hz, corresponding to a rise time of about 10ms. The audio is therefore delayed by 10ms before pre-emphasis.

Emphasized audio is examined in the step-size detection circuitry to determine the signal slope and corresponding optimum step size. The logarithm of this value is coded into the step-size data stream and decoded with an identical bandwidth limitation as that of the emphasis control signal. The emphasized audio is delayed a further 10 ms before being applied to the delta modulator.

Since the emphasized audio is delayed relative to the emphasis control signal, an equal delay of 10ms is required in the emphasis control data path so that all data arrive properly timed at the decoder.

ERROR CONTROL

Step-size and emphasis control signals are of narrow bandwidth and are greatly oversampled in the encoding process. As a result, errors occuring in the control bit streams produce only minor audible effects; error rates approaching 10^{-2} can be tolerated without correction.

The effects of reproduced errors in p.c.m. and delta modulation systems are quite different. Those in p.c.m. introduce audible impulses lasting one sample period with amplitudes corresponding to the significance of the bit in error. Errors in the most significant bit will produce impulses of half full-scale. In contrast, an error in a delta modulation system will produce a small exponentially decaying step extending over the decay time period of the decode integrator. Experimental results indicate that reproduced p.c.m. errors are virtually always audible, while the reproduced errors in practical delta modulation systems are more likely masked by the program spectrum. Therefore even at low error rates (i.e. 10^{-5}) a viable p.c.m. system necessarily requires some form of error protection, while a delta modulation system may perform quite well without error concealment or correction.

Error concealment in p.c.m. systems works by reducing the amplitude of error impulses through data interpolation or substitution. Concealment can give good results as long as errors are reliably detected, but at higher error rates, where concealment may break down, detection can become unreliable resulting in reproduction of many unconcealed errors. Signal muting is often employed under these conditions, but erratic muting is likely to be equally annoying.

In delta modulation, error concealment works by reducing the duration of the error step. In our scheme, encoded audio data is blocked into N-bit blocks and a modulo-4 summation is performed based on the number of data ones in the block. The two-bit result is transmitted along with the data block as redundant information. In the presence of single-bit errors, an identical modulo-4 summation performed in the decoder will yield information on the presence and polarity of the transmission errors.

On detection, the error is concealed by intentionally introducing an error of opposite polarity into the respective data block.

Since it is desirable to introduce the artificial error as close to the original error as possible, it is inserted in the middle of the concealment block. The time difference between real and artificially induced errors range between zero and N/2 bits; the average difference being N/4 bit periods. The step introduced into the audio will consequently average N/4 bit periods in length.

Note that 2/(N+2) errors will hit a concealment bit causing misconcealment. The probability of misconcealment can be substantially eliminated by carrying a third parity bit on the two concealment bits.

Pulse-code and delta modulation system operating with proper concealment will produce small error steps of similar duration. However, errors reproduced in a delta modulation system operating above the error rate where the concealment begins to break down are likely to be tolerable, thereby reducing the need to mute. A delta modulation system is likely to be usuable at an order of magnitude greater error rate than a p.c.m. system.

CODEC PERFORMANCE

In theory, the codec dynamic range can be greater than 100dB and is largely independent of audio data rate. Practical hardware implementations readily achieve 90dB.

Non-linear distortions are not inherent in delta modulation, but practical considerations in first generation analogue circuitry yield performance near 0.15%. In contrast to p.c.m. however, distortion decreases at lower operating levels.

At audio data rates near 300kb/s/channel subjective performance closely rivals 16-bit linear p.c.m. The minimum recommended audio data rate for high-quality audio applications is about 200kb/s/channel. At this data-rate codec performance is still quite good; noise modulation becomes audible only under critical listening conditions with high quality program material. Future improvements in encode technology may yield a further reduction in the recommended minimum bit-rate.

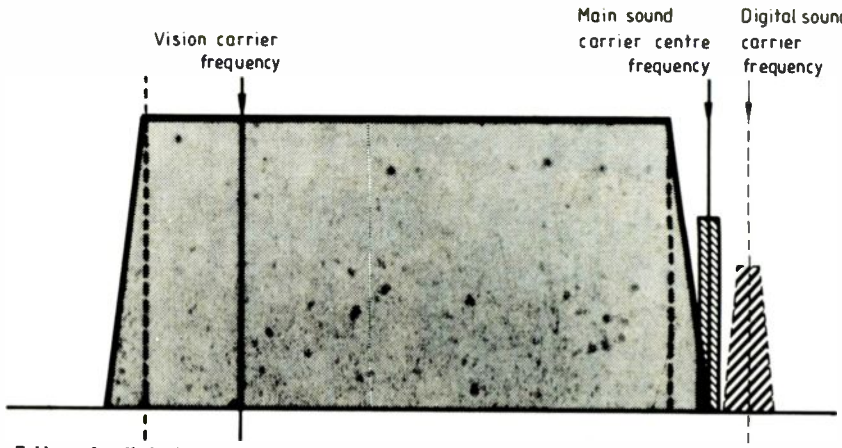


Fig.7. Use of a digital carrier within an existing television channel.

BROADCAST DATA FORMATS

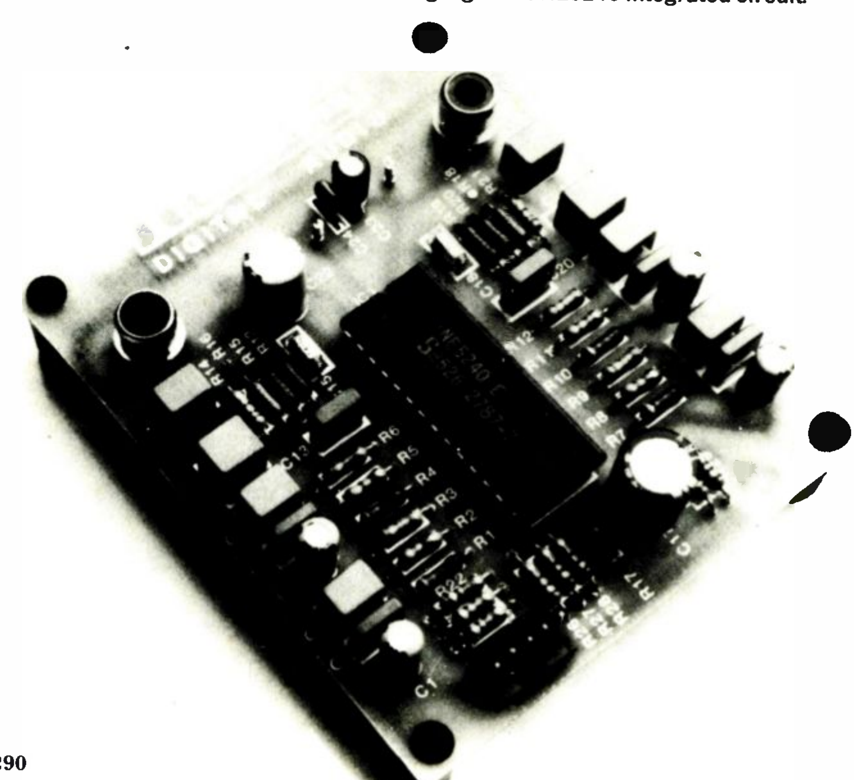
Use of any digital codec system in broadcasting requires some form of data formatting to permit subsequent synchronization and recovery at the receiver. Audio data is typically transmitted accompanied by recognizable synchronization patterns as a continuous stream, or in packets or bursts. Transmission of audio data in the horizontal blanking interval of an NTSC or PAL television signal or via data packets in MAC systems are examples of burst formats.

The data rate of our system is quite flexible. However, in audio-with-video applicants it is desirable to operate at a data rate coveniently related to video frequencies. Present systems use one-half horizontal line rate for control data and a multiple of the line rate for audio data. In one application 13 bits of audio data for each of 2 audio channels is transmitted on each line of an NTSC video format. A second system, using a B-MAC* format conveys six audio channels with 13 bits per line at an audio data rate of 204 kb/s.

An alternative method employing continuous transmission of digital signals is to use a digital subcarrier using a modulation scheme such as quaternary phase-shift keying to transmit the digital data. This technique is particularly suited to the transmission of high quality stereo sound on the existing terrestial television network where the new subcarrier can be placed above the existing analogue sound subcarrier Fig.7.

In addition to the B-MAC satellite broadcast system adopted in Australia, the independent television stations have recently decided on a professional distribution system for picture and up to four high quality audio channels. This uses a.d.m. on a single subcarrier above the vision signal (page 335-ed.).

Implementation of consumer decoder using Signetics NE5240 integrated circuit.



CONCLUSION

The delta modulation codec described provides an efficient, cost effective, and practical means to convey a multiplicity of audio and audio-with-video programming of excellent quality to consumers via d.b.s., cable tv and terrestial broadcasting systems. Further improvements in encoder technology should allow cost reductions leading to more widespread use. Future development will provide the means to further control the dynamic range of the received programme in the home without some of the limitations of existing compression and limiting systems.

*Adopted by the Australian Department of Communications for HACBSS satellite broadcasting.

Steven E. Forshay is with Dolby Laboratories, Inc. at San Francisco, California, and acknowledges original codec development by colleagues K.G. Gundry and C.C. Todd.

References

1. C.R. Caine, A.R. English, J.W.H. O'Clarey, Nicam-3: Near-instantaneous companded digital transmission for high-quality sound programs, *Radio and Electronic Engineer* vol. 50 no.10, pp. 519-530, 1980 October.
2. K.G. Gundy, D.P. Robinson and C.C. Todd, Recent Developments in Digital Audio Techniques, presented at the 73rd AES Convention, 1983 March (preprint 1956).
3. C.C. Cutler, Transmission Systems 'Employing Quantization, U.S. Patent 2927962 (1960).
4. C.C. Todd and K.G. Gundry, Digital Audio System for Broadcast and Prerecorded Media, presented at the 75th AES Convention, 1984 March (preprint 2071).
5. K.G. Gundry, Audio Broadcast System Using Delta Modulation, presented at the 19th Annual SMPTE Television Conference, 1985 February.

Pioneers

3. André Marie Ampère (1775-1836), father of electrodynamics.

W.A. ATHERTON

Execution by guillotine is a grisly death. For an 18-year old to have his dear father die in that way is a profound psychological shock. Ampère's father died on the guillotine during the French Revolution on 22nd November 1793. Grief stricken, the man whose name we now remember on every plug, socket and fuse became a recluse for almost a year.

Though his life continued to be marred by tragedy and unhappiness, Ampère grew to become a respected mathematician and chemist, and an electrical physicist of world renown. Maxwell dubbed him the Newton of electricity.

Even if Ampère had died in the early months of 1820 he would still be honoured for his contributions to mathematics and chemistry. In France, for example, Avogadro's law is known as the Avogadro-Ampère law, Ampère having arrived at it just three years later. He was also narrowly beaten to the recognition of chlorine (1810) and iodine (1813) as elements, this time by Humphrey Davy. However it was his monumental work on electrodynamics from 1820 to 1827 which earned him a place in history. It was he who founded the subject and he who crafted the beauty of its structure.

André Marie Ampère was born in Lyons on 22nd January 1775. His father was a well-to-do merchant who moved his family out of the city soon after his son was born. Ampère grew up in a village. His home was his school. His education, provided and supervised by his father, seems to have consisted mainly of studying a large variety of books. In this way he discovered and developed interests in science, metaphysics, mathematics and poetry, even teaching himself Latin in order to read the mathematical works of Euler and Bernoulli.

Besides science and mathematics (and Latin!) Ampère also received a thorough grounding in the Roman Catholic faith. As with Oersted, his Christianity helped determine his view of nature. Throughout his life the teachings of Christianity and those of the 18th century philosophers, though not always mutually supportive, had great influence on him.

After the tragedy of his father's grotesque death, a year passed before Ampère began to rejoin the world, partly through a study of botany and by writing poetry. By the time he was 22 he had met the girl he was to marry, but had no skilled trade and only a small inheritance. Financial worries were never to be far away.

The couple married in 1799 and settled in Lyons, with Ampère earning a modest living by teaching mathematics. His first published paper, on the theory of games of chance, earned him a step up the academic ladder to the post of professor of physics and chemistry at Bourg, near Lyons, and more money.

Tragedy however struck again. After less than four years of very happy marriage his wife died. Plunged into grief and despair, Ampère left Lyons, with all its memories, for Paris.

There he made an unfortunate second marriage and was swindled by his new father-in-law. After a divorce he set up a new home in Paris with his mother and an aunt, where his two children, a son by his first wife and a daughter by his second, were raised. And there he conducted his immortal work.

Paris was now his home. He obtained a position at the renowned École Polytechnique, became a member of the Institut Imperial (1814), and in 1819 began teaching at the University of Paris. His contemporaries included Arago, Biot, Savart, Laplace and Poisson. It is said that he was the epitome of the absent-minded professor – even forgetting a dinner date with the Emperor Napoleon, so the story goes.

For the first time, an experiment on magnetism had been performed without a magnet...

For much of his life Ampère seems never to have been far from unhappiness, a stunning contrast to the public service he rendered. Late in life, it is said, he confessed that only a few years had brought him real happiness. He died alone in Marseilles on 10th June 1836, aged 61.

Oersted's epic discovery that an electric current produces magnetic effects was published on 21st July 1820 and it created a sensation. For many years there had been speculation that electricity and magnetism were somehow connected, yet Charles Coulomb some 30 years before had apparently proved beyond doubt that they were not. Oersted's news was conveyed by François Arago to an astonished meeting of the French Académie des Sciences on 4th September.

In the days and weeks that followed, Paris witnessed the spectacular birth of a new branch of science as Ampère dissected Oersted's discoveries and extended them. Others joined in, notably Arago, Jean Biot and Félix Savart in Paris, Johann Schweigger in Germany, and Davy in London.

But it was Ampère who became the major contributor to the new science of *electrodynamics*, the name which he gave to the newly-discovered phenomena. "It expresses their true character, that of being produced by electricity in motion", he wrote. The older type of electricity he named *electrostatics* – "phenomena produced by the unequal distribution of electricity at rest in the bodies in which they are observed" (1822).

As well as giving us these new words, Ampère carefully defined the terms electric current and electric tension (voltage), phrases which had until then been used very loosely. Ohm's Law, however, was still a few years away (1826-27).

After verifying Oersted's work Ampère expressed it as a law: if an observer had a current flowing from his feet to his head then a needle placed in front of him would have its north-seeking pole deflected to his left. Later this was re-expressed as the right-hand screw rule.

With electricity and magnetism now known to be related the question arose as to which of the two was the fundamental phenomenon.

To Ampère, electrical 'fluids' seemed more likely than magnetic 'fluids' as the fundamental cause, and so he formed an hypothesis that electric currents were the cause of magnetism. If that were true, then when an electric current caused a magnetic compass needle to move it could only be the

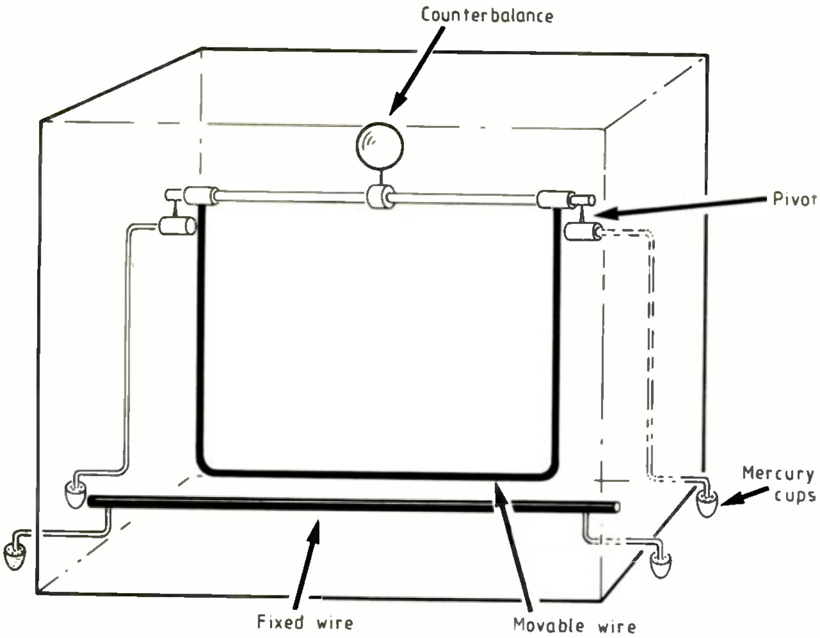


Fig 1: Ampère's experiment to show the magnetic effects of one (direct) electric current on another. The movable wire, hanging on pivots, would swing towards or away from the fixed wire when currents flowed. Connections to the wires were via cups of mercury.

result of electricity acting upon electricity. Therefore, he reasoned, two electric currents should interact via their magnetic effects. In a very clever experiment, suggested by Laplace, two parallel wires each carrying a current were shown to attract one another magnetically when the currents were in the same direction and repel when the currents were in opposite directions (Fig.1).

For the first time an experiment on magnetism had been performed without a magnet.

Ampère proved that these attractions and repulsions were not due to electrostatic phenomena. He described them as *voltaic* so as to emphasise the point. The name of Volta, the Italian inventor of the electric battery, was passing into electrical terminology.

Ampère also gave us the word *galvanometer*, an instrument he described as *"similar to a compass needle, which, in fact, differs from it only in the use that is made of it."*

He simply placed the conductor horizontally above or below the magnetic compass needle. The direction of movement of the needle indicated the direction of flow of the current through the conductor and the angle indicated the magnitude. He named the instrument after Galvani, the Italian usually credited with the discovery of the electric current. It was left to someone else to name its unit of measurement after Ampère himself.

With a little of what now might be called lateral thinking Ampère suggested another use for the galvanometer.

"By employing as many conducting wires and magnetized needles as there are letters, by fixing each letter on a different magnet ... we may form a sort of telegraph, by which we can write all the matters we may wish to transmit."

He also suggested a way of using a keyboard at the transmitter to make transmission easier.

Ampère's telegraph was never built and it is doubtful that his suggestion contributed to the electrical telegraphs which appeared a decade and a half later. But the galvanometer certainly did. When telegraphs did appear, codes were used to minimize the number of wires and needles needed.

Meanwhile in Germany, Schweigger had made a more sensitive galvanometer using a coil of wire of about 100 turns with a compass needle pivoted within it. Announced on 13th September 1820, it was this *multiplier* that became important in the early telegraphs.

Ampère also used coils of wire which he named *solenoids*. He and others showed that such coils could imitate all the effects of a magnet. These solenoids were developed into powerful electromagnets, notably by William Sturgeon in England and especially by Joseph Henry in America. By 1831 Henry had constructed a giant which could lift a ton.

Ampère now made a great conceptual leap.

A bar magnet itself could be explained, he suggested, by assuming the presence of circular electrical currents within it, running concentric to its axis. Such concentric currents might, he speculated, originate from contact between the molecules of the material. It was now only a short step for him to explain the Earth's magnetism as being caused by electric currents running from east to west.

However, Ampère's friend Augustin Fresnel, of wave theory of light fame, pointed out a serious flaw. Iron was not a very good electrical conductor and any such currents would produce a very noticeable heating effect in bar magnets. If Ampère was right, bar magnets should be warm, perhaps hot. And they are not.

Fresnel himself suggested a way out of the dilemma. Since nothing was known of the internal properties of molecules, why not assume circular currents within the molecules themselves? Ampère did. And he used this electrodynamic molecule in developing his mathematical theory of electrodynamics. The magnetism of a bar magnet was simply the sum of the magnetic effects of the molecular currents. Further, in materials such as iron, nickel and cobalt, the randomly-oriented molecular currents, which summed to give a zero effect, could be realigned by the action of other currents so as to produce a permanent magnet. In other non-magnetizable materials this realignment did not take place.

This theory was later considerably advanced by Wilhelm Weber and became the basis of his theory of electromagnetism. It is still basic to our understanding of magnetism.

Ampère pushed his electrodynamic molecule even further, suggesting that it was not only the source of electromagnetism but also of chemical combinations. He was suggesting a whole new theory of matter, but it had relatively few adherents.

It is of interest to note a comment of nearly a century and a half later. R.P. Feynmann, a renowned physicist discussing modern quantum electrodynamics in 1965 wrote: "In this one theory we have the basic rules of all ordinary phenomena except for gravitation and nuclear processes. For example, out of quantum electrodynamics come all known electrical, mechanical, and chemical laws."

Though he could not have foreseen quantum electrodynamics Ampère would have found the theory to his liking.

Ampère was without doubt the leading light of the period, performing many beautiful experiments and consolidating electrodynamics into a mathematical subject. In 1827 he published a synthesis of his work which became famous and is still the foundation of the mathematical theory of electrodynamics.

Later, his interests returned to a subject he had long held dear: the classification of the sciences. His last major publication was his own classification published in 1834, which he is said to have regarded as the capstone of his career. Today it is largely forgotten. The capstones that history awarded him are his work on electrodynamics and the naming after him of the unit of electric current. And, of course, the words he coined: electrodynamics, electrostatics, galvanometer, voltaic and solenoid.

Though his epitaph is "Happy, at last", a tribute by his son is more fitting: "He was never content with probabilities but always sought Truth."

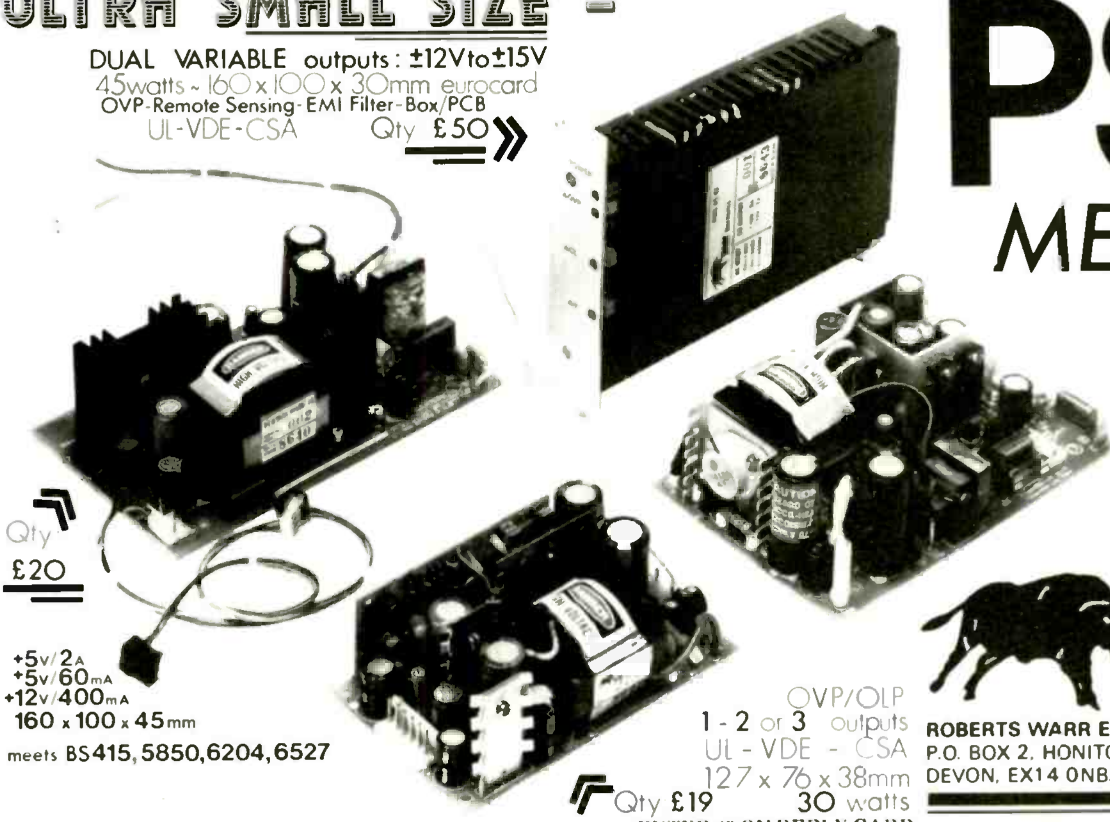
Tony Atherton works at the Independent Broadcasting Authority's engineering training college in Devon. His book, From Compass to Computer, A History of Electrical and Electronics Engineering, was published by Macmillan in 1984.

Next in this series of pioneers of electrical communication: Charles Wheatstone, developer of the electric telegraph.

ADVANCED DESIGN – HIGH PERFORMANCE – VERY LOW COST – ULTRA SMALL SIZE – YES!

RW'S PSU's MEET THEM ALL!

DUAL VARIABLE outputs: ±12V to ±15V
45watts ~ 160 x 100 x 30mm eurocard
OVP-Remote Sensing-EMI Filter-Box/PCB
UL-VDE-CSA Qty £50



Qty £20
+5v/2A
+5v/60mA
+12v/400mA
160 x 100 x 45mm
meets BS415, 5850, 6204, 6527

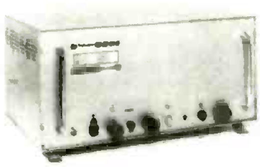
OVP/OLP
1 - 2 or 3 outputs
UL - VDE - CSA
127 x 76 x 38mm
Qty £19 30 watts

Qty £20 3 outputs
meets BS & VDE
UL/CSA approved
> 75 % efficiency
40 watts

RW Electronics
ROBERTS WARR ELECTRONICS LTD. TEL: 040484 568
P.O. BOX 2, HONITON, TELEX: 42513 SHARET
DEVON, EX14 0NB. FAX: 040484 575

ENTER 49 ON REPLY CARD

Valradio



50 YEARS OF EXPERIENCE IN POWER CONVERSION
1937–1987

- ☐ DC-AC Inverters (Transvertors)

SINE/SQUARE WAVE INVERTERS 30 to 1000 watts, 50 (or 60) Hz, 115/230V, single phase AC. From 12, 24, 50, 110 or 220 Volts DC.

- ☐ DC-DC Converters
- ☐ AC-DC Power Supplies
- ☐ AC-AC Frequency Changers
- ☐ Battery Chargers
- ☐ Standby/UPS Systems
- ☐ Line Conditioners

For details:
VALRADIO POWER LTD
LAWRENCE ESTATE, GREEN LANE, HOUNSLOW TW4 6DN, UK
Tel: 01-570 5622

ENTER 50 ON REPLY CARD

NEW! AFFORDABLE PCB CAD

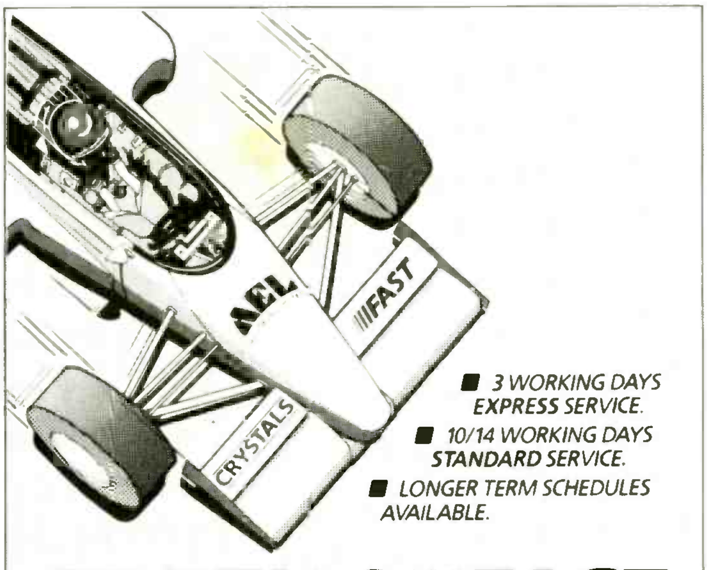
FROM
CHANNEL MICRO PRODUCTS LTD

- Maximum circuit board size greater than 2' x 2'.
- Powerful zoom facility and fast screen re-draw.
- Full off-screen editing. Mouse & Trackball compatible.
- Hard copy at 1:1, 2:1 & 4:1 from Epson FX or RX printer.
- Plotter drivers for most popular plotters available.
- Low cost BBC Micro hardware keeps system cost below £1500. Software only £240.

Please write or telephone for full details.

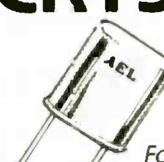
227 Canterbury Street, Gillingham
Kent ME7 5XB. Tel: 0634 570256

ENTER 41 ON REPLY CARD



- *3 WORKING DAYS EXPRESS SERVICE.*
- *10/14 WORKING DAYS STANDARD SERVICE.*
- *LONGER TERM SCHEDULES AVAILABLE.*

CRYSTALS ///FAST



AEL Crystals carry full specifications for most Communications Equipment used today.

For further details contact the Sales Office.

AEL
CRYSTALS LIMITED

GATWICK HOUSE · HORLEY · SURREY · ENGLAND RH6 9SU · TEL: HORLEY (0293) 785353
TELEX: 87116 & 87180 AERC G · CABLES: AEROCON TELEX HORLEY · FAX: 0293 774658

ENTER 4 ON REPLY CARD

CIRCUIT IDEAS

SIBILANCE DISTORTION SUPPRESSOR

Distortion in a communications channel or recording process, for example due to over-modulation, is noticeable on sibilants. This distortion takes the form of added lower-frequency signals, causing a rushing-wind sound during words containing the letter s. Suppressing low-frequency signals when high-frequency signals are present makes this effect less irritating.

Input feeds a high-pass filter which drives an electronic switch via a rectifier with adjustable bias. The input signal also feeds a second high-pass filter and a low-pass filter. Output from these filters is normally mixed but when there is a large burst of high frequency, the electronic switch stops the low-pass signal.

Since filter requirements for detecting sibilance and passing frequencies to the output are different, two independent filters are used. Two Sallen and Key high-pass filters are cascaded to detect sibilance and their output is passed to the active rectifier.

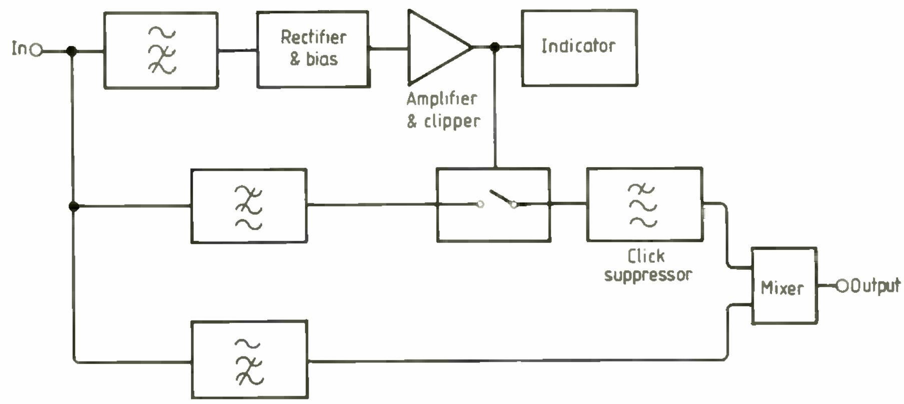
Filters in the signal path were chosen by trial and error to give best results with the material that prompted this design – a bad cassette recording of a lecture. Capacitors and resistors in these circuits could be made variable. Simple filtering removes switching clicks.

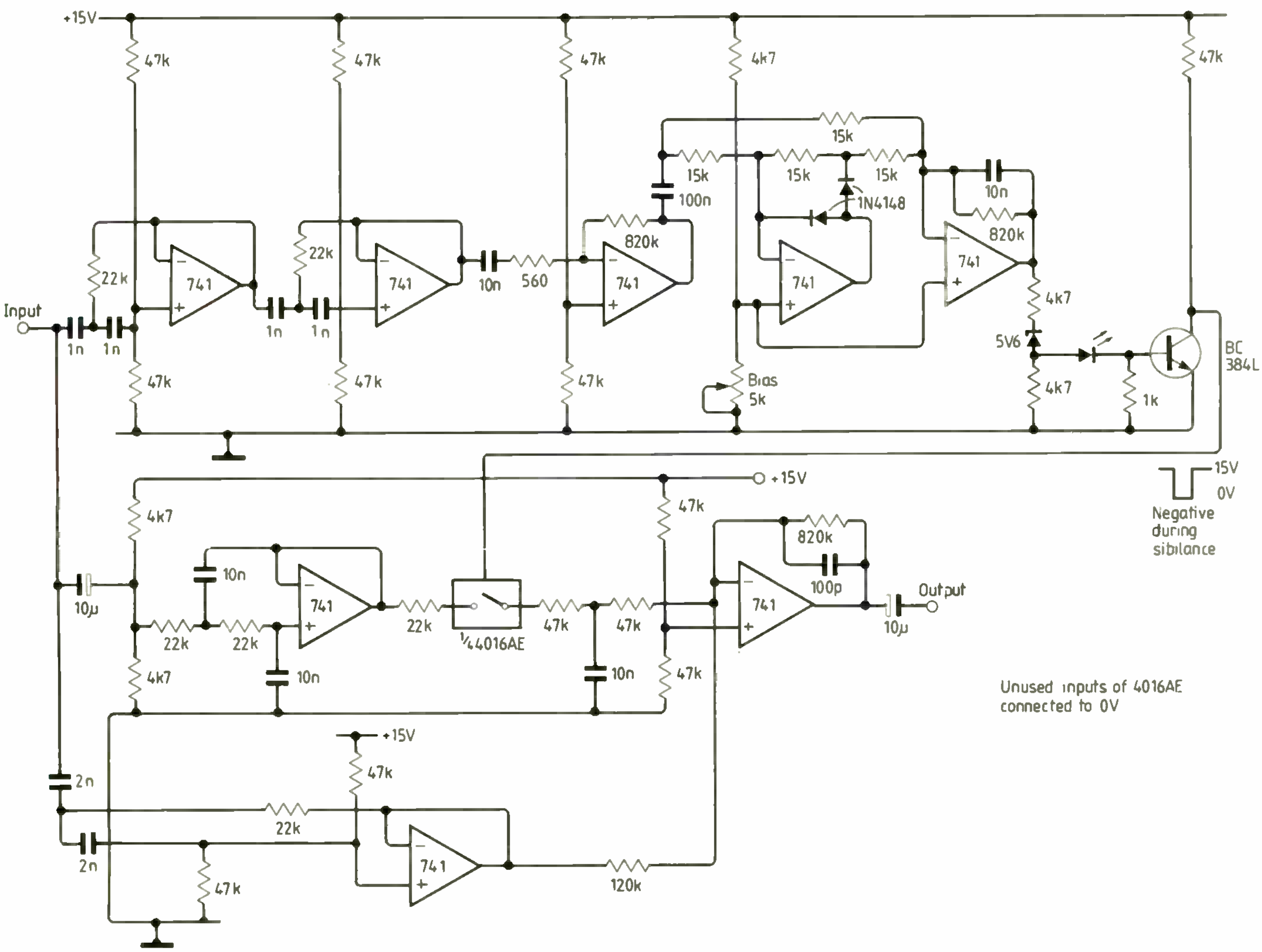
With the aid of a led which lights during sibilance, switching level is set using a bias control on the active rectifier. This control is advanced until the led lights on sibilant peaks. The prototype was connected between output of a cassette recorder and input of a loudspeaker amplifier.

John de Rivaz
Truro
Cornwall

Reading

Wireless World Circards 1.4 and 1.5 for low and high-pass Sallen and Key filters respectively and 4.3 for absolute value circuits.





CIRCUIT IDEAS

VOLTAGE-CONTROLLED STATE-VARIABLE FILTER

The well known Kerwin-Huelsman-Newcomb state-variable filter using a summer and two phase-inverting integrators suffers from two disadvantages – low gain and dependency between resonance frequency and Q. These disadvantages are removed when integrators without phase inversion are used as shown in the first diagram.

A positive integrator consists of a differential amplifier, IC_2, and non-inverting amplifier, IC_1, the feedback resistor of which is replaced by capacitor C. The XR2208 comprises a multiplier and a high-gain op-amp which forms the differential amplifier.

Output voltage of the integrator is

$$\frac{V_{in}}{sR'C}$$

where R′ is AR/V_c. Multiplier constant A is given by the device manufacturer and V_c is control voltage. Integrator time constant is set to the desired value using V_c.

The second diagram shows a state-variable filter with two positive integrators whose transfer functions are

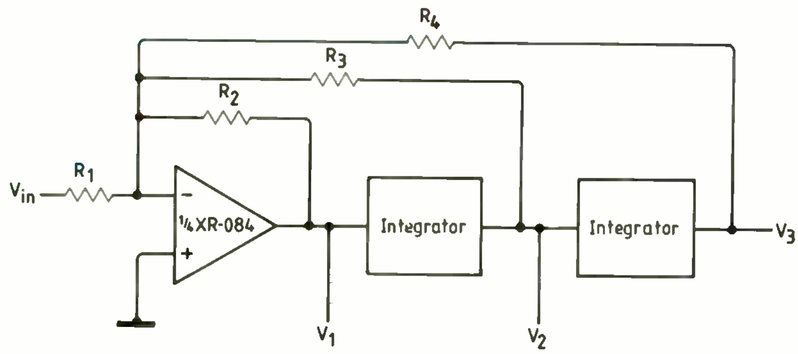
$$V_1/V_{in} = -G.s^2\tau^2/K$$
$$V_2/V_{in} = -G.s\tau/K$$
$$V_3/V_{in} = -G/K$$

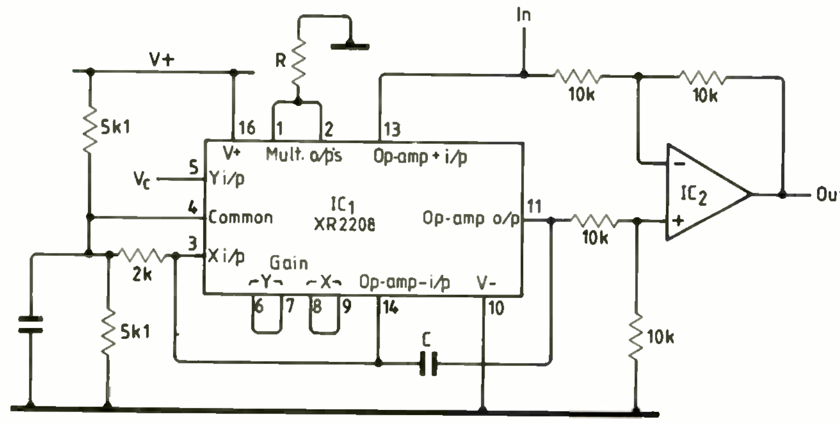
where K is $1+R_2/R_3.s+s^2\tau^2$ and τ is the integrator time constant.
From this,

$$\omega_0 = 1/R'C$$
$$Q = R_3/R_2$$
$$G = R_2/R_1$$

Hence resonance frequency ω_0 is controlled by V_c. Q can be set to a desired value independently of ω_0 by varying R_3 and gain G can be varied using R_1. Values of Q and G are thus set to a value of the order of 10^2.

Kamil Kraus
Rokycany
Czechoslovakia



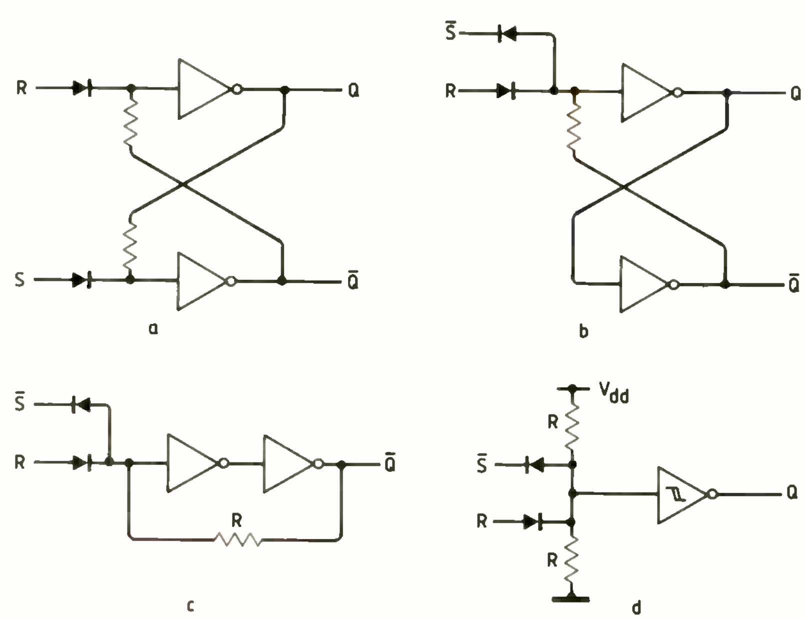


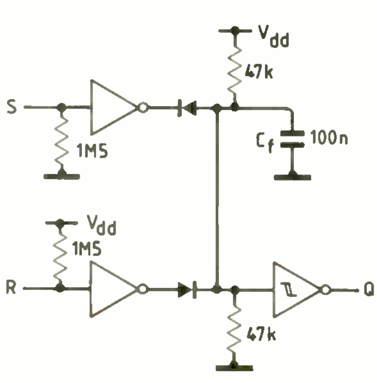
RS LATCHES USING INVERTERS

Three ways of producing an RS latch using two c-mos inverters and diodes are shown here, and an even simpler circuit using just one c-mos Schmitt inverter with diodes.

A touch-controlled latch is also shown (a.c. power supply is required). Touching S sets the Q output and touching R resets it. Optional capacitor C_f provides high-frequency noise immunity.

Hernán Tacca
Buenos Aires
Argentina



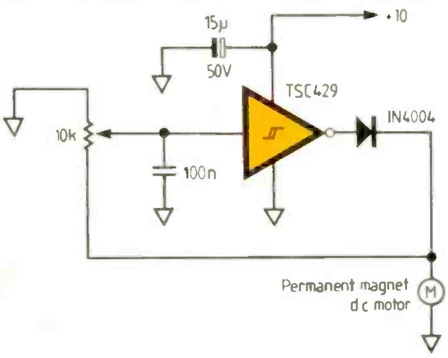


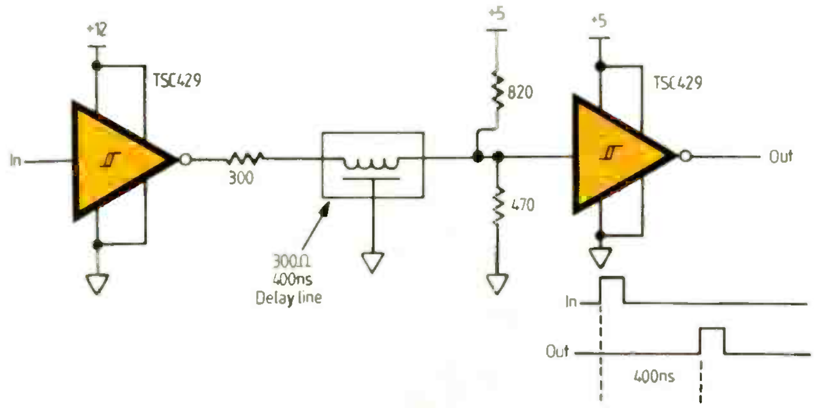
APPLICATIONS SUMMARY

HIGH-SPEED MOSFET INTERFACE I.C. IN POWER DRIVING

Back e.m.f. is used as feedback representing motor speed in this controller for small motors (left). Being capable of 6A peak output current, the TSC429 mosfet power interface i.c. can form both the comparator and driver so the circuit is simple. With rise and fall times of 25ns, the device is also fast enough to drive short-time delay lines (right).

These two circuits are from Teledyne application note 28, which covers operation and uses of the 429. There are a further seven circuits in the note, including voltage converters and a pulse-transformer driver.



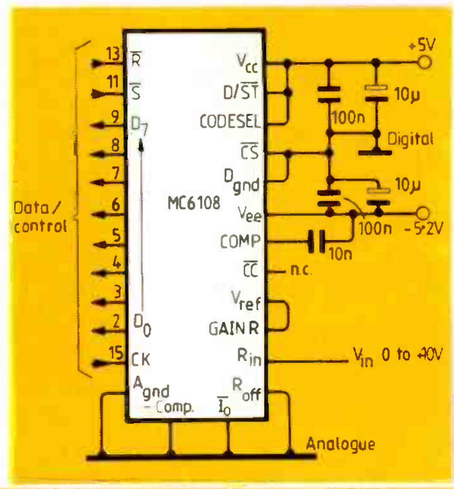


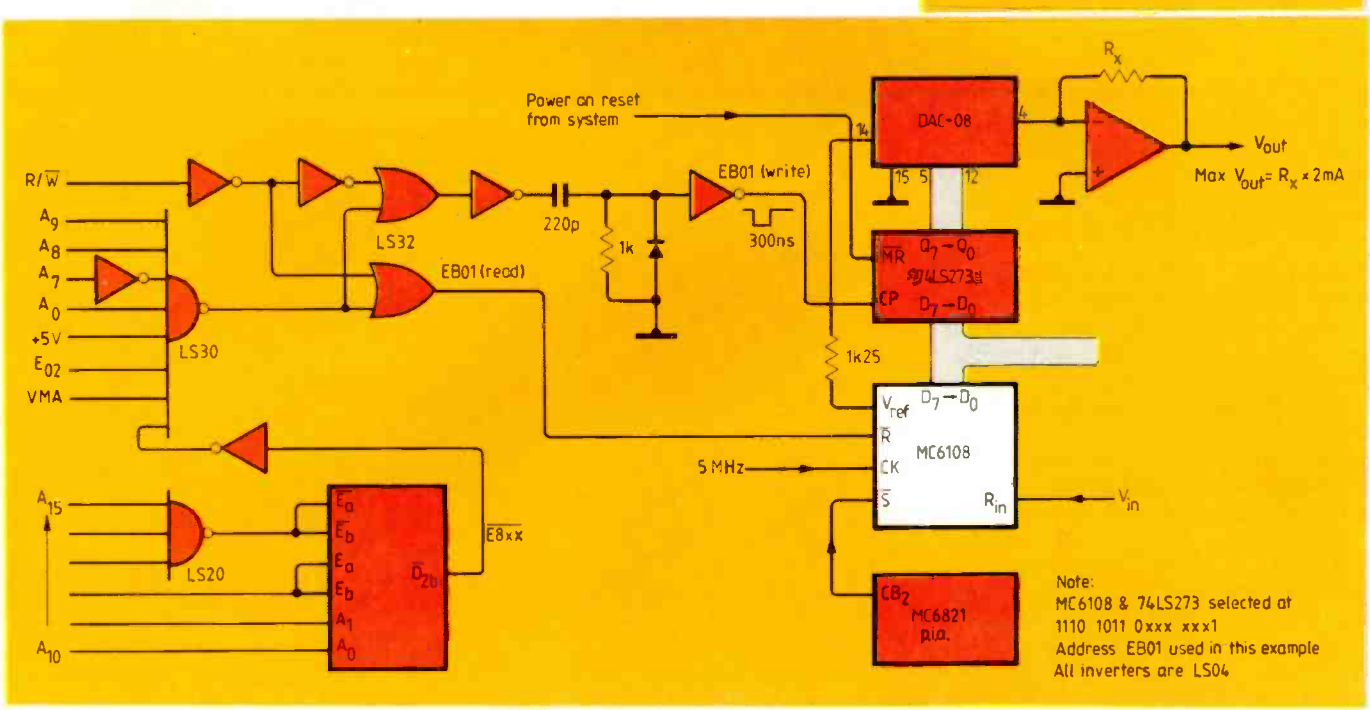
MICROPROCESSOR INTERFACING FOR A HIGH-SPEED A-TO-D CONVERTER

Assembly-language software is included in application note AN963 which describes how MC6108 eight-bit analogue-to-digital converters are interfaced to a 6802 processor system. Within the a-to-d converter is a d-to-a converter with comparator, successive approximation registers, a reference, control logic and three-state buffers.

Although operation of the converter is only guaranteed with a clock signal of up to 5MHz, the Motorola note says that clocks of up to 10MHz can be used when 'careful attention to detail' is paid. After describing how the converter operates, address decoding is discussed. Most of the examples given require a 6821 peripheral interface adaptor either to provide control signals or to control the converter and read its data but there is one example of interfacing the device directly using only address decoding.

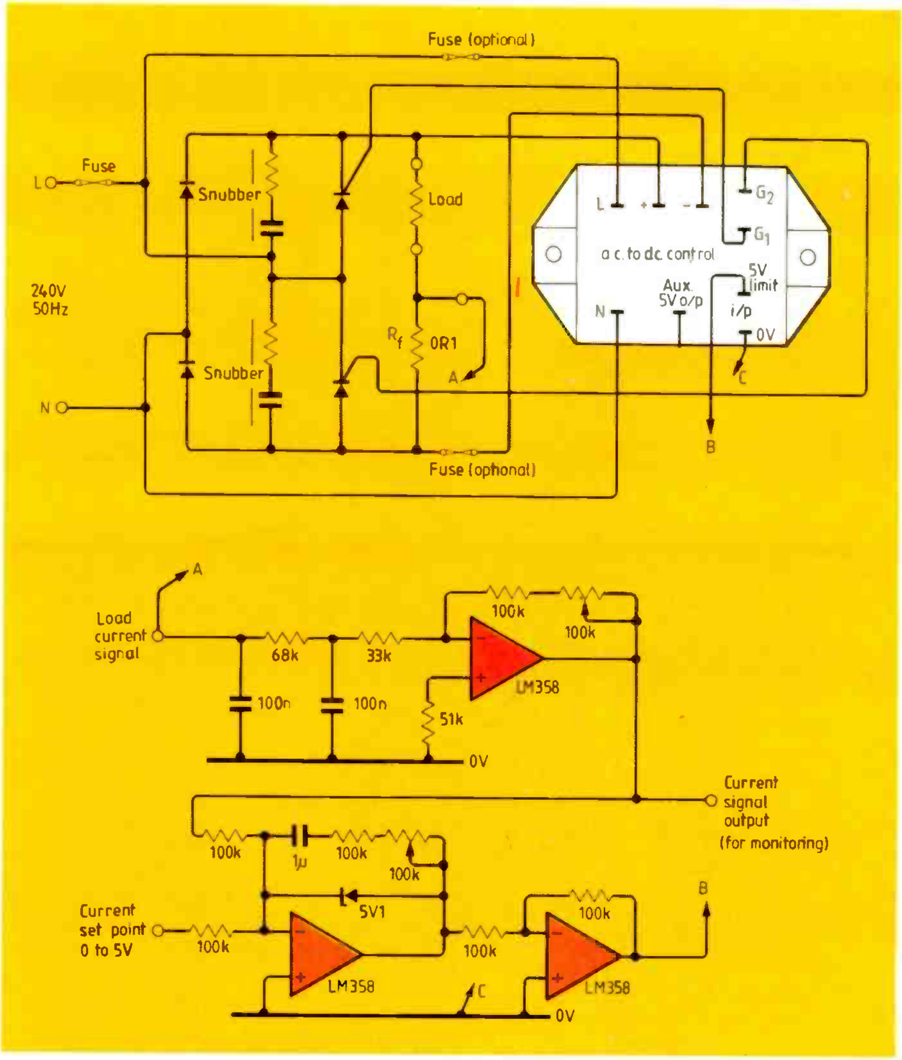
In the example shown, analogue information can be read, processed, and then sent out as an analogue signal again through the DAC08 digital-to-analogue converter. Digital data to be converted to analogue form is held in a 273 octal latch when an active-low latching pulse is sent from the address decoder. On the rising edge of the pulse, data is transferred to the d-to-a converter. Output of the converter is a current proportional to the reference current and the digital data presented to it.





APPLICATIONS SUMMARY

10A DC CONTROLLER



Heavy-duty supply circuits arsimplified by phase-angle trigger modules as this constant-current closed-loop controller circuit from Semikron's M2DrHL/SP application note shows. The modules provide isolated trigger signals for thyristors.

In the low-power circuit, bottom the first amplifier senses current over the shunt resistor and feeds the second amplifier which is configured as a comparator and pi controller. Current feedback is compared with the input signal; difference between the two signals determines the trigger-module firing angle.

Used to drive a d.c. motor armature winding, the circuit becomes a constant-torque controller. The high-power section of this circuit is for a.c. to d.c. control but there is also a configuration for a.c. to d.c. control in the note. Remaining circuits are op-amp circuits for trigger-module driving, one for speed control of a d.c. motor and the other a power controller.

Teledyne Semiconductor
SSI Ltd
Dawson House
128 Carshalton Road
Sutton, Surrey SM1 4RS
01-643 1126

Motorola Semiconductor Products
European Literature Centre
88 Tanners Drive
Blakelands, Milton Keynes MK14 5BP
0908 614614

Semikron UK Ltd
4 Marshgate Drive
Hertford SG13 7BQ
0992 584677

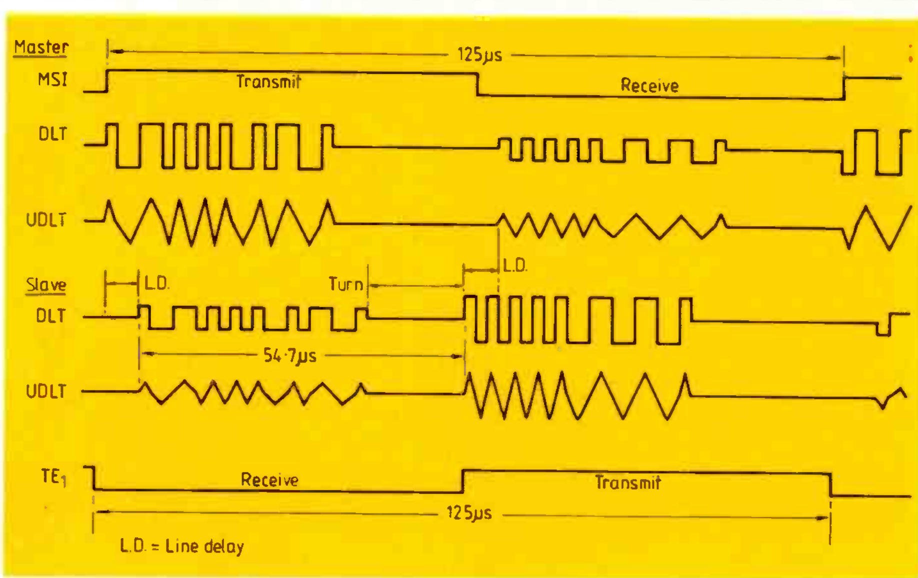
Siemens Ltd
Siemens House
Windmill Road
Sunbury-on-Thames
Middlesex TW16 7HS
(09327) 85691

OFFICE COMMUNICATIONS

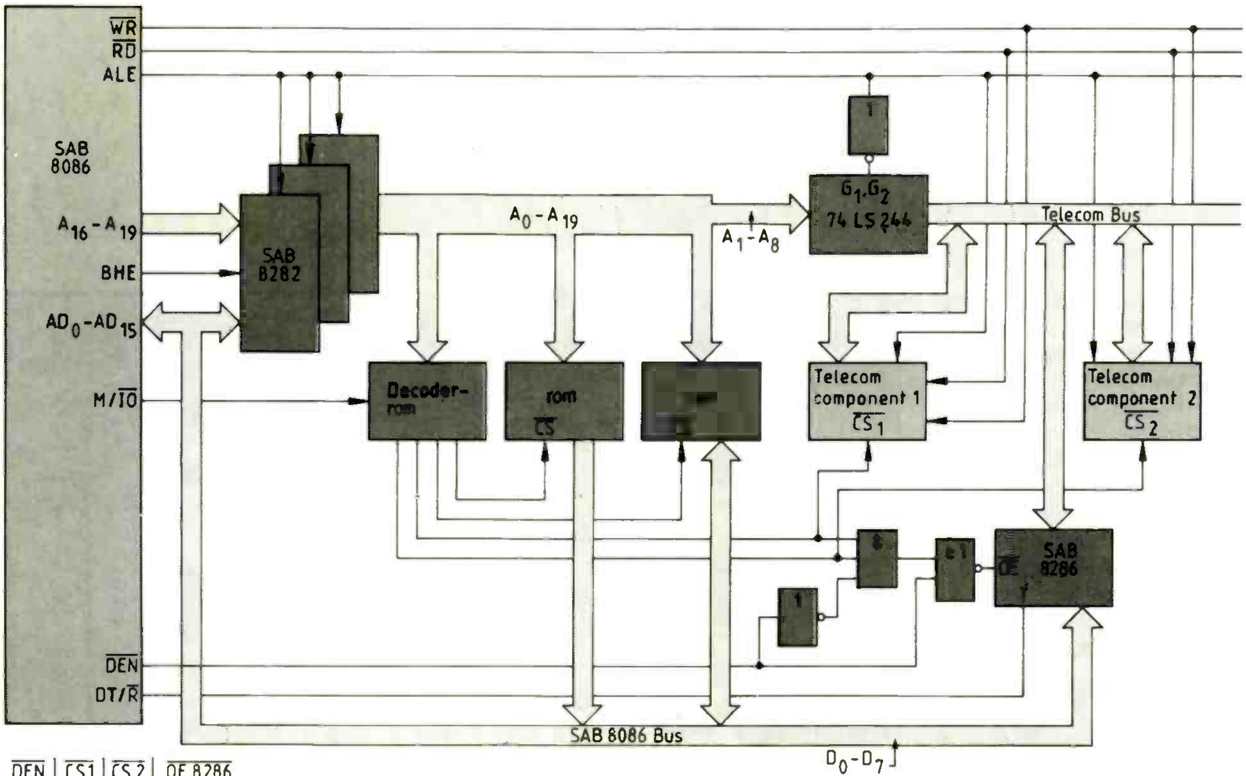
Leaflet AR239, called 'Implementing integrated office communications,' is produced by Motorola to give an overview of their various i.cs related to office communications.

The leaflet briefly covers some questions and answers relating to integrated services digital networking and places the various i.cs in block diagrams like the one shown to complement descriptions of what they do.

The universal digital-loop transceiver chip set, u.d.l.t., is an 80kbit/s synchronous transceiver capable of transmitting data over up to 2km using a twisted pair. Over shorter distances, of up to 1km, the similar d.l.t. set can be used.



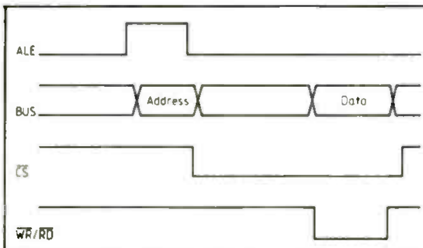
APPLICATIONS SUMMARY



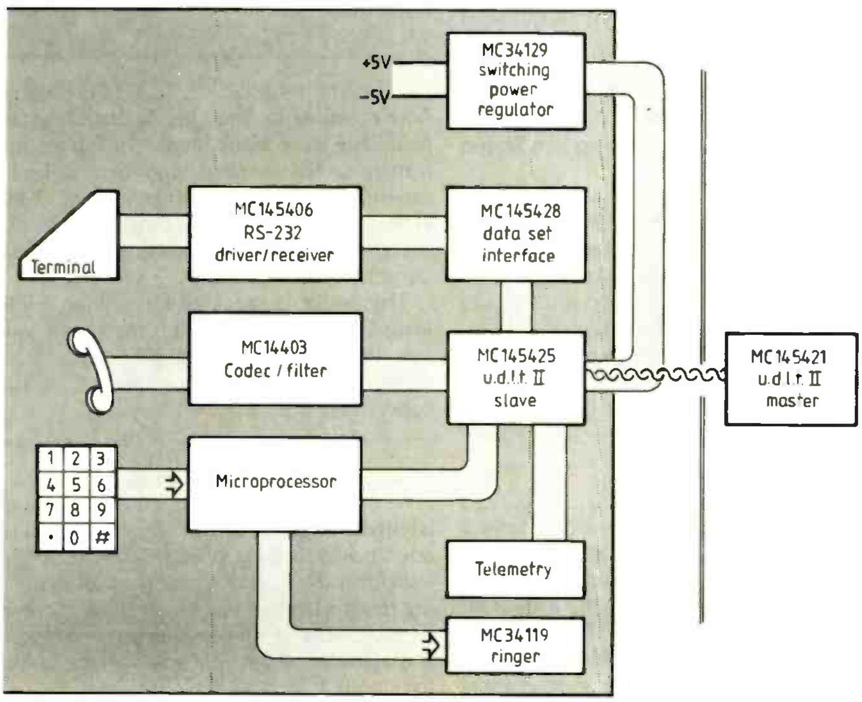
$\overline{DEN}$	$\overline{CS1}$	$\overline{CS2}$	$\overline{OE}$ 8286
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

$\overline{OE\ 8286} = \overline{DEN} + \overline{\overline{DEN}} \cdot \overline{CS1} \cdot \overline{CS2}$

To address a register use IN AL, x.2
where x is the telecommunication, i.e. register address



Normal data transfer for an eight-bit peripheral (left)



CONNECTING 8-BIT TELECOMMUNICATIONS I.CS TO 8081/80186 PROCESSORS

With 8086/186 processors, data and addresses are 16 bits and problems can arise when eight-bit PEB20 telecommunications i.cs are interfaced.

Processor i/o addressing consists of two 32Kbyte areas – one with odd bytes and one with even bits. Even-address i/o data bytes pass on D_{0-7} and odd bytes on D_{8-15} so components with even addresses connect to the lower part of the bus while components with odd addresses connect to the upper part.

Eight-bit peripherals using both even and odd addresses cause problems. Application note i.s.d.n.(3) from Siemens describes how to overcome this problem using hardware to form a separate bus for the telecommunications i.cs. To ensure that only even addresses are used, the real address is multiplied by two in software and only address lines A_{1-8} pass to the telecommunications bus.

Video frame store

To conclude this series, a colour palette module which extends the possibilities of the basic frame store with a variety of colour effects.

D. E. A. CLARKE

The basic frame store enables most forms of image capture and manipulation to be performed in the monochrome domain. However, for certain types of image the use of colour vastly improves the presentation of data.

Adding the colour palette is straightforward since it is connected in parallel with the existing boards; monochrome and pseudo-colour displays are then available for simultaneous display on separate monitors if desired. Provision has also been made for overlaying either an external video source or the (monochrome) stored image.

COLOUR PALETTE FEATURES

The colour palette is constructed on a separate board with connections to the pixel data bus, the control bus, the host data bus and the host control bus (the board $\overline{CS}$ signal is unique).

The unit is programmed by the host computer and offers the following features:

- 16 colours displayed from a palette of 4096.
- 1V pk-pk RGB video output with selectable sync polarity
- t.t.l. RGB video output with selectable video/sync polarity
- 1V pk-pk video input for programmable overlays
- selectable programming modes.

Several colour palette chips are now available including devices from Signetics, Inmos and Thomson. The Thomson device (EF9369) was chosen because of its low cost, availability, excellent performance and a feature not available on other devices which enables dynamic switching between video sources.

The EF9369 combines the functions of look-up table, microprocessor interface and digital-analogue conversion in a 28-pin d.i.l. plastic package working at pixel rates to 30MHz (Fig.26). The RGB d.a.cs have gamma-weighted outputs and high output impedance. The M-bit is a digital output which in this design is used to switch between video sources.

The chip has been designed for interfacing to a variety of microprocessor buses including multiplexed and non-multiplexed types. With this design it is best to drive the board via i/o ports.

In multiplexed mode the processor must output the look-up table address followed by data. In non-multiplexed mode, the processor need only set an internal index register and the internal table address register will automatically be incremented after each data access. The method chosen will depend on your application but in non-multiplexed mode there is a dynamic timing condition which may not be met by slow processors (or i/o via non-compiled high-level languages). For maximum flexibility the board is configurable for operation by either technique.

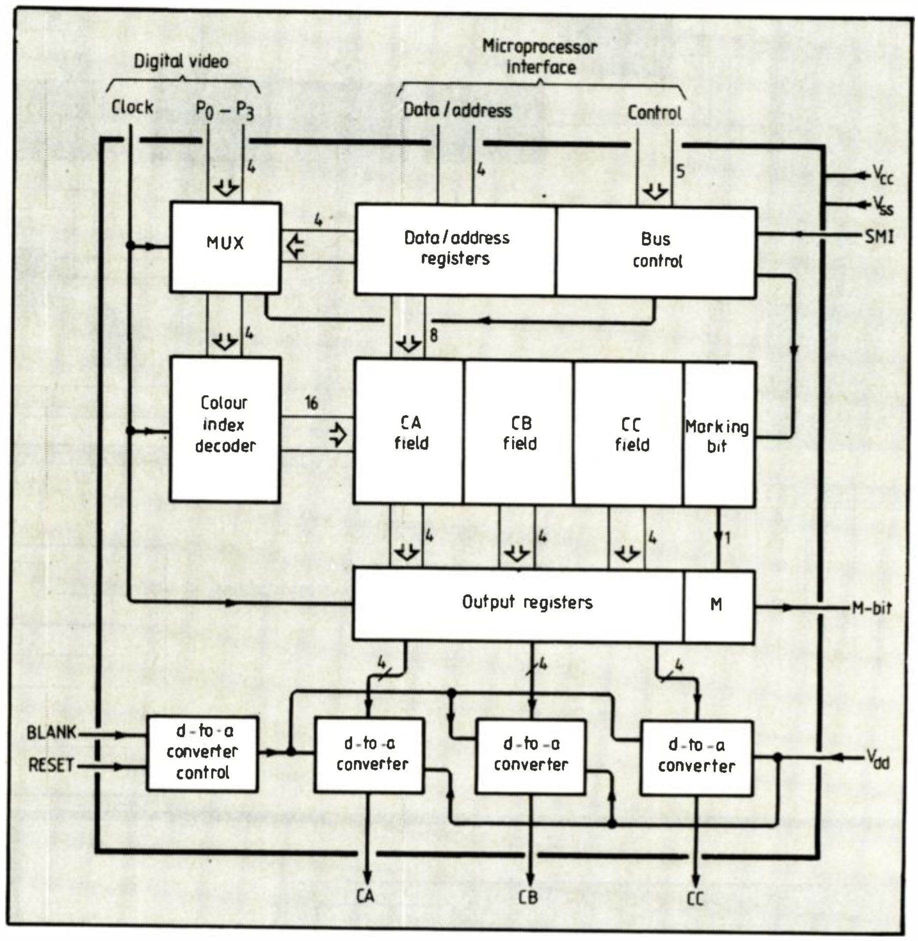


Fig.26. Thomson's EF9369 combines a microprocessor interface, d-to-a converters and a colour look-up table in a 28-pin package.

VIDEO BUFFER

Analogue outputs from the palette have a source impedance of about 300 ohms and they must therefore be buffered. The voltage swing is also inadequate, varying from 0.8V black level to 1.8V peak white. The functions of boost, buffer and high speed video switch are conveniently packaged in another inexpensive Thomson device, TEA5114 (Fig.27). Also provided by the chip is clamping for equalized video black levels. An interesting feature of the internal amplifiers is level-dependent gain which comes into effect for video output levels exceeding 1.5V pk-pk, thereby preventing overloading of monitor outputs.

The device is specified for driving 150Ω loads (i.e. 75Ω source/load) for supply voltage (V_{DD}) not exceeding 10V; this ties in nicely with the 10V supply needed for the converter board.

CIRCUIT DESCRIPTION

Pixel data from the bus is buffered and latched by IC_{305} (Fig.28) which introduces one clock cycle delay relative to the blanking waveform. This delay is necessary for matching the un-latched blanking on the converter board (the EF9369 latches both pixel data and blanking). Link 9 is available for use in the colour-keying mode.

With the colour palette, monochrome images can be coloured in up to 16 shades from a range of 4096.

Programming data/address lines are buffered by IC_{302}; the pull-up resistors prevent the c-mos buffers from entering their linear region of operation if the host is disconnected. These resistors should be omitted if the corresponding pull-ups on the memory board are fitted.

Programming signals ($\overline{ALE}$, $\overline{CS}$ and $\overline{WR}$); are buffered by IC_{301}. The chip select signal $\overline{CS}$ is unique while the others have dual function: it enables programming of the palette to take place without disrupting operation of the control board. Processing access mode is determined by Links 5,6 and 7.

Colour palette outputs from IC_{303} are a.c. coupled to the buffer-amplifier/switch IC_{304} where they are d.c.-restored and clamped to an internal reference voltage. The palette outputs are also boosted to t.t.l. levels by a high speed line receiver IC_{307} which switches at the mid-point of the output voltage range of the d.a.cs. as set by R_{307}, R_{308}. The palette should therefore be programmed for maximum output excursions for bright/dark levels when driving t.t.l. monitors.

The t.t.l. outputs could be derived from the outputs of IC_{304}; however, the d.c. output levels of IC_{304} shift significantly with temperature and would require a temperature-tracking comparator reference in place of the simpler $R_{307, 308}$.

The M-bit could also be used as an additional t.t.l. video output, but the overall delay in the d.a.c. boosting circuitry is about 60ns which would need to be compensated. In any case, few monitors have four t.t.l. video inputs.

Buffer IC_{306} also enables selection of output video polarity via link 4.

Composite sync from the converter board is buffered by Tr_{301} and limited to about 2V pk-pk; polarity is determined by Link 1. Sync at t.t.l. levels is also available via IC_{306} with polarity set by link 2.

External RGB video is a.c. coupled, d.c. restored and connected at IC_{304}; the black levels are then identical. The M-bit from the palette IC_{303} pin 7 then determines whether the palette or external source is selected, depending on image content and the programming of the lookup table. The video source gates are internally or-ed with an external signal FBI and the resulting signal FB appears as an output.

An optional switch S_{301} selects unterminated or terminated RGB positions 1,2 and combined RGB for monochrome sources in positions 3,4.

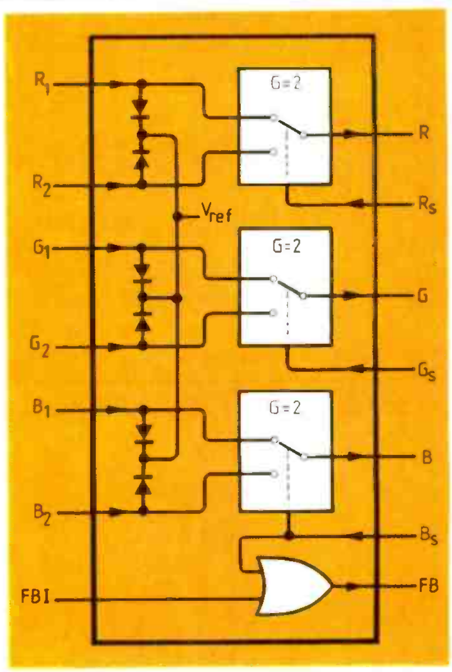


Fig.27. A second Thomson device, TEA5114, includes black-level clamps, high-speed video switches and output limiting.

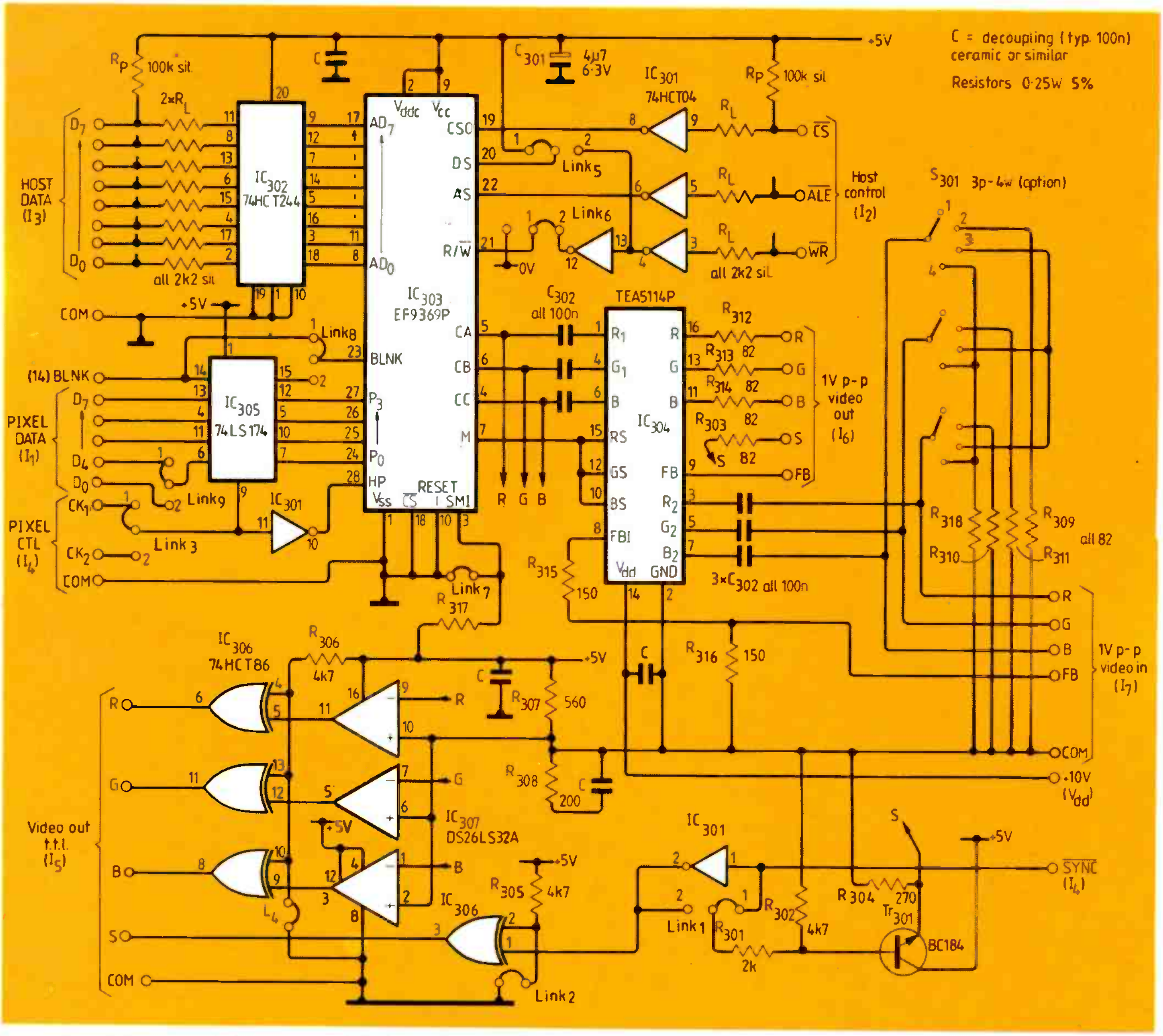


Fig.28. Circuit diagram of the colour palette board. This unit can be added to the basic frame store described in the November 1986-February 1987 issues.

PALETTE PROGRAMMING

The format of the EF9369 look-up table is shown in Fig.30; corresponding palette output voltages are listed in Table 1. After power-up, the device must be initialized by the host computer before a colour display can be obtained.

The EF9369 can be both read and written to by the host c.p.u. In this application, the read function is not implemented since it is a trivial procedure to keep track of device status in software, and so the interface circuitry can be simplified. Timing sequences for interfacing via parallel ports are detailed in Fig.31.

Table 1: EF9369 video output voltages

Binary input	Analogue output (V)
0000	0.80
0001	1.18
0010	1.28
0011	1.36
0100	1.42
0101	1.47
0110	1.52
0111	1.56
1000	1.60
1001	1.63
1010	1.66
1011	1.69
1100	1.72
1101	1.75
1110	1.78
1111	1.80

Multiplexed mode: referring to Fig.28, links 5,6 are in position 1 and link 7 is shorted. Address (binary 0-31) is output and latched on the positive edge of ALE while $\overline{CS}$ is low; $\overline{CS}$ is also latched at this time and the video outputs are blanked. Data is now output and $\overline{WR}$ pulsed low; the data is captured on the rising edge of $\overline{WR}$. In this way any combination of look-up table locations can be accessed, but the final operation must be to re-enable the video outputs by pulsing ALE with $\overline{CS}$ high.

Non-multiplexed mode: In this mode links 5,6 are in position 2 and link 7 is open. The R/W input (IC_{303} pin 21) is tied low to select write operation permanently (the condition is latched on the rising edge of $\overline{WR}$). The first operation is to output the initial lookup table address with the EF9369 address input high (ALE low); this will usually be address 0. Subsequent writes with ALE high access the EF9369 look-up tables and an internal index register auto-increments. This is a very fast way to initialize the entire chip and the video is blanked only while $\overline{CS}$ is low. However, maximum $\overline{WR}$ pulse width is 10µs because of dynamic structure on the chip.

DISPLAY MODES

The best combination of on-screen colours is usually obtained by trial and error. For many of the colour displays shown in this series the palette was initialized with the values in Table 2. Notice that the M bit is low.

External video will be selected when the M bit is set to logic 1 in a particular palette location and therefore a form of colour-keyed overlay of video sources on the sorted image can be obtained. In its simplest form, the look-up table is configured so that, say, locations 8 to 15 have the M bit set to logic 1. Image pixels should then be shifted right by one bit, and bit 7 set to 1 by software in those areas where it is required to select overlay video.

This technique has the advantage of reduced grey-level range on the monochrome

Table 2: typical look-up table values (all hexadecimal).

Location	MBGR
0	0000
1	0200
2	0600
3	0640
4	0F61
5	0010
6	0030
7	0060
8	00F0
9	0002
A	0003
B	000F
C	004F
D	009F
E	00FF
F	0FFF

video output. A better method is to switch video sources according to the state of pixel data bit 0 as selected by link 9.

Recall that when images are digitized, bit 0 is tied to logic 0. Software manipulation of this bit has minimal effect on the displayed monochrome image, but it can be used for overlay purposes. When overlay is not required, full 16-colour images can still be obtained by software copying bit 4 into bit 0.

VIDEO OVERLAYS

A powerful use for the overlay facility is the mixing of pseudo-colour images from the palette board and high quality stored images from the main converted board. This is achieved by connecting a cable from the main (monochrome) video output to any external RGB input with s_{301} in position 4.

Of course, the overlay video could originate from a live source such as a tv camera as long as the source is also connected to the main video input to synchronize the frame store.

When overlaying live video images with their stored equivalents, bear in mind that the frozen image has accumulated several clock cycles' delay with respect to the original, and will be noticeably displaced to the right.

Components and a set of printed circuit boards for this design are available from Ipswich Electronics Ltd, Hadleigh Road Industrial Estate, Ipswich IP2 0HB. tel: 0473-216056. Semiconductors can be obtained from Technomatic Ltd, 17 Burnley Road, London NW10 1ED.

IC101	74LS221	R101	1k	C101	1.5n
IC102	74LS74	R102	560	C102	6.8n
IC103	74LS74	R103	5.6k	C103	390p
IC104	74F74	R104	20k	C104	220p
IC105	74F161	R105	3.3k	C105	10–100p
IC106	74F161	R106	2.7k		variable
IC107	74HCT244	R107	3.3k	C106	see
IC108	74LS157	R108	2.7k		Table 1,
IC109	74LS04	R109	470		January
IC110	74LS02	R110	220	C107	4.7µ
IC111	74F00	R111	82k	C	10n
IC112	74LS132	R112	27k		
IC113	74F74	R	33	L1	6.8µH
IC114	74LS74	RP	100k		
IC115	74HCT393	P101	10k		
IC116	74HCT393	P102	20k		

Component values were accidentally omitted from the circuit diagram of the control board, Fig.13 in the December 1986 article. A list appears above.

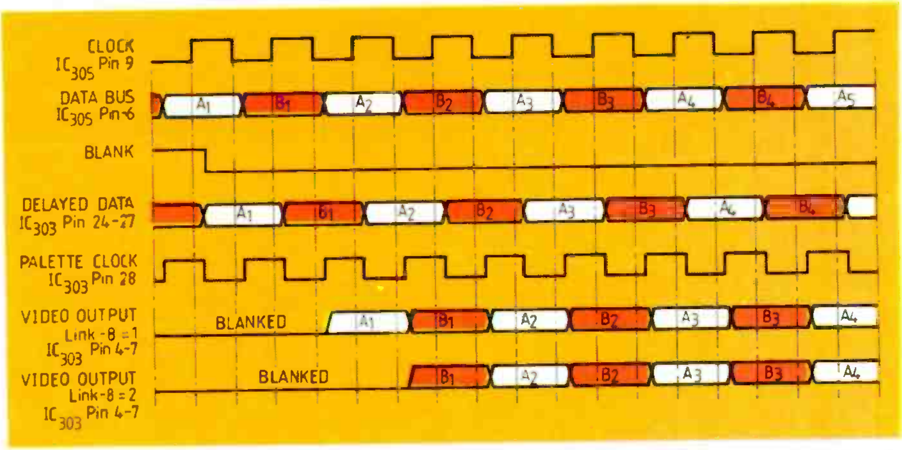


Fig.29. Colour palette timing. Data is available on the bus during memory write. In memory read mode, data appears after the positive clock edge.

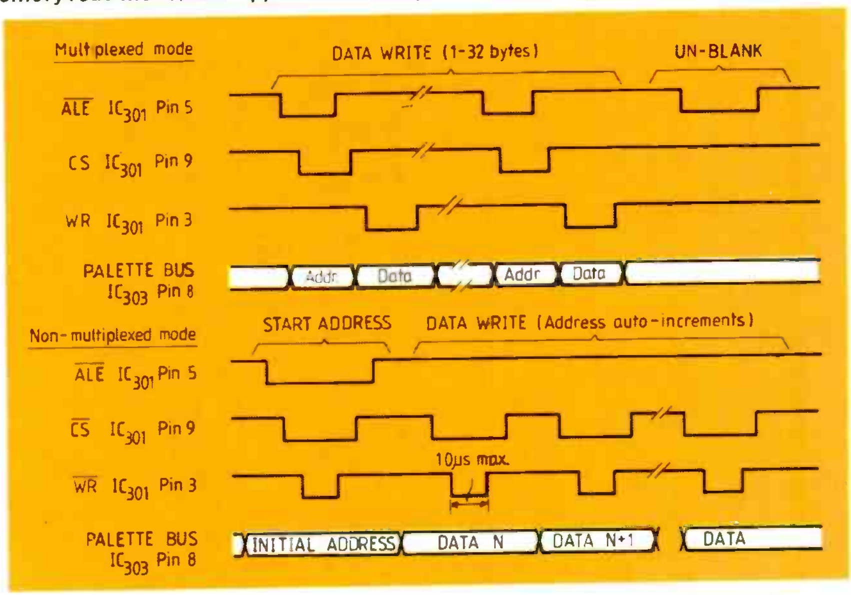
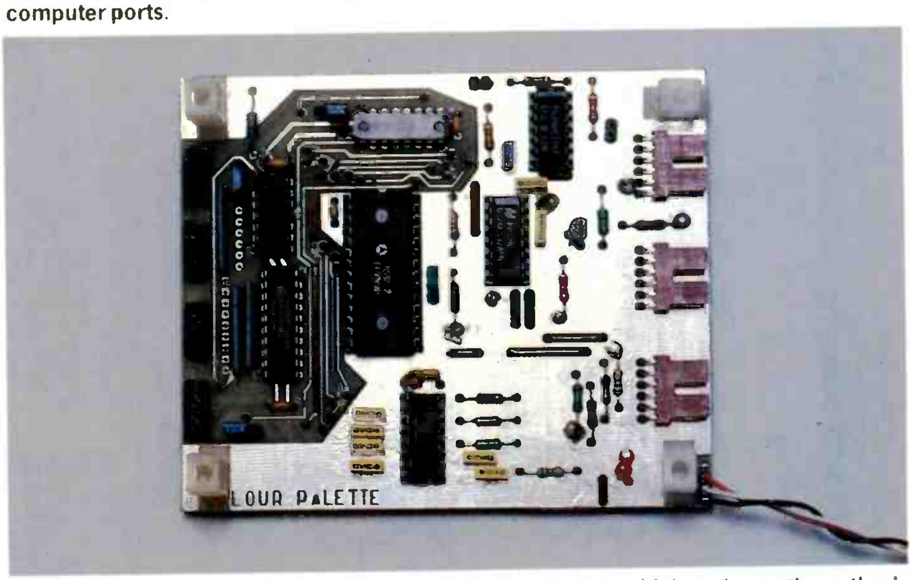


Fig.31. Programming the colour palette: timing sequences for interfacing via parallel computer ports.



This colour palette board (above) is one of the four boards which make up the author's prototype frame store.

Colour look-up table 7	6	5	4	3	2	1	0	Byte address 7	6	5	4	3	2	1	0	Register index
CB3 X	CB2 X	CB1 X	CB0 M	CA3 CC3	CA2 CC2	CA1 CC1	CA0 CC0	X X	X X	X X	0 0	0 0	0 0	0 0	0 1	0
CB3 X	CB2 X	CB1 X	CB0 M	CA3 CC3	CA2 CC2	CA1 CC1	CA0 CC0	X X	X X	X X	0 0	0 0	0 0	1 1	0 1	1
CB3 X	CB2 X	CB1 X	CB0 M	CA3 CC3	CA2 CC2	CA1 CC1	CA0 CC0	X X	X X	X X	1 1	1 1	1 1	1 1	0 1	15

Fig.30. EF9369 look-up table format (abridged): X indicates 'don't care'.

PHONE
0474 60521
4 LINES

P. M. COMPONENTS LTD

**SELECTRON HOUSE, SPRINGHEAD ENTERPRISE PARK
SPRINGHEAD RD, GRAVESEND, KENT DA11 8HD**

TELEX
966371
TOS—PM

VISA

A SELECTION FROM OUR STOCK OF BRANDED VALVES

1	24.50
1	7.50
?	11.50
?	11.50
1	14.95
1	6.50
;	35.00
;	37.50
;	27.50
)	11.50
)	24.00
3	24.00
DD	4.00
-II	4.00
2	59.75
1	39.00
8	39.00
	6.00
	14.00
2	0.70
14	1.25
15	2.00
	4.50
	2.50
	2.00
4	55.00
	27.50
	22.00
	20.00
	20.00
8	65.00
4	32.00
8A	115.00
9/1	195.00
0/1	135.00
4	32.00
	29.50
	0.90
306	3.50
Nos prices on request	
	27.50
	1.20
1	22.50
2	17.50
0	4.50
00	125.00
91	0.70
96	0.65
0	1.75
0	3.50
-4-5000	25.00
16	28.50
18	28.50
22	35.00
23	35.00
24	39.00
25	22.00
29	32.00
1	1.00
2	0.60
6	0.65
7	1.00
3	1.20
7	0.90
9	0.56
149	2.00
31	0.90
32	1.20
35	2.50
33	1.00
70	2.50
73	1.50
32	0.95
33	1.10
34	2.50
36	2.50
S10	13.50
S16	10.00
170	1.95
1160	3.50
51	1.50
86/87	0.65
802	0.72
0L	29.50
1L	12.00
2CC	3.50
3CC	3.50
3F	5.50
6C	9.50
8C	7.95
8CC	3.50
8CC Siemens special	5.95
0CC	7.95
0F	7.95
1H	4.50
2CC	3.95
9F	6.99
30L	18.50
182CC	9.00
180F	6.50
186F	8.50
188CC	7.50
1T	15.00
280F	19.50
283CC	10.00
288CC	13.50
310F	29.50
1148	1.00
1524	6.95
A50	1.00
A76	1.95
A79	1.95
ABC80	0.70
AC91	2.50
AF42	1.20
AF801	2.00
B34	1.50
B41	3.95
B91	0.85
BC33	2.50
BC41	1.95
BC81	1.50
BC90	0.90

EBC91	0.90
EBF80	0.95
EBF83	0.95
EBF85	0.95
EBF89	0.70
EBF93	0.95
EBL1	2.50
EBL21	2.00
EC52	0.75
EC70	1.75
EC81	7.95
EC86	1.00
EC88	1.00
EC90	1.10
EC91	5.50
EC92	1.95
EC93	1.50
EC95	7.00
EC97	1.10
EC8010	12.00
ECC32	3.50
ECC33	3.50
ECC35	3.50
ECC81	1.15
ECC81 Special Quality	2.25
ECC82 Philips	1.95
ECC83	0.65
ECC83 Brimar	1.35
ECC83 Philips	1.95
ECC83 Siemens	2.50
ECC83 Tungsram	1.50
ECC84	0.50
ECC85	0.75
ECC86	2.75
ECC88	0.95
ECC91	2.00
ECC180	0.72
ECC189	1.95
ECC801S	3.50
ECC803S	4.95
ECC804	0.60
ECC2000	12.00
ECF80	1.15
ECF82	1.15
ECF86	1.70
ECF200	1.85
ECF202	1.85
ECF801	0.85
ECF805	2.50
ECF806	10.25
ECH3	2.50
ECH4	3.00
ECH35	3.50
ECH42	1.50
ECH81	1.00
ECH83	1.00
ECH84	1.00
ECH2000	1.50
ECL80	0.60
ECL82	0.79
ECL83	2.50
ECL84	0.74
ECL85	0.69
ECL86	0.95
ECL805	0.69
EF37A	2.50
EF39	1.50
EF40	4.50
EF41	3.50
EF42	3.50
EF50	2.50
EF55	4.95
EF70	1.20
EF71	1.50
EF72	1.20
EF73	1.00
EF80	0.55
EF83	3.95
EF85	0.50
EF86	2.25
EF86 Mullard	4.50
EF89	1.50
EF91	1.95
EF92	2.15
EF93	0.95
EF94	0.95
EF95	1.95
EF97	0.90
EF98	0.90
EF183	0.65
EF184	0.65
EF730	1.80
EF731	3.50
EF732	3.50
EF800	11.00
EF804S	19.50
EF805S	19.50
EF806S	14.50
EF812	0.65
EFL200	1.50
EH90	0.72
EK90	0.95
EL32	0.95
EL33	5.00
EL34	2.25
EL34 Mullard/Philips	4.50
EL36	1.95
EL37	9.00
EL38	6.50
EL41	3.50
EL42	2.00
EL81	6.95
EL83	5.95
EL84 Brimar	0.95
EL84 Mullard	2.95
EL85	4.50
EL86	1.25
EL90	1.75
EL91	6.00
EL95	1.75

EL153	12.15
EL183E	3.50
EL18P	3.50
EL360	6.75
EL500	1.40
EL504	1.40
EL509	5.25
EL519	6.95
EL802	3.65
EL821	8.50
EL822	12.95
EM1	9.00
EM4	9.00
EM80	0.70
EM81	0.70
EM84	1.65
EM85	3.95
EM87	2.50
EN32	15.00
EN91	1.95
EN92	4.50
EX35	235.00
EY51	0.80
EY81	2.35
EY83	1.50
EY84	5.95
EY86/87	0.50
EY88	0.55
EY91	5.50
EY802	0.70
EZ40	2.75
EZ41	2.75
EZ80	0.75
EZ81	0.75
EZ90	1.50
F606	2.95
FWA/800	2.95
G55/1K	9.00
G180/2M	6.95
G240/2D	9.00
GC10B	17.50
GC10D	17.50
GC10/48	17.50
GC10/4E	17.50
GC12/4B	17.50
GD86W	6.00
GDT120M	5.00
GN4	6.00
GN10	15.00
GR10G	4.00
GS10C	18.50
GS10H	12.00
GS12D	12.00
GT1C	14.00
GT1CS/S	13.00
GTN175M	8.00
GTR150W	1.00
GU20	35.00
GU50	17.50
GXU1	13.50
GXU3	24.00
GXU50SS	14.50
GY501	1.50
GY802	1.50
GZ30	1.50
GZ31	1.50
GZ32	1.50
GZ33	4.50
GZ34	2.15
GZ37	4.50
HAA91	1.00
HABC80	0.90
HBC90	0.75
HBC91	0.80
HF93	0.75
HF94	1.50
HK90	1.05
HL2K	4.95
HL23DD	4.00
HL41	3.50
HL42DD	3.50
HL90	0.70
HL92	1.50
HL13DD	3.50
HT2	4.00
HY90	1.00
HVR2	3.00
K3118	85.00
KR6/3	45.00
KT8C	7.00
KT33C	3.50
KT36	2.00
KT44	4.00
KT45	4.00
KT61	5.00
KT63	2.00
KT66 USA	9.95
KT66 GEC	17.50
KT66 Sp. Yellow Spot	19.50
KT67	9.00
KT77 Gold Lion	10.95
KT81	7.00
KT88 USA	10.95
KT88 G Lion	18.95
KTW61	2.50
KTW62	2.50
KTW63	2.00
KTZ63	2.50
L102/2K	6.95
L102/2K	12.00
LB7-20	95.00
LS9B	6.95
M502A	60.00
M537A	60.00
M5143	155.00
M8079	6.00
M8082	7.50
M8083	3.25
M8091	7.50
M8096	3.00
M8098	5.50
M8099	5.00
M8100	5.50
M8136	7.00
M8137	7.95
M8161	6.50
M8162	5.50
M8163	5.50
M8190	4.50

M8195	6.50
M8196	5.50
M8204	5.50
M8223	4.50
M8224	2.00
M8225	3.95
ME1401	29.50
ME1402	29.50
ME1501	14.00
MH4	3.50
MHL6	4.00
ML4	4.50
MP25	195.00
MS4B	5.50
MU14	3.50
MZ1-100	125.00
N37	12.50
N78	9.85
OA2	0.85
OA2WA	2.50
OA3	2.50
OB2	0.85
OB2WA	2.50
OC2	2.50
OC3	1.50
OD3	1.70
OM4	1.00
OM5B	3.00
OM6	1.75
ORP43	2.50
ORP50	3.95
P61	2.50
P41	2.50
PABC80	0.75
PC86	0.75
PC88	0.75
PC92	3.50
PC97	1.10
PC800	1.10
PC900	1.25
PCC84	0.40
PCC85	0.55
PCC88	0.70
PCC89	0.70
PCC189	0.70
PCC805	0.70
PCC806	0.80
PCE82	0.80
PCF80	0.65
PCF82	0.60
PCF84	0.65
PCF86	1.20
PCF87	0.40
PCF200	1.80
PCF201	1.80
PCF800	0.40
PCF801	1.35
PCF802	0.60
PCF805	1.25
PCF806	1.25
PCF808	1.25
PCH200	1.50
PCL82	0.85
PCL83	2.50
PCL84	0.75
PCL85	0.80
PCL86	0.85
PCL800	0.80
PCL805	0.90
PE1-100	69.00
PEN25	2.00
PEN40DD	2.50
PEN45	3.00
PEN45DD	3.00
PEN46	2.00
PE06-40N	42.00
PFL200	0.95
PL21	2.50
PL36	1.75
PL38	1.50
PL81	0.72
PL81A	0.72
PL82	0.60
PL83	0.52
PL84	0.78
PL88	1.00
PL95	2.95
PL302	1.00
PL345	12.50
PL500	1.10
PL504	1.15
PL508	1.75
PL509	4.85
PL519	4.95
PL802T	3.50
PL820	2.95
PL5557	29.50
PY32	0.60
PY33	0.50
PY81	0.70
PY82	0.70
PY83	0.70
PY88	0.65
PY500A	1.95
PY800	0.79
PY801	0.79
QB3-300	54.95
QB3-1750	139.50
QB5-3500	595.00
QE03-10	4.95
QE08-200	145.00
QF40	65.00
QP25	1.00
QQE02-5	19.50
QQE03-12	7.95
QQE03-20	35.00
QQE06-40	45.00
QQV02-6	19.50
QQV03-10	5.50
QQV03-10 Mullard	15.00
QQV03-20	25.00
QQV06-40A	27.50
QQV06-40A Mullard	45.00
QQV07-50	63.50
QQZ03-20	42.50
QS75/20	1.50
QS75/40	3.00
QS92/10	2.50
QS95/10	4.85
QS108/45	4.00
QS150/15	6.95
QS150/30	1.15
QS150/45	7.00
QS1200	3.95
QS1202	3.95

QS1203	4.15
QS1205	3.95
QS1206	1.05
QS1207	0.90
QS1208	0.90
QS1209	3.15
QS1210	1.50
QS1211	1.50
QS1212	3.20
QS1213	5.00
QS1215	2.10
QS1218	5.00
QU37	9.50
QV03-12	5.75
QV05-25	2.50
QV06-20	29.50
QV08-100	145.00
QV2-2500	45.00
QY3-125	65.00
QY4-250	70.00
QY4-400	76.00
R10	4.00
R16	12.00
R17	1.50
R18	2.50
R19	2.50
R20	1.20
R1169	55.00
RG1-125	4.95
RG1-240A	14.50
RG3-250A	3.50
RG3-1250A	35.00
RK2K25	62.50
RK-208	12.00
RL16	1.50
RPL16	12.00
RPY13	2.50
RPY43	2.50
RPY82	2.50
RR3-250	15.00
RR3-1250	35.00
RS613	45.00
RS685	54.95
RSS688	52.15
S6F17	5.95
S6F33	28.95
S11E12	38.00
A30/2K	12.00
S104/1K	10.00
S109/1K	15.00
S130	5.59
S130P	5.95
SC1/800	5.00
SC1/1100	6.00
SC1/1200	5.00
SC1/1300	6.00
SC1/200	9.00
SP41	5.00
SU42	4.95
TB2.5/300	85.00
TB2-300	45.00
TB3-2000	395.00
TD1-100A	25.00
TD03-10F	35.00
TD3-12	4.00
TDD4	5.50
TP25	1.50
TSP4	7.00
TT11	1.50
TT21	45.00
TT22	45.00
TT100	57.00
TTR-31MR	65.00
TY2-125A	85.00
TY4-400	85.00
TY8-600W	365.00
TYS2/250	375.00
U18-20	2.75
U19	11.95
U24	2.00
U25	0.90
U26	0.90
U37	9.00
U41	6.95
U50	1.20
U82	3.00
U191	0.70
U192	1.00
U193	0.65
U251	1.00
U801	0.75
UABC80	0.65
UAF42	1.00
UBF80	0.60
UBC41	2.25
UBC81	1.50
UBF89	1.00
UBL21	1.75
UC92	1.20
UCC84	0.70
UCC85	0.60
UCF80	1.00
UCH21	1.20
UCH42	2.50
UCH81	1.00
UCL82	1.75
UCL83	2.50
UF41	1.15
UF42	1.15
UF80	1.75
UF85	1.20
UF89	2.00
UL41	5.50
UL44	3.50
UL84	1.50
UL85	0.85
UU5	3.50
UU7	8.00
UU8	9.00
UY41	3.50
UY85	0.70
V235A/1K	250.00
V238A/1K	295.00
V246A/2K	315.00
V246/1K	225.00
V241C/1K	195.00
V339	3.50
V453	12.00
VLS631	10.95
VP4B	4.50
VP133	2.00
VR75/30	3.00
VR101	2.00
V105/30	1.50
VR150/30	1.15
VT52	2.50

VU29	4.50
VU39	1.50
W21	4.50
W77	5.40
W729	1.00
W739	1.50
X24	4.50
X66/X65	4.95
X76M	1.95
XC24	1.50
XC25	0.50
XFW47	1.50
XFW50	1.50
XG1-2500	75.00
XG5-500	22.50
XL628FT	7.50
XNP12	2.50
XR1-1600A	49.50
XR1-3200A	79.50
XR1-6400A	149.50
Y502	25.00
Y65	6.95
YD1100	75.00
YJ1060	265.00
YL1020	42.50
YL1060	195.00
YL1070	195.00
YL1071	195.00
YL1290	65.00
Z77	1.20
Z302C	12.00
Z359	9.00
Z505S	15.00
Z520M	4.00
Z521M	8.00
Z700U	3.00
Z749	0.60
Z759	19.85
Z803U	18.95
ZA1000	12.50
ZA1001	1.50
ZM1005	8.00
ZM1020	6.00
ZM1021	8.00
ZM1023	7.95
ZM1041	14.00
ZM1082	9.00
ZM1084	10.00
ZM1177	9.00
ZM1202	55.00
ZM1263	4.00
1B22	10.00
1B27	55.00
1B35A	45.00
1B63A	75.00
1C1	2.50
1C5GT	2.50
1FD1	2.50
1G3GT	2.50
1J3GT	2.50
1K3	2.50
1N2	4.50
1N5GT	2.50
1P28	25.00
1P39	19.50
1R5	4.90
1T4	1.00
1U4	1.75
1U5	1.00
1X2B	1.40
1Z2	8.95
2AS15A	11.50
2B7	1.50
2B22	69.50
2C39A	32.50
2C39BA	39.50
2C40	37.00
2C42	29.50
2C43	60.00
2C51	0.75
2C53	45.00
2CY5	1.50
2D21	1.95
2D21W	2.50
2E22	49.00
2E26	7.95
2J42	93.00
2J55	295.00
2K25	35.00
2K25 Raytheon	75.00
2K26	95.00
2K29	250.00
2K48	140.00
2K56	250.00
2X2A	5.00
3A/107B	12.00
3A/108A	9.00
3A/109B	11.00
3A/110B	12.00
3A/141K	11.50
3A/147J	7.50
3A/167M	10.00
3A/2	3.95
3A3A	3.95
3A4	1.10
3A5	4.50
31L5	0.95
3AT2	3.35
3B2	3.00
3B4	4.95
3B7	4.50
3B24	10.00
3B26	24.00
3B28	15.00
3BZ6	1.50
3C4	1.00
3C23	19.00
3C45	24.00
3CB6	1.50
3CN3A	2.50
3CS6	0.95
3CX3	2.50
3CY5	1.50
3D6	4.50
3D21A	29.50
3E22	49.50
3EH7	1.95
3EJ7	1.95
3V4	1.75
3W4GT	2.50
4B5518	115.00
4-65A	59.00
4-250A	79.50
4-400A	87.50
4-1000A	425.00

4B32	35.00
4BQ7A	1.75
4BZ6	1.95
4C27	25.00
4C28	25.00
4C35	145.00
4CX1000A	425.00
4CX4000A	1100.00
4CX250B	49.00
4CX250B EIMAC	59.50
4D32	125.00
4CX250BN	75.00
4CX250K EIMAC	95.00
4CX125C EIMAC	125.00
4CX350A	95.00
4CX350F	79.50
4XC1500B	398.50
4E27	195.00
4GS7	2.25
4J52	75.00
4JC6A	2.95
4KT6	1.50
4X150A	35.00
5A/102D	9.50
5A152M	9.00
5A163K	10.00
5A170K	6.25
5A-180M	9.00
5A-206K	10.00
5AM8	2.15
5AN8	1.20
5AR4	2.00
5AU4	1.50
5B 110M	10.00
5B-254M	14.50
5B-255M	19.50
5B-256M	15.00
5B-257M	15.00
5B-258M	14.50
5C22	125.00
5CL8A	2.50
5J180E	2950.00
5R4GB	5.50
5R4GY	4.95
5T4	5.95
5U4G	2.95
5U4GB	4.50
5V4G	1.50
5Y3GT	1.95
5Z4GT	1.50
6/30L2	0.70
6A/203K	9.00
6A7	4.95
6A8G	1.50
6AC7	2.00
6AG5	1.50
6AG7	1.95
6AH6	2.50
6AJ4	2.00
6AJ7	2.00
6AK5	1.95
6AK6	2.50
6AL5	0.60
6AM4	3.25
6AM5	6.00
6AM6	1.95
6AN5	4.50
6AN8A	3.50
6AQ5	1.75
6AQ8	0.85
6AR5	5.95
6AR8	3.95
6AS5	1.50
6AS6	2.50
6AS7G	4.50
6AT6	0.75
6AT8	1.75
6AU4	2.00
6AU5GT	4.50
6AU6	0.95
6AV6	0.75
6AW8A	2.50
6AX4GT	1.95
6AY3B	1.95
6AZ8	4.50
6B7	2.80
6B8G	1.50
6B10	1.95
6BA6	0.95
6BA7	4.50
6BA8A	3.50
6BE6	0.95
6BG6G	3.00
6BH6	1.95
6BH8	1.50
6BJ6	1.50
6BK4	4.00
6BK7A	1.95
6BL6	85.00
6BL8	1.15
6BM6	115.00
6BM8	0.58
6BN4	1.65
6BN6	1.65
6BN7	4.50
6BN8	3.95
6BQ5	0.75
6BQ7A	0.72
6BL7GTA	3.95
6BR5	0.70
6BR7	4.95
6BR8	2.15
6BR8A	2.15
6BS7	5.50
6BW4	1.50
6BW6	5.35
6BW7	1.50
6BW8	4.00
6BX6	0.48
6BX7GT	3.50
6BZ6	2.50
6BZ7	2.95
6C4	1.25
6C5	1.95
6C6	2.50
6C8G	1.50
6C11	2.50
6C18	2.50
6CA4	4.95
6CA7	3.50
6CB5	3.95
6CB6	1.95

6CD6GA	4.50
6CF6	1.50
6CG7	2.25
6CH6	6.95
6CL3	3.95
6CL6	3.25
6CL8A	1.50
6CN5	1.60
6CM7	2.95
6CS6	0.75
6CS7	0.95
6CW4	6.50
6D6	2.50
6DC6	2.35
6DJ8	0.95
6DK6	1.50
6DQ5	5.95
6DQ6B	2.50
6DT6A	1.50
6DW4	2.15
6E5	3.95
6EA4	4.95
6EA7	2.50
6EA8	2.50
6EB8	1.75
6EM5	2.50
6EM7	2.50
6EU7	1.95
6EU8	1.75
6EV7	2.95
6EW6	2.95
6EW7	4.50
6F1	2.00
6F5	4.95
6F6	2.50
6F6G	2.00
6F7	5.50
6F12	1.50
6F13	3.00
6F14	1.00
6F17	2.75
6F21	2.50
6F23	0.60
6F24	1.25
6F25	1.25
6F28	1.25
6F32	1.25
6F33	17.00
6FG5	1.95
6FQ7	2.95
6G6G	5.50
6GE5	3.95
6GH8A	0.80
6GK5	1.50
6GK6	1.95
6GM6	2.65
6GS7	2.15
6GV7	2.50
6GW6	2.50
6GW8	2.50
6GY5	3.95
6H1	9.50
6H3N	2.50
6H6	1.95
6H6GT	1.95
6HF5	5.50
6HF8	2.50
6HS6	4.95
6J4	2.15
6J4WA	3.15
6J5	2.50
6J6	2.00
6J7	4.15
6JB6A	4.50
6JE6C	6.50
6JU8	2.50
6JS6C	6.50
6J7G	4.15
6K7G	2.00
6K8G	3.00
6KD6	6.50
6KM8	2.50
6KT8	2.95
6L1	2.50
6L15	3.15
6L19	3.95
6L6GC	2.95
6L6GC(GE)	4.95
6L6GT	1.95
6LD20	1.15
6LF6	7.50
6L6GAY SYLVANIA	5.50
6LJ8	2.50
6LQ6	6.50
6Q7GT	1.20
6R7G	3.15
6S4A	1.50
6SA7GT	1.35
6SC7	1.50
6SG7	2.50
6SH7	1.35
6SJ7GT	1.20
6SK7	1.35
6SK7GT	1.35
6SL7GT	0.85
6SN7GT	1.35
6SQ7	1.35
6SS7	1.95
6U4GT	1.75
6U6WA	3.50
6U8	1.15
6U8A	1.50

6V6G	1.25
6V6GT	1.50
6VGG	1.00
6Y6G	3.95
6X2N	1.00
6×4	1.50
6×5GT	1.00
6×5GTY	1.00
6×8B	2.25
7A6	4.50
7A7	2.00
7AD7	1.75
7AU7	1.50
7B6	3.50
7B7	2.50
7C5	3.50
7C6	2.50
7E7	2.50
7H7	3.50
7J7	5.50
7Y4	2.50
8B8	2.50
8B10	2.50
8BQ5	1.95
8FQ7	1.95
10D2	1.25
10DE7	2.50
10EW7	2.95
10F1	0.75
10GK6	1.95
10P14	2.50
10P18	0.75
10LD12	0.65
11E2R	45.00
11E3	55.00
11R3	5.50
12A6	3.95
12AD6	1.50
12AH7GT	4.95
12AL5	1.00
12AT6	1.25
12AT7	1.15
12AT7WA	2.50
12AU6	1.50
12AU7	0.65
12AV6	1.95
12AV7	2.50
12AX7GT	1.00
12AX7	0.65
12AX7WA	2.50
12AY7	3.95
12AZ7A	1.95
12B4A	4.50
12BA6	1.50
12BE6	1.95
12BH7A	2.50
12BL6	1.75
12BY7A	2.75
12C8	2.40
12CA5	1.95
12CX6	1.20
12DQ6B	3.50
12DW4A	3.50
12E1	19.50
12E14	38.00
12GN7	3.95
12HG7	4.50
12HG7A	4.50
12J5GT	3.95
12J7GT	3.50
12JZ8	2.95
12K5	1.95
12K7GT	1.50
12K8	1.95
12SA7GT	1.95
12SG7	4.75
12SH7	1.95
12SK7	1.95
12SJ7	1.50
12SQ7GT	1.95
12SN7GT	1.85
12X4	1.95
12SY7	4.50
13D3	3.20
13D7	3.20
13D9	3.20
13DE7	2.50
13DR7	2.95
13E1	145.00
13EM7	3.50
14S7	1.95
16GY5	2.95
17BE3	2.50
17DW4A	2.95
17EW8	0.95
17JZ8	4.50
18D3	6.00
18GB5	3.50
19AQ5	3.50
19AU4GT	2.50
19G6	9.00
19G3	17.00
19H4	35.00
19H4R	25.00
19H5	33.50
19Q6	9.00
20A2	10.50
20D1	0.70
20LF6	7.95
20L1	0.95
20P1	0.55
20P3	0.60
20P4	1.95

20P5	1.15
21JZ6	4.95
21LU8	3.75
24B1	39.50
25DQ6B	2.95
25L6GT	1.75
25BQ6	1.75
29C1	19.50
29KQ6	6.50
30C17	0.40
30C18	1.48
3F5	0.95
30FL1	1.00
30FL2	1.35
30FL12	0.95
30FL13	1.10
30FL14	1.25
30L1	0.45
30L15	0.60
30L17	0.60
30P4MR	1.00
30P12	1.00
30P18	0.60
30P19	1.00
30PL1	2.50
30PL13	0.60
30PL14	1.75
31JS6C	5.50
33A/158M	19.50
35A5	4.50
35L6GT	2.00
35Z3	1.85
38HE7	4.50
40KD6	5.50
42	6.95
47	6.00
50A5	1.50
50C5	0.95
50CD6G	1.15
50EH5	1.50
50JY6	2.95
52KU	2.00
53CG	15.00
61SPT	4.50
75B1	3.50
75C1	2.50
80	4.50
83	8.50
84	3.00
85A1	6.50
85A2	1.95
90AV	15.00
90C1	3.50
90CG	13.50
90CV	12.50
91AG	9.00
92AG	19.50
92AV	15.00
95A1	6.50
100E1	10.00
108C1	1.50
150B2	6.50
150C2	2.50
150C4	2.15
155UG	25.00
185BT	1.50
211	33.50
274A	15.00
307	5.00
328A	15.00
388A	17.50
425A5	8.00
431U	4.50
572B	55.00
705A	8.00
708A	8.00
715C	45.00
724A	275.00
726A	75.00
803	14.95
805	59.00
807	2.50
810	85.00
811A	15.00
812A	35.00
813	27.50
829B	14.50
833A	95.00
866A	6.50
872A	20.00
873	60.00
884	5.50
930	9.95
931A	13.95
954	1.00
955	1.00
958A	1.00
1299A	0.60
1619	2.50
1625	3.00
1626	3.00
2050W	6.95
2050	5.50
2051	5.50
3534	4.00

404A	10.95
927	15.00
1927	25.00
4687A	9.50
4212E	250.00
4313C	4.00
4328D	9.00
5636	5.50
5642	9.50
5651	2.50
5654	1.95
5663	1.95
5670	3.25
5672	4.50
5675	28.00
5678	7.50
5687	4.50
5692	3.50
5696	4.50
5704	3.50
5718	6.15
5725	2.50
5726	2.50
5727	2.50
5749	2.50
5750	1.85
5751	2.95
5763	5.75
5814A	3.25
5823	9.50
5829WA	6.50
5840	3.50
5842	11.00
5847	10.95
5879	5.00
5886	13.95
5894	39.50
5899	4.50
5963	1.75
5065	2.25
6005	1.85
6012	16.00
6021	3.65
6057	3.75
6058	3.95
6059	3.75
6060	2.25
6062	4.50
6063	2.00
6064	3.25
6067	7.00
6072	4.20
6080	8.50
6080WA	9.50
6132	10.50
6136	2.50
6146B	9.50
6155	65.00
6156	65.00
6157	2.50
6158	3.20
6201	6.45
6205	6.95
6211	2.50
6267	4.50
6350	3.50
6360	4.50
6386	14.50
6463	7.50
6545	8.50
6550A GE	10.95
6550 RCA	15.00
6688	6.50
6870	11.50
6887	9.50
6883B	9.95
6973	5.95
7025	2.50
7027A	4.50
7032	2.00
7059	2.50
7167	3.95
7189	3.50
7193	7.50
7199	7.50
7247	4.95
7360	13.50
7462	15.00
7475	5.00
7486	125.00
7527	85.00
7551	8.50
7558	9.45
7586	15.00
7587	29.50
7791A	4.95
7609	47.00
7733	5.50
7788	29.50
7815	72.95
7868	4.95
8012	15.00
8950	7.50
18042	10.50
18045	10.00
18046	11.50

OVER 4 MILLION VALVES IN STOCK
4,000+ Different Types
Please enquire for types not listed.
Specially selected and matched valves available on request

AUDIO TAPE HEADS

MONO HEAD	2.50
AUTO REVERSE	3.95
STEREO HEAD	3.50

VALVE AND CRT BASES

B4	3.95	SK406	35.00
B5D	5.50	SK410	25.00
B7G	0.25	SK610	35.00
B7G SKTD	0.25	UX5	1.75
B8G	1.50	UX7	1.7
B8H	0.70	VALVE CANS	
B9A	0.35	B7 and B9	0.35
B9A SKTD	0.60	ANODE CAPS	
B9G	0.75		0.50
B10B	0.20	QQV06	
B13B	0.50	SOCKET	10.00
B14A	3.00	813 SOCKET	
OCTAL	0.35		8.50

CALLERS WELCOME

OPEN MON-THUR 9AM-5.30PM
FRI 9AM-5.00PM
'24-HOUR ANSWERPHONE SERVICE'
ACCESS & BARCLAYCARD PHONE ORDERS WELCOME
UK ORDERS P&P £1
PLEASE ADD 15% VAT
EXPORT ORDERS WELCOME
CARRIAGE AT COST
PLEASE SEND YOUR ENQUIRIES FOR SPECIAL QUOTATIONS FOR LARGE REQUIREMENTS.

ENTER 44 ON REPLY CARD

FEEDBACK

Aftersales

There must be many sales representatives who are unaware of the existence of The Royal Pinner School Foundation, which is an educational trust set up for the purpose of assisting, by means of grants and awards in the education, up to the age of 25, of sons and daughters of sales representatives where the family has suffered adversity.

The majority of children assisted attend local state schools, colleges of further education, university or special schools in the case of handicapped children, and financial assistance is given towards school clothing, books, tools, school trips, field courses, music, etc.

If any of your readers would like to have further information I would be pleased to send them, on request, a copy of our leaflet.

S. Thurtell
Secretary
The Royal Pinner School Foundation
110 Old Brompton Road,
London SW7 3RB

Frequency allocations

Mr Eaton, in his reply (*E & WW*, December, 1986) to my letter said that the UK's l.f. allocation of 200kHz could have been maintained if a different channel grouping plan had been adopted for the l.f. band at the 1979 WARC.

This would be the case if the major cause of intermodulation product interference in the l.f. band were other l.f. signals. However, in practice, a more significant problem is that of intermodulation products generated by strong signals in the m.f. band. Since the m.f. band is organised on multiples of 9kHz any intermodulation products will also fall on multiples 9kHz. To minimize the effect of such products falling inside the l.f. band, the broadcast carriers have to be located at multiples of 9kHz.

For example, if two strong m.f. signals were present at 909kHz and 1107kHz then a second order intermodulation product could be generated in the receiver front end at 198kHz (1107-909kHz). This would cause a 2kHz interfering whistle to the reception of 200kHz but because it would fall directly on the carrier of a 198kHz signal the degradation to this service would not be so severe.

Henry Price
Assistant Head of Engineering
Information Department, BBC

S5/8

In reply to Mr Hayard's letter in the January, 1987 issue, I am sorry that he remains "unconvinced" about the merits of S5/8, but I must, again, take issue with his comments.

Transmission and termination: a series resistor at the transmitter end is a terminator! The value suggested (270Ω) is not the ideal value (which would be calculated from line impedance – driver output impedance), but was a compromise between ringing suppression and output short circuit protection. A higher value will, in any case, reduce the problem of ringing. The incidence of ringing is dependent on the rise and fall time of the driver in relation to the cable's electrical length. The series resistor, in conjunction with the cable's capacitance, reduces the rise and fall time, so reducing the ringing. I suggest Mr Hayward tries driving some cable with an HCMOS gate with 270Ω series resistor and observes the result. The resistor used on the floppy disc interface is more of an open-collector pullup than a terminator (although it is often referred to as such), and with only a uni-directional (sink) drive at the source end can hardly be considered an example of how to properly terminate a line! Also, modern low power 90mm (3.5 in) disc drives are using 1kΩ pullups, because of the high power consumption of the traditional 150Ω.

Costs and consumption: the question of an "extra pound or two" for components is a question that will be settled by market forces, not by discussion in a letters column, but I think if Mr Hayward took the matter up with Alan Sugar, he might get a more forthright answer! On the consumption question, 100mA (or more) for differential is highly significant, despite Mr Hayward's dismissal. In battery portable equipment, an extra 100mA would make the difference between a saleable product, with a useful battery endurance, and an unsaleable one, in constant need of recharging. Of course, every user would like an error-free transmission link, but using RS-485, or any other electrical transmission scheme, does not guarantee that; a detection/retransmit or correction protocol would still be required.

On Mr Hayward's final point, about consultation, the Draft for Development (DD) is the normal method of inviting comments on proposed British Standards. So far as publication of early information in the pages of *Wireless World* is concerned, if the editor is willing, I am quite prepared to write a regular column summarizing standards activities in my field (Data transmission, floppy discs, ISDN, etc.).

However, there is a way in which Mr Hayward could participate at an earlier stage: I have just been appointed convenor of IST6/7 and I am actively looking for new members. IST6/7 is not only responsible for S5/8, but also is the UK member for ISO SC13, which handles equipment interface standards, such as Small Computer System Interface (SCSI, used on intelligent disc and cartridge drives), Fibre Distributed Data Interface (FDDI, a fibre-optic token ring network), Intelligent Peripheral Interface (IPI, also used for disc and tape drives), and the proposed standard for floppy-disc interfaces. How about it, Mr Hayward? Are you willing (and able) to join IST6/7 and participate in the meetings (about six a year, in London)?

This invitation is also open to any other readers who are interested. You don't need to be an expert, but you may become one when you have finished a project. You will need to have some level of technical knowledge, of course, but your chief requirements are interest and enthusiasm. Most of the proposals listed above are manufacturers' "*de factos*" originating in the USA. It is time the UK took a more active and contributory role, actually creating new standards, not just commenting on US proposals. *Wireless World* is well known for its knowledgeable and active readership. Any readers interested in taking up this offer are invited to contact me.

Andrew Hardie
Oval Automation Ltd
Courtwick Lane
Littlehampton
West Sussex

Maximum power theorem

Whilst I can claim no originality for Thévenin's theorem or maximum power transfer theorem I believe it would have been both useful to readers and courteous to give reference to my article 'Impedance Mismatching', *Wireless World*, March 1980, pages 59 and 78, which follows the same theme as the above article appearing in the January issue of your journal.

F.J. Lidgey
Principal Lecturer in Electronics
Oxford Polytechnic

Heat transfer

I was delighted to read the letter by Nigel Pritchard of SGS (January, 1987) on heat transfer in transistors. I cannot agree that the differences in sound which I noted were due to factors other than junction temperature. Firstly, the TO126 devices (BD139 & BD140) had replaced TO92 small signal transistors with a marked improvement in sound quality. Secondly the sound quality improved further when the TO 220 transistors were mounted on the same sheet of aluminium. Further evidence in other parts of the circuit backs up my argument. An amplifier project which I designed for low-temperature-generated distortion for *Practical Electtronics* was very favourably reviewed by one of their regular contributors.

It should be possible to measure the increased harmonic distortion caused by temperature-generated distortion, but I would guess that it would be a small part of the overall distortion.

The real problem, I find, is to locate suitable transistors for audio use which combine the gain at low collector currents of small-signal transistors and the

FEEDBACK

low thermal resistance of typical audio output transistors. Such transistors must have a metal tab to screw to a heat sink, constant H_{fe} over a wide current range (e.g. 10µA to 100mA), Minimum H_{fe} guaranteed not less than 50 or 100 over this current range, V_{be} close to 600mV at 1mA collector current and a thermal resistance from junction to case of 3 to 5°C/watt. Such transistors would need to be available in n-p-n and p-n-p configurations, with dual matched pairs available and high-voltage versions also available with some relaxation of the above specs.

If Mr Pritchard can help, I would be delighted to hear from him.

Graham Nalty
Audiokits
Borrowash
Derby

Relativity

I have always found the experience of reading James MacHarg's letters rather like reading a novel by James Joyce, and the feeling was intensified when I saw his letter in the January issue. The letter includes a 'mathematical proof' that 2 equals 1. If every schoolboy had been taught that dividing both sides of an equation by a factor whose value is zero is a legitimate mathematical operation British technology would be in a poor way. In Victorian times continental mathematicians accused their English colleagues of lack of rigour and of excessive formalism. It seems old habits die hard.

Lee Coe in a letter in the same issue used the phrase 'wave velocity' for what is evidently the phase velocity for the wave pattern within a pulse travelling down a wave guide. Information is propagated, not at the phase velocity, but at the group velocity, so that Special Relativity does allow phase velocities in excess of the velocity of light. For a normal waveguide the product of the phase and group velocities is c^2. It is easier to avoid exciting unwanted modes at drive frequencies near cut-off, but at those frequencies the group velocity falls well below the velocity of light and the phase velocity therefore rises well above it. Loading the guide in the way described in the *Scientific American* article reduces the product of the phase and group velocities. The guide can then be driven at near its cut-off frequency to minimise the rise of mixed-mode excitation, yet will still allow a pulse to propagate for which the phase velocity is less than the velocity of light, so that it is suitable for accelerating electrons. Thus the design of the Stanford Electron Linac does not provide evidence against Special Relativity. How could it, seeing that the Lorentz Transformations were first introduced as transformations which when made left the form of Maxwell's equations unaltered?

Alex Jones' letter in the January issue includes a photograph of an interesting demonstration devised by the arch-engineer, inventor, and showman Professor Eric Laithwaite. However, the account he gives is wrong. The downward force on the finger is almost exactly 24 pounds, as anyone can verify who cares to weigh a toy gyroscope and its tower first stationary, and secondly after the gyroscope has been brought up to speed, and then set with its axis horizontal and supported at one end on the top of the tower. There is nothing out of the way about supporting a 24 pound weight from a little finger if it is suspended directly below; what is surprising is that with the weight over a foot off to one side the finger isn't twisted out of its socket. In fact the twist exerted is almost nil.

I have seen Professor Laithwaite's demonstration, which makes it quite obvious that most of us have very little feeling for the behaviour of gyroscopes, even if we are aware that the equations governing the motion of a rigid body include some which describe the effects of torques on angular momentum as well as those which describe the effects of resolved forces on linear momentum. On that occasion members of the audience were invited to try their hand. A secretary who did what she was told to do coped with the massive rotor very well, but a senior physicist who 'knew' he would have to exert a substantial torque on the end of the shaft to prevent the rotor from swinging downwards lost control in a fraction of a second!

The rotor demonstrations themselves have no relevance to Special Relativity, but a rotor does have one very important characteristic. While rotating at constant speed it experiences strong internal stresses, which if it is rotating fast enough can cause it to fly to bits. The existence of these stresses must therefore be recognised in every inertial frame, i.e. rotational motion is not relative, but absolute. It may be more than a coincidence that the experiments by Aspect which violate the Bell inequality (derived from Special Relativity) involve the observation of quantised rotations.

C.F. Coleman
Grove
Oxfordshire

Mathematics

In the January 1987 issue of *E&WW*, Mr James MacHarg of Northumberland has tried to demonstrate "the lack of value of mathematics, unless backed by an active dynamic logic which may be expressed in words" In this he has totally failed.

By its very nature, as any mathematician will tell you, the science of mathematics is an active dynamic logic and may be expressed in plain English if so required.

I hope not all schoolboys have been shown his 'proof' that 2 = 1, for in his attempt to create a mathematical catastrophe, he has made a number of fundamental errors, as I will now show.

MacHarg	Remarks
Let a = b	
Multiply both sides by a $a^2 = ab$	
Subtract b^2 from both sides $a^2 - b^2 = ab - b^2$	As $a = b$, so $a^2 = b^2$, therefore $a^2 - b^2 = 0$ and $(ab) - b^2 = b^2 - b^2 = 0$ very neat, we have just proved that zero equals zero.
Let us continue	
Factorize $(a + b)(a - b) = b(a - b)$	
Cancel $\frac{(a+b)(a-b)}{(a-b)} = \frac{b(a-b)}{(a-b)}$	Dividing by $(a - b)$. At the beginning, we set $a = b$ i.e. $(a - b) = 0$. Dividing by zero is an invalid operation as it is non defined. So, this reduces to $\frac{(a+b) \times 0}{0} = \frac{b \times 0}{0}$ What is zero divided by zero? It certainly isn't unity as Mr MacHarg is suggesting.
$(a + b) = b$	Perfectly OK so long as
but a = b	a = 0, but as a = b (our defination) b must also be zero.
2b = b	Correct if b = 0
2 = 1	Nonsense.

I'm sorry, Mr MacHarg, but one should be sure of one's methods before attempting to discredit anything, especially by reductio ad absurdam.

John R. Ridley
Ruwi
Sultanate of Oman

Purple plague is back

'Purple plague', thought to have been eliminated in the 1970s as an i.c. failure mode, is now back with a vengeance according to a paper by P.K. Footner, B.P. Richards and R.B. Yates of the GEC Hirst Research Centre (*GEC Journal of Research* Vol.4 No3). Named after the characteristic colour of a gold/aluminium intermetallic compound $AuAl_2$, purple plague is a failure of the joint between the i.c. connecting pads and the wire that connects them to the external packaging.

Ten years ago, the cause of purple plague was attributed to chemical action between the bonding wire and the metallization of the chip's connecting packs. This process was shown to be accelerated by high temperatures, leading to the formation not just of $AuAl_2$, but a whole range of intermetallics having different physical and electric properties from either parent element. The prime cause of bond failure, however, was shown to be mainly due to a process called Kirchendall voiding. Gold diffuses faster than aluminium, resulting in vacancies in the atomic lattice on the gold-rich side of a bond. Towards the end of the 1970s the application of low-temperature fabrication processes – such as ultrasonic bonding – and improved bond design virtually eliminated purple plague failures.

Now, it appears, the disease is back. According to Footner *et al* there is a variety of reasons, including an increasing use of gold bonding wire and a tendency among manufacturers and users to disregard the possibility of purple plague failure. Other factors are also mentioned, including a Russian suggestion that intermetallic formation in a bond is governed in some way by the current or field conditions operating through or around the bond.

In analysing the failure of some modern l.s.i. chips using optical and scanning electron microscopy, the GEC team conclude that the reappearance of purple plague is partly the result of carelessness and partly a consequence of the changing design of chips. They say that the constraints currently applied to MSI are not directly applicable to l.s.i. and v.l.s.i. Also, the use of plastic encapsulants has in some cases led to new mechanisms of bond failure, such as chemical attack or the ingress of water.

How then can purple plague be eliminated in today's chips? Footner and his colleagues suggest that if it is impractical to employ single-metal systems, then at least it might be possible to use intermediate alloys such as titanium/tungsten to reduce the rate of diffusion. Apart from that, it is a matter of re-establishing sound design criteria and carefully monitoring factors such as fabrication temperature and chemical cleanliness. Ultimately, they say, it is important to remember that as long as dual-metal systems are employed, there will be the possibility of purple plague existing in some form.

Transputer in the driving seat

Dr Barry Thomas and Professor Erik Douglas of Bristol University are developing a transputer-based expert system for the control of unmanned vehicles. The three-year project, backed by £150,000 from the Ministry of Defence, will lead to a fully engineered vision system together with the control software necessary to drive a robot vehicle accurately and smoothly.

By human standards, the driving ability will be unspectacular; the robot is expected to be able to drive itself along an empty road and to turn right and left as necessary. Yet even this modest capability will require real-time algorithms capable of analysing each separate frame from a video camera mounted on the vehicle. Dr Thomas is developing the software to run on a bank of between 10 and 20 transputers which, unlike existing vision systems, will take the video signal directly without any external frame store.

The Bristol system is expected to be an order of magnitude more responsive than that of other robot vehicles, which up till now haven't been able to drive safely at more than a few km/h. Nor have they been able to distiguish the road from the verge by its texture alone.

In answer to the obvious question of why such large sums are to be spent in doing what a human being can do far better, Dr Thomas points to the possibility of having a military surveillance vehicle that could explore dangerous enemy territory entirely by passive sensing. There would be no need for give-away emissions or jammable radio links.

Ultimately, however, its true value is seen as 'enabling technology'. A real-time vision analyser could equally well act as a security guard or a method of checking goods on a production line...or eventually perhaps as a means of getting you home safely from the pub?

3-D optical memory

A new kind of photorefractive effect has been discovered by two physicists at the Racah Institute of Physics at the Hebrew University of Jerusalem's Faculty of Science. With further work, this effect, discovered by Professor Yizhak Yacoby and Aaron Agranat, will possibly be used for the development of holographic-type memories and other optical computing devices.

In contrast with ordinary disc or tape memories of computers where the information is stored on the surface of a magnetic film, holographic memories store information in the volume of special types of crystals. The information is written in and read out using laser beams.

Scientists in many laboratories have realised the distinct advantages of such memories and are looking for ways to put them into effect. The information density of such memories is enormous, and large quantities of information can be written and read in parallel using one flash of a laser beam. In these memories, it is possible to store directly both numbers and pictures without the need to translate the pictures into numbers first, as is done in present computers. The information is stored in such a way that defects in the crystal and small scratches do not spoil any part of the information. They just increase the intensity of the light which is needed to write the information.

The most promising way to write the information into the crystals is to use the photorefractive effect. This effect is simply the change in the refractive index of the crystal by the absorption of light in it. Experimental holographic memories using the photorefractive effect have been built, but the information stored in the memory is usually erased when the memory is read. This is a fundamental problem resulting from the very nature of the classical photorefractive effect.

Professor Yacoby proposed a new mechanism for a photorefractive effect which has been experimentally demonstrated and investigated by Agranat. The new photorefractive effect is at least as efficient as the classical effect and holograms written into the crystal are not erased when the information is read. Thus, this new effect may open a new way to utilize holographic computer memories.

Even though the Hebrew University scientists still have a long way to go to produce a practical device, they draw confidence form the fact that they have already demonstrated the existence of their new photorefractive effect and have the ability to produce the type of crystals that they need.

Radio telescope commissioned

The first radio signals have recently been received by the James Clerk Maxwell Telescope (JCMT) at the Mauna Kea Observatory in Hawaii. This is good news for British and Dutch astronomers, who have planned a schedule of observations for the whole of the year.

To test the new telescope it was first pointed at the moon with a receiver tuned to 230 GHz. As expected, a strong signal was received. All 'warm' objects emit signals at these high frequencies and for an object as close as the moon they are very easily detected. The telescope was then pointed at the planets Jupiter and Mars, and again strong signals were detected.

These events mark the successful commissioning of the telescope, in which engineering tests of its drive systems were carried out and the reflecting surface (consisting of 276 individual panels) was measured and adjusted to the correct paraboloidal shape. The sensitivity of the telescope is now being tested on far more distant objects and over a wide range of frequencies.

The construction of the 15 metre diameter radio telescope,

RESEARCH NOTES

The James Clerk Maxwell Telescope, the Mauna Kea. The viewing aperture can be covered by a p.t.f.e. membrane.

which is at the 4000 metre high Mauna Kea Observatory, by an arrangement with the University of Hawaii, began in the early summer of 1983. The foundations for the telescope and its co-rotating enclosure were completed in the following year. The major components of the telescope and its control system were delivered during 1985 and the assembly of the facility completed in June 1986.

The Rutherford Appleton Laboratory, in close collaboration with the University of Cambridge, has been responsible for the design, development, construction and commissioning phases of the project. Significant UK contributions have also been made by the Royal Observatory, Edinburgh, Queen Mary College, London and the University of Kent. In the Netherlands major contributions have been made by the University of Utrecht and the Laboratory for Space Research, Groningen. When it is commissioned the facility will be handed over to the Royal Observatory Edinburgh to be operated in conjunction with the United Kingdom Infrared Telescope (UKIRT) which is adjacent to the JCMT at Mauna Kea.

The James Clerk Maxwell Telescope will be the world's largest instrument capable of observing at frequencies above 300 GHz. This new telescope will give astronomers the opportunity to study one of the few remaining relatively unexplored parts of the electromagnetic spectrum where, in particular, they hope to discover new information about star formation and the microwave background radiation.

Supercomputer for advanced research

The Science and Engineering Research Council's Atlas Centre at the Rutherford Appleton Laboratory is now using a Cray X-MP/48 Supercomputer as part of a national initiative in research computing, covering all disciplines.

The Cray has four processors and 8 Mwords of memory. There is also a 32 Mword solid state device memory and about 14 Gbytes of disc storage. It is front-ended by existing powerful IBM mainframe equipment and accessed through the Joint Academic Network JANET. Other front-end computers may be added in due course. The new machine, together with the centres already established at Manchester and London, is the latest of three national supercomputer centres dedicated to advanced research. Professor John Forty of Stirling University has agreed to be the chairman of a new management committee for the supercomputing service.

Use of the Cray will help UK scientists and engineers engaged in a wide range of computer simulation problems including: aircraft design; the evolution of the galaxies; molecular reactions; the physics of liquids and solids; large scale integrated circuit design; the circulation of the atmosphere and oceans; and the design and operation of new pharmaceutical products.

In many areas of science the laws governing the behaviour of matter and materials are well known, but the application of these laws to complex systems, which is of pressing scientific interest, results in equations which require enormous computing power to solve. The advent of supercomputers makes it possible to tackle problems of this type which could not be approached with earlier generations of computers.

These areas spread across the boundaries of the five Research Councils, and many are relevant to the needs of industry. The expoitation of supercomputers is thus an area of rapidly growing importance.

Radioactivity and soft faults

Studies at the University of Southampton have investigated in detail the phenomenon of 'soft' errors in dynamic rams due to alpha particles. Ever since the introduction of high density rams in the mid 1970s, alpha sensitivity has been widely reported, though there has always been some uncertainty over which parts of the chips are most sensitive.

What the Southampton researchers did was to take samples of 65K nmos drams from three different manufacturers and prepared them by removing their lids and protective coatings. Then, by using masks and an alpha source (Americium-241), they were able, selectively, to expose different areas of the chips to radiation.

With each different position of the masks, the rams were then subjected to a sequence of write/read cycles, with the error rates being noted in each case. These tests showed quite clearly that alpha hits cause the most errors, not when they hit a memory cell, but when they hit a bit line. In fact, for chips from all three manufacturers, hits on the bit lines provided the only significant source of alpha-induced soft errors. Cells, sense amplifiers and peripheral circuitry appear to make a negligible contribution.

The Southampton workers, in a recently published paper (*Electronics Letters*, Vol.22 No 25), provide evidence that the increased sensitivity of the bit lines, compared with other components is, in all probablity, a reflection of nothing more than their greater collecting area.

Research Notes is written by John Wilson.

COMPUTER WAREHOUSE

1000's OF BARGAINS FOR CALLERS

THE "ALLADINS" CAVE OF COMPUTER AND ELECTRONIC EQUIPMENT

HOT LINE DATA BASE

DISTEL®

The **ORIGINAL FREE OF CHARGE** dial up data base. Buy, browse or place **YOUR OWN AD** for goods or services to sell. 1000's of stock items, spares and one off bargains. Updated daily. **ON LINE NOW.** CCITT, 8 bit word, no parity. For **300** baud modems call 01-679 1888 For **1200-75** baud modems call 01-679 6183

DON'T MISS THE CPM Deal OF the CENTURY

The FABULOUS CPM TATUNG PC2000 Professional Business System

A cancelled export order and months of negotiation enables us to offer this professional **PC CPM** system, recently on sale at **OVER £1400**, at a **SCOOP** price just over the cost of the two internal disk drives!! Or less than the price of a dumb terminal!!

Not a toy, the **BIG BROTHER** of the **EINSTIEN** computer, the **DUAL PROCESSOR PC2000** comprises a modern stylish three piece system with ALL the necessities for the **SMALL BUSINESS, INDUSTRIAL, EDUCATIONAL** or **HOBBYIST USER**. Used with the THOUSANDS of proven, tested and available CPM software packages such as **WORDSTAR, FAST, DBASE2** etc. the **PC2000** specification, at our prices, **CANNOT BE BEATEN**!!

The central processor plinth contains the **64K, Z80A** processor, **DUAL TEAC 55 F 5¼"** Double sided **40/80** track disk drives (1Mb per drive), **PSU, 4K** of memory mapped screen RAM, disk controller, **RS232, CENTRONICS** and system expansion ports, and if that's not enough a ready to plug into **STANDARD 8" DRIVE** port for up to **FOUR 8"** disk drives, either in double density or **IBM** format. The ultra slim **92** key, detachable keyboard features 32 user definable keys, numeric keypad and text editing keys, even its own integral microprocessor which allows the main **Z80A** to devote **ALL** its time to **USER** programs, eliminating "lost character" problems found on other machines. The attractive, detachable 12" monitor combines a green, anti-glare etched screen, with full swivel and tilt movement for maximum user comfort. Supplied **BRAND NEW** with **CPM 2.2**, user manuals and full 90 day guarantee. Full data sheet and info on request.

PC2000 System with CPM Etc. COST OVER £1400 — **NOW only £399**

PC2000 Business System with CPM and 'Ready to Run' FAST Sales and Purchase ledger, supports up to 9000 Accounts, VAT etc. COST OVER £1700 — **NOW only £499** Carriage & Insurance £12.00

PC2000 Wordprocessor System with CPM and TEC FP25 daisywheel printer — **NOW only £799**

FREE

Your monitor from its computer!! For only **£24.95** it becomes a **SUPERB HIGH QUALITY • COLOUR • TV SET**

The fabulous **TELEBOX**, an **INVALUABLE MUST** for the owner of **ANY** video monitor with a composite input, colour or monochrome. Made by a major UK Co. as a **TOP QUALITY**, stand alone **UHF** tuner and costing **OVER** £75 to manufacture, this opportunity to give your monitor a **DUAL FUNCTION** must not be missed!! The **TELEBOX** consists of a compact, stylish two tone charcoal moulded case, containing ALL electronics tuner, power supply etc to simply plug in and convert your previously dedicated computer monitor into a **HIGH QUALITY COLOUR* TV SET**, giving a real benefit to ALL the family!! Don't worry if your monitor doesn't have sound – **THE TELEBOX** even has an integral 4 watt audio amplifier for driving an external speaker. **PLUS** an auxiliary output for superb quality television sound via your headphones or **HI FI** system etc. Other features include: Compact dimensions of only 15.75" w x 7.5" d x 3.5" h, latest technology, **BRITISH** manufacture, fully tuneable 7 channel push button tuner, Auto **AGC** circuit, **SAW** filter, LED status indicator, fully isolated 240v AC power supply for total safety, Mains ON-OFF switch etc. Many other uses.

LIMITED QUANTITY – DON'T MISS THIS OFFER!!!

ONLY £24.95 OR £19.95 if purchased with **ANY** of our video monitors. Supplied **BRAND NEW** with full instructions and 2 YEAR warranty. Post and packing £3.50. *When used with colour crt.

COLOUR & MONOCHROME MONITOR SPECIALS

'SYSTEM ALPHA' 14" COLOUR MULTI INPUT MONITOR

Made by the famous **REDIFFUSION** Co. for their own professional computer system this monitor has all the features to suit your immediate and future requirements. Two video inputs, **RGB** and **PAL** Composite Video, allow direct connection to **BBC/IBM** and most other makes of micro computers or **VCR's**, including our very own **TELEBOX**. An internal speaker and audio amp may be connected to computer or **VCR** for superior sound quality. Many other features: **PIL** tube, Matching **BBC** case colour, Major controls on front panel, Separate Contrast and Brightness – even in **RGB** mode. Separate Colour and audio controls for Composite Video input, **BNC** plug for composite input, 15 way 'D' plug for **RGB** input, modular construction etc etc.

This Must be ONE OF THE YEAR'S BEST BUYS. PC USER

Supplied **BRAND NEW** and **BOXED**, complete with **DATA** and 90 day guarantee. **ONLY £149.00** as above **OR IBM PC** Version **£165.00**. 15 Day 'D' skt **£1.00**, **BNC** skt **75p** **BBC** interface cable **£5.50**

DECCA 80 16" COLOUR monitor. RGB input.

Little or hardly used manufacturer's surplus enables us to offer this special converted **DECCA RGB** Colour Video TV Monitor at a super low price of only **£99.00**, a price for a colour monitor as yet unheard of!! Our own interface, safety modification and special 16" high definition PIL tube, coupled with the **DECCA 80** series TV chassis give 80 column definition and quality found only on monitors costing **3 TIMES OUR PRICE**. The quality for the price has to be seen to be believed!! Supplied complete and ready to plug direct to a **BBC MICRO computer** or any other system with a **TTL RGB** output. Other features are: internal speaker, modular construction, auto degaussing circuit, attractive **TEAK CASE**, compact dimensions only 52cm W x 34 H x 24 D, 90 day guarantee. Although used, units are supplied in **EXCELLENT condition**. **ONLY £99.00** + Carriage

DECCA 80, 16" COLOUR monitor. Composite video input. Same as above model but fitted with Composite Video input and audio amp for **COMPUTER, VCR** or **AUDIO VISUAL** use. **ONLY £99.00** + Carr

REDIFFUSION MARK 3, 20" COLOUR monitor. Fitted with standard 75 ohm composite video input and sound amp. This large screen colour display is ideal for **SCHOOLS, SHOPS, DISCO'S, CLUBS** and other **AUDIO VISUAL** applications. Supplied in **AS NEW** or little used condition **ONLY £145.00** + Carr.

BUDGET RANGE EX EQUIPMENT MONOCHROME video monitors.

All units are fully cased and set for 240v standard working with composite video inputs. Units are pre tested and set up for up to 80 column use. Even when **MINOR** screen burns exist – normal data displays are unaffected. 30 day guarantee.

12" KGM 320-1 B/W bandwidth input, will display up to 132 x 25 lines. **£32.95**

12" GREEN SCREEN version of KGM 320-1. Only **£39.95**

9" KGM 324 GREEN SCREEN fully cased very compact unit. Only **£49.00**

Carriage and insurance on all monitors £10.00

DC POWER SUPPLY SPECIALS

GOULD OF443 enclosed, compact switch mode supply with DC regulated outputs of +5v @ 5.5a, +12v @ 0.5a, −12v @ 0.1a and −23v @ 0.02a. Dim 18 x 11 x 6 cm. 110 or 240v input. **BRAND NEW** only **£16.95**

GOULD G6-40A 5v 40 amp switch mode supply **NEW £130.00**

AC-DC Linear PSU for **DISK** drive and **SYSTEM** applications. Constructed on a rugged **ALLOY** chassis to continuously supply fully regulated DC outputs of +5v @ 3 amps, −5v @ 0.6 amps and +24v @ 5 amps. Short circuit and overvoltage protected. 100 or 240v AC input. Dim 28 x 12.5 x 7 cm **NEW £49.94**

Carriage on all PSU's £3.00

KEYBOARDS

Manufacturer's **BRAND NEW** surplus.

DEC LA34 Uncoded keyboard with 67 quality gold plated switches on X-Y matrix – ideal micro conversions etc. **£24.95**

AMKEY MPNK-114 Superb word processor chassis keyboard on single PCB with 116 keys. Many features such as On board Micro, Single 5v rail, full ASCII coded character set with 31 function keys, numeric keypad, cursor pad and 9600 baud **SERIAL TTL ASCII OUTPUT**!! Less than half price. Only **£69.00** with data. Carriage on Keyboards £3.50

SURPLUS SPECIALS ON PRESTEL – VIEWDATA – TELEX

PLESSEY VUTEL, ultra compact unit slightly larger than a telephone features **A STANDARD DTMF TELEPHONE** (tone dial) with 5" CRT monitor and integral modem etc for direct connection to **PRESTEL VIEWDATA** etc. Designed to sell to the **EXECUTIVE** at over £600!! Our price **BRAND NEW AND BOXED** at only **£99.00**

DECCAFAX VP1 complete Professional **PRESTEL** system in slimline desk top unit containing Modem, Numeric keypad, CPU, PSU etc. Connects direct to standard **RGB** colour monitor. Many other features include: Printer output, Full keyboard input, Cassette port etc. **BRAND NEW** with **DATA**. **A FRACTION OF COST** only **£55.00**

ALPHATANTEL, Very compact unit with integral **FULL ALPHA NUMERIC** keyboard. Just add a domestic TV receiver and you have a superb **PRESTEL** system and via **PRESTEL** the cheapest **TELEX** service to be found!! Many features **CENTRONICS** Printer output, Memory dialling etc. Supplied complete with data and **DIY** mod for **RGB** or Composite video outputs. **AS NEW** only **£125.00**

Post and packing on all PRESTEL units £8.50

EX-STOCK INTEGRATED CIRCUITS

4164 200 ns D RAMS 9 for £11 **4116** ns £1.50 **2112** £10.00 **2114** £2.50 **2102** £2.00 **6116** £2.50 EPROMS **2716** £4.50 **2732** £3.00 **2764** £4.95 **27128** £5.50 **6800** £2.50 **6821** £1 **68A09** £8 **68B09** £10 **8085A** £5.50 **8086** £15 **8088** £8 **NEC765** £8 **WD2793** £28 **8202A** £22 **8251** £7 **8748** £15 **Z80A DART** £6.50 **Z80A CPU** £2.00. Thousands of IC's **EX STOCK** send SAE for list.

DISK DRIVES

Japanese 5¼" half height, 80 track double sided disk drives by **TEAC, CANON, TOSHIBA** etc. Sold as **NEW** with **90 day guarantee ONLY £85.00**

TEC FB-503 Double sided HH 40 TRK **NEW £75.00**

SUGART SA400 SS FH 35 TRK **£55.00**

SIEMENS FDD100 SS FH 40 TRK **£65.00**

carriage on 5¼" drives £5.50

Brand NEW metal 5¼" **DISK CASES** with internal **PSU**.

DSKC1 for 2 HH or 1 FH drive **£29.95** +pp £4.00

DSKC 2 for 1 HH drive **£22.95** +pp £3.50

DKSC 3 As DSK1 LESS PSU **£12.95** +pp £2.50

DSKC 4 As DSK2 LESS PSU **£10.95** +pp £2.00

8" IBM format TESTED EX EQUIPMENT.

SHUGART 800/801 SS **£175.00** +pp £8.50

SHUGART 851 DS **£250.00** +pp £8.50

TWIN SHUGART 851's 2 Mb total capacity in smart case, complete with PSU etc. **£595.00**

MITSUBISHI M2894-63 8" DS 1 Mb equiv. to **SHUGART SA850R. BRAND NEW** at **£275.00** +pp £8.50

DYSAN 8" Alignment disk **£29.00** + pp £1.00

Various disk drive PSU's **Ex Stock SEE PSU section.**

HARD DISK DRIVES

DRE/DIABLO Series 30 2.5 Mb front load **£525.00**

Exchangeable version **£295.00**. **ME3029** PSU **£95.00**

DIABLO 44/DRE4000A, B 5+5 Mb from **£750.00**

CDC HAWK 5+5 Mb **£795.00**. **CDC 9762** 80 Mb RMO3 etc. **£2500.00**

PERTEC D3422 5+5 Mb **£495.00**

RODIME 5¼" Winchesters ex-stock from **£150** CALL

Clearance items – Sold as seen – No guarantee.

ICL 2314 BRAND NEW 14" Mb Removable pack hard disk drive, cost **over £2000** with data **ONLY £99.00**

BASF 6172 8" 23Mb Winchesters **£199.00**

Unless stated all drives are refurbished with 90 day guarantee. Many other drives and spares in stock – call sales office for details.

MODEMS

Join the communications revolution with our super range of **DATA MODEMS**, prices and specifications to suit all applications and budgets ...

BRAND NEW State of the art products.

DACOM DSL2123 Multi standard 300-300, 1200-75 Auto answer etc. **£268.00**

DACOM DSL2123AQ Auto dial, smart modem with multi standard **AUTO SPEED** detect, and data buffer with flow control etc. **£365.00**

DACOM DSL2123GT The **CREAM** of the intelligent modems, auto dial, auto call, index, buffer etc etc. **£498.00**

Steebeck SB1212 V22 1200 baud **FULL DUPLEX**, sync or async, optional auto dial **£465.00**

TRANSDATA 307A Acoustic coupler 300 baud full duplex, originate only, RS232 interface **£49.00**

Ex **BRITISH TELECOM** full spec, CCITT, ruggedised, bargain offers. Sold **TESTED** with data. Will work on any **MICRO** or system with RS232 interface.

MODEM 13A 300 baud unit, only 2" high fits under phone. CALL mode only **£45.00**

MODEM 20-1, 75-1200 baud. Compact unit for use as subscriber end to **PRESTEL, TELECOM GOLD, MICRONET** etc. **£39.95** +pp £6.50

MODEM 20-2 1200-75 baud. Same as 20-1 but for computer end **£65.00** +pp £6.50

DATEL 2412, Made by SE Labs for BT this two part unit is for synchronous data links at 1200 or 2400 baud using **2780/3780** protocol etc. Many features include 2 or 4 wire working, self test, auto answer etc. **COST OVER £800.** Our price **ONLY £199** +pp £8.00

DATEL 4800, RACAL MPS4800 baud modem, EX BT good working order. **ONLY £295.00** +pp £8.00

SPECIAL OFFER

MODEM TG2393, Ex BT, up to 1200 baud, full duplex 4 wire or half duplex over 2 wire line. **ONLY £85.00 PER PAIR** +pp £10.00

For more information contact our Sales Office.

MATRIX PRINTERS

SPECIAL BULK PURCHASE of these compact, high speed matrix printers. Built in Japan for the Hazeltine Corporation this unit features quality construction giving 100cps bidirectional, full pin addressable graphics, 6 type fonts, up to 9.5" single sheet or tractor paper handling, RS232 and CENTRONICS parallel interface. Many other features. **BRAND NEW** and **BOXED** COST £420. **Our price Only £199.00**

RECHARGEABLE BATTERIES

Dry Fit **MAINTENANCE FREE** by Sonnenschein & Yuasa

A300 07191315 12v 3Ah NEW **£13.95**

A300 07191312 6v 3Ah NEW **£9.95**

A300 07191202 6-0-6v 1.8Ah TESTED Ex Equip **£5.99**

VDU TERMINALS

Standard VDU data entry terminals at give away prices!!

QUME QVT108. Current product, state of the art terminal with detachable keyboard, 12" Green screen, 2 page **RAM, TVI 925**, Hazeltine, **ADMSA** emulations, software setup, 25 x 80. Clock, Swivel and tilt base, Printer port, Function keys etc. **BRAND NEW** and **BOXED AT ALMOST HALF PRICE** Only **£425.00**

AJ510 – EX RENTAL, Z80 controlled, 15" green screen 24 x 80 display, graphics, cursor addressing, printer port etc. Very good condition **TESTED** complete with manual only **£225.00**

ADDS 520 – Dumb terminal, used, 12" b/w screen RS232 interface and printer port. **TESTED. ONLY £125.00.** Carriage on terminals £10.00

100's of other terminals in stock. CALL for more details.

DISPLAY -ELECTRONICS-

All prices quoted are for U.K. Mainland, paid cash with order in Pounds Sterling PLUS VAT. Minimum order value ***£2.00***. Minimum Credit Card order ***£10.00***. Minimum BONAFIDE account orders from Government Depts., Schools, Universities and established companies ***£20.00***. Where post and packing not indicated please ADD £1.00 + VAT. Warehouse open Mon-Fri 9.30-5.30. Sat 10.30-5.30. We reserve the right to change prices and specifications without notice. Trade, Bulk and Export

32 Biggin Way, Upper Norwood, London SE19 3XF
Telephone 01-679 4414 Telex 894502 Data 01-679 1888

ERS — PRINTERS — PRINTERS — PRINTERS

SUPER DEAL? NO – SUPER STEAL

THE FABULOUS 25 CPS "TEC STARWRITER"

Made to the very highest spec the **TEC STARWRITER FP1500-25** features a very heavy duty die cast chassis and **DIABLO** type print mechanism giving superb registration and print quality. Micro-processor electronics offer full **DIABLO/QUME** command compatability and full control via **CPM WORDSTAR ETC.** Many other features include bi-directional printing, switchable 10 or 12 pitch, full width 381mm paper handling with up to 163 characters per line, friction feed rollers for single sheet or continuous paper, internal buffer, standard **RS232** serial interface with handshake. Supplied absolutely **BRAND NEW** with 90 day guarantee and FREE daisy wheel and dust cover. Order **NOW** or contact sales office for more information. Optional extras **RS232** data cable **£10.00**. Tech manual **£7.50** Tractor Feed **£140.00**. Spare daisy wheel **£3.50**. Carriage & Ins. (UK Mainland) £10.00.

NOW ONLY £499 + VAT

DIY PRINTER MECH

Brand New surplus of this professional printer chassis gives an outstanding opportunity for the **Student**, **Hobbyist** or **Robotics** constructor to build a **printer** – **plotter** – **digitiser** etc. entirely to their own specification. The printer mechanism is supplied ready built, aligned and pre tested but **WITHOUT** electronics. Many features include all metal chassis, phosphor bronze bearings, **132** character optical shaft position encoder, **NINE** needle head, 2 x two phase 12V stepper motors for carriage and paper control, 9.5" Paper platten etc. etc. Even a manufacturer's print sample to show the unit's capabilities!! Overall dimensions 40 cm x 12 cm x 21 cm.

Sold **BRAND NEW** at a **FRACTION** of cost **ONLY £49.50** + pp £4.50.

TELETYPE ASR33

DATA I/O TERMINALS

Industry standard, combined ASCII 110 baud printer, keyboard and 8 hole paper tape punch and reader. Standard **RS232** serial interface. Ideal as cheap hard copy unit or tape prep. for CNC and NC machines. **TESTED** and in good condition. Only **£250.00** floor stand **£10.00**. Carr & Ins. £15.00.

EX NEWS SERVICE PRINTERS

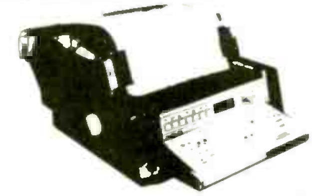
Compact ultra reliable quality built unit made by the **USA EXTEL Corporation**. Often seen in major Hotels printing up to the minute News and Financial information, the unit operates on **5 UNIT BAUDOT CODE** from a Current loop. **RS232** or **TTL** serial interface. May be connected to your micro as a low cost printer or via a simple interface and filter to any communications receiver to enable printing of worldwide **NEWS**, **TELEX** and **RTTY** services.

Supplied **TESTED** in second hand condition complete with **DATA, 50 and 75 baud xtals and large paper roll.**

TYPE AE11 50 Column	**ONLY £49.95**
Spare paper roll for AE11	£4.50
TYPE AF11R 72 Col. + Ribbon	£65.00
TYPE AH11R 80 Col. ASCII/BAUDOT	£185.00

Carriage and Insurance £7.50

GE TERMIPRINTER



A massive purchase of these desk top printer terminals enables us to offer you these quality **30** or **120** cps printers at a **SUPER LOW PRICE** against their original cost of over £1000. Unit comprises of full **QWERTY** electronic keyboard and printer mech with print face similar to correspondence quality typewriter. Variable forms tractor unit enables full width – up to 1[illegible] 120 column paper, upper – lower case standard **RS232** serial interface, internal vertical and horizontal tab settings, standard ribbon, adjustable baud rates, quiet operation plus many other features. Supplied complete with manual. Guaranteed working **GE30 £130.00. GE1200 120 cps £175.00**

Untested **GE30 £65.00** Optional floor stand **£12.50**. Carr & Ins £10.00.

SEMICONDUCTOR 'GRAB BAGS'

Mixed Semis amazing value contents include transistors digital, linear, IC's, triacs, diodes, bridge recs. etc. etc. All devices guaranteed brand new full spec with manufacturer's markings, fully guaranteed **50+ £2.95 100+ £5.15**

TTL 74 Series. A gigantic purchase of an "across the board" range of **74 TTL** series IC's enables us to offer 100+ mixed **"mostly TTL"** grab bags at a price which two or three chips in the bag would normally cost to buy. Fully guaranteed all IC's full spec. **100+ £6.90, 200+ £12.30, 300+ £19.50**

20,000 FEET OF ELECTRONIC AND COMPUTER GOODIES

ENGLAND'S LARGEST SURPLUS STORE – SEEING IS BELIEVING!!

DEC CORNER

PDP 1140 System comprising of CPU, **124k** memory & MMU 15 line RS232 Interface. RP02 40 MB hard disk drive. **TU10** 9 track 800 BPI Mag tape drive, dual track system. VT52 VDU. etc. etc. Tested and running. £3,750.00

BA11-MB 3.5" Box, PSU, LTC	£395.00
DH11-AD 16" x RS232 DMA interface	£1.900.00
DLV11-J4 x EIA interface	£350.00
DLV11-E Serial. Modem support	£190.00
DUP11 Synch. Serial data i/o	£650.00
DQ200 Dilog – multi RK controller	£495.00
DZ11-B 8 line RS232 mux board	£650.00
KDF11-B M8189 PDP 1123 PLUS	£1.100.00
LA30 Printer and Keyboard	£80.00
LA36 Decwriter EIA or 20 mA loop	£270.00
MS11-JP Unibus 32kb Ram	£80.00
MS11-LB Unibus 128kb Ram	£450.00
MS11-LD Unibus 256kb Ram	£850.00
PDP11/05)u Ram, i/o etc	£450.00
PDP11/40)u, 124k MMU	£1,850.00
RT11 ver 3 documentation kit	£70.00
RK05-J 2.5 Mb disk drives	£650.00
KL8 JA PDP 8 async i/o	£175.00
M18E PDP 8 Bootstrap option	£75.00
VT50 VDU and Keyboard – 20 mA	£175.00
VT52 VDU and RS232 interface	£250.00

Give your **VT100** a Birthday!!!
Brand New **VT100** Keyboards only **£85.00**

1000's OF EX STOCK spares for **PDP8, PDP8A PDP11, PD P1134** etc. **SAE.** for list. or **CALL** sales office for details.

ALL TYPES OF COMPUTER EQUIPMENT AND SPARES WANTED FOR PROMPT CASH PAYMENT.

MAG TAPE DRIVES

Many **EX STOCK** computer tape drives and spares by **PERTEC, CIPHER, WANGO, DIGIDATA, KENNEDY** etc. Special offer this month on **DEI** Cartridge tape drives **ONLY £450.00 each.**

CALL FOR DETAILS

COMPUTER/SYSTEM CABINET & PSU

All in one quality computer cabinet with integral switched mode PSU, mains filtering, and twin fan cooling. Originally made for the famous **DEC PDP8** computer system costing thousands of pounds. Made to run 24 hours per day the psu is fully screened and will deliver a massive **+5v DC at 17** amps, **+15v DC at 1 amp and –15v DC at 5 amps**. The complete unit is fully enclosed with removable top lid, filtering, trip switch, **power** and **run leds** mounted on all front panel, rear cable entries, etc. etc. Units are in good but used condition – supplied for 240v operation complete with full circuit and tech. man. Give your system that professional finish for only **£49.95** + carr. 19" wide 16" deep 10.5" high. Useable area 16" w 10.5" h 11.5" d.

Also available less psu, with fans etc. Internal dim. 19" w, 16" d, 10.5" h. **£19.95. Carriage £8.75**

66% DISCOUNT ON ELECTRONIC COMPONENTS EQUIPMENT

Due to our massive bulk purchasing programme, which enables us to bring you the best possible bargains, we have thousands of ICs, Transistors, Relays, Caps, PCBs, Sub-assemblies, Switches etc. etc. surplus to OUR requirements. Because we don't have sufficient stocks of any one item to include in our ads we are packing all these items into the **BARGAIN OF A LIFETIME**. Thousands of components at giveaway prices. Guaranteed to be worth at least 3 times what you pay. Unbeatable value and perhaps one of the most consistently useful items you will every buy!!! Sold by weight

2.5kls £5.25 + pp £1.25
10kls £11.25 + pp £2.25
5 kls £6.90 + £1.80
20kls £19.50 + pp £4.75

MAINS FILTERS

CURE those unnerving hang ups and data glitches caused by mains interference with professional quality filters **SD5A** matchbox size up to **1000 watt 240 V** Load **ONLY £5.95**. **L12127** compact completely cased unit with 3 pin fitted socket up to **750** watts **ONLY £9.99.**

EPROM COPIERS

The amazing **SOFTY 2** The "Complete Toolkit" for copying, writing, modifying and listing **EPROMS** of the **2516, 2716, 2532, 2732** range. Many other functions include integral keyboard, cassette interface, serial and parallel i/o UHF modulator ZIF socket etc.

ONLY £195.00 + pp £2.50

"GANG OF EIGHT" intelligent Z80 controlled 8 gang programmer for ALL single 5v rail **EPROMS** up to **27128**. Will copy 8 27128 in **ONLY 3 MINUTES**. Internal **LCD** display and checking routines for **IDIOT PROOF** operation. Only **£395.00** + pp £3.00.

"GANG OF EIGHT PLUS" Same spec as above but with additional **RS232** serial interface for down line loading data from computer etc. **ONLY £445.00** + pp **£3.00**

Data sheets on request

COOLING FANS

Keep your hot parts **COOL** and **RELIABLE** with our range of **COLING FANS ETRI 126LF21** 240v 5 blade equipment fan Dim 80 · 80 · 38mm £9.95 **ETRI 99XUOI** 240v Slimline Dim 92 · 92 · 25mm equipment gfan **NEW** £9.95 **GOULD JB-3AR** Dim. 3" · 3" · 2.5 compact very quiet running 240v operation **NEW £6.95**. **MUFFIN-CENTAUR-BOXER** standard 120 · 120 · 38mm fans Order 110v OR 240v. 3 or 5 blade. **NEW at £10.50** or tested **EX EQUIPMENT** £5.50 Low Voltage DC Fans **BUHLER 69.11.22.** 8 16v DC micro minaiature reversible. Uses brushless servo motor almost silent running, guaranteed 10,000 hr life. Measures only 62 · 62 · 22mm. Current cost **£35.00 OUR PRICE ONLY £13.95** complete with data 120 · 120 · 38mm (4" DC fans). **PANSONIC FB-12C12H** 12v DC 5 blade **£18.00** **PAPST 4124X 24** – 28v DC 5 blade **£18.00**.

100's of other fans Ex Stock.

Call for Details. Post & Packing on all fans £2.00

1000's of other EX STOCK items including POWER SUPPLIES, RACKS, RELAYS, TRANSFORMERS, TEST EQUIPMENT, CABLE, CONNECTORS, HARDWARE, MODEMS, TELEPHONES, VARIACS, VDU'S, PRINTERS. POWER SUPPLIES, OPTICS, KEYBOARDS etc. etc. Give us a call for your spare part requirements. Stock changes almost daily.

Don't forget, ALL TYPES and QUANTITIES of electronic surplus purchased for CASH

ENTER 43 ON REPLY CARD

Mastering multi-tasking

The multi-tasking version of BBC Basic, supplied by Cambridge Microprocessor Systems, has been converted for use on the BBC Master Series computers. MultiBasic is control oriented and adds over 50 commands to the Basic language to enable the development of event-driven multi-tasking programs. Up to eight background tasks can be run concurrently with the main program: up to seven v.i.a. commands, two five-byte timers which can be accessed from within normal Basic, and three four-byte timers which can hold an integer value.

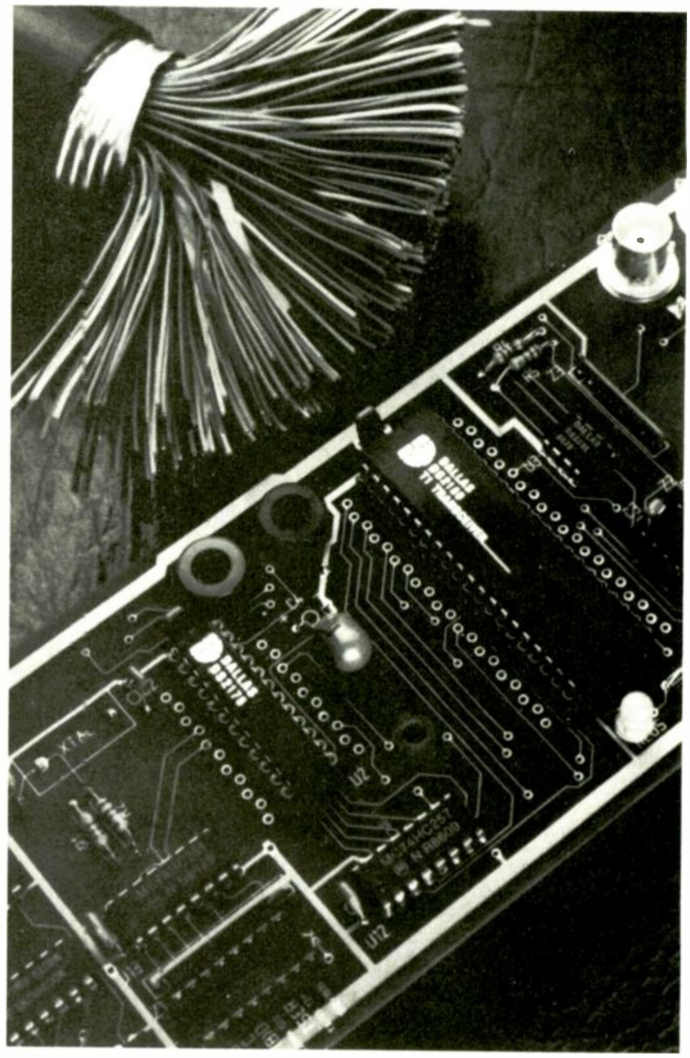
The language on a rom can be used in conjunction with the CMS 1MHz card which connects the Master to an industrial racking system for the addition of a range of i/o cards. These include digital i/o, 12 and 13-bit a-to-d, GPIB interface, additional graphic facilities. The system card includes a real-time calendar/clock, 8K of battery-backed ram and gives the user access to additional MultiBasic commands. The rom comes with a comprehensive manual with a detailed description of each command and example programs. CMS Ltd, Brookfield Business Centre, Twentypence Road, Cottenham, Cambridge CB4 4PS. Tel: 0994 51122.

Test and control from a PC

An analogue and digital multi-function plug-in card for the IBM PC/XT/AT and their equivalents, can be used in test, measurement and control applications. The card, from Kenda Electronic Systems, has 16 analogue input channels, expandable to 32, with programmable gain, 12-bit, 25μs a-to-d converters (optional 12 and 8μs versions) provide throughputs of up to 71,000 samples/s. It is provided with three a-to-d trigger modes including an external trigger and offers eight digital input and eight digital output channels along with two analogue output channels. Three counter/timer channels are provided. The system has a resolution of 12 bits.

Internally the card supports direct memory access with polled status and interrupt operation. It comes with software including machine-code routines for analogue and digital input/output and is also supported by several high-level language extensions including some to Basic, Pascal, Turbo Pascal, C, and Fortran running under MS/PC-DOS.

Typical applications include test and measurement, data logging, robot and machinery control and quality assurance work. Kenda Electronic Systems Ltd, Nutsey Lane, Totton, Southampton SO3 3NB. Tel: 0703 869922.

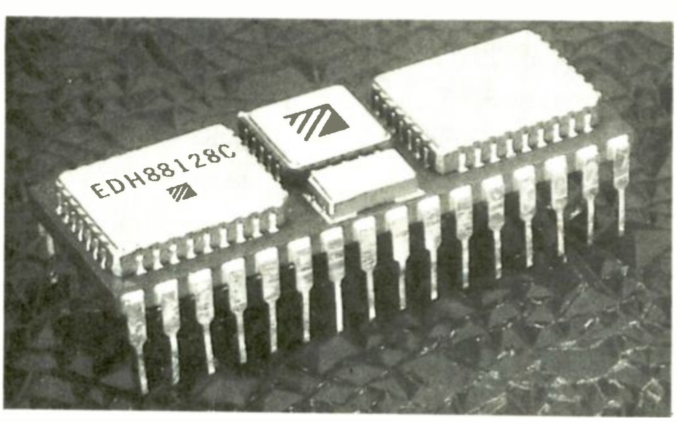


Megabit static ram

One-megabit static ram modules are now available from Electronic Designs with a standard 32-pin package. The EDH88128C is a 1024K-bit c-mos static ram based on four 32K by eight rams in leadless chip carriers. The device has an on-board decoder circuit that interprets the higher order address to select one of the static rams.

Organised as 128K by eight bits, the module is suitable for use in bus-based systems. Access times of 100, 120 and 150ns are available, and the fully static operation means no clocks or strobe signals are required. Power requirements are a single +5V supply, and all inputs are t.t.l. compatible.

This module has a 32-pin dual-in-line outline and is suitable for upgrading systems using existing 8K by eight or 32K by eight modules or monolithic memory parts. A future upgrade path to a maximum of 512K by eight will be available. Electronics Designs Europe, Shelley House, The Avenue, Lightwater, Surrey GU18 5RF. Tel: 0276 72637.



Design kit for twisted-pair networks

A design kit to help engineers take advantage of a high-speed twisted-pair data communications network for digitized voice and video services has been announced by Dallas Semiconductor. High-speed links (1.5-2.0 mbits) of the T1* kind can cause difficulties with framing and supervision, synchronization and twisted-pair interference, when linked to equipment running on a different time-base. The DS1280K kit provides a source of specialised information, necessary for successful T1 design, or the CEPT equivalent.

Based on a Dallas DS2180 transceiver and DS2176 receive buffer, the kit contains demonstration p.c.b. support logic circuits and provision for microprocessor control and line interface. Central to the kit is the transceiver. Featuring flexible control architecture, it allows soft configuration of T1 links under microprocessor control. The DS2176 buffer uses a two frame deep fifo memory, on-chip control and contention logic to adapt the data transmission rate. The buffer therefore acts as a 'system shock absorber' eliminating synchronization problems which can occur when linking with equipment running on a different timebase.

The buffer is claimed to be the first integrated solution to problems of synchronization between dissimilar backplanes and signalling supervision, and extracts, integrates and buffers signalling information embedded in the data stream.

Also supplied with the kit is an 80-page instruction manual, which contains data sheets on both the DS2180 and 2176, software control examples and assembly instructions, as well as discussions of the recent revisions of T1 standards. The European equivalent of T1, defined by CEPT, has a data transmission rate 2 million bits per second, and requires a different kit, also available from Joseph Electronics Ltd, Westminster House, 188 Stratford Road, Solihull, B90 3AQ. Tel: 021-745 3251.

*T1 (and T-carrier) is a high-speed digital communications network developed by AT&T in the early 1960s to carry digitized voices. They can multiplex 24 p.c.m. channels on a twisted pair.

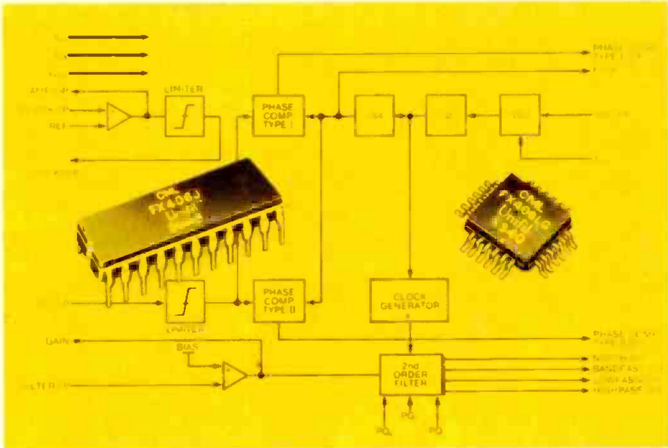
NEW PRODUCTS

COMPONENTS

Small dual digital-to-analogue converters

Dual 12-bit monolithic digital-to-analogue converters come from Analog Devices. The AD7537 and AD7547 are packaged in small 0.3in, 24-pin dips, claimed to be the smallest dual d-to-a available in the industry. Both devices contain two 12-bit current-output converters on one chip and different bus structures to handle a variety of applications. Also on-chip are data registers and control logic for easy microprocessor interfacing. The dual device occupies half of the area required by two separate 12-bit converters and allows ladder resistance matching of 0.5% and precise tracking.

The AD7537 offers a two-byte (8+4) input structure for right-justified loading from an eight-bit bus. The AD7547 features a 12-bit parallel loading structure that enables the user to load data in one 12-bit word, facilitating loading from a 16-bit data bus. Applications for the dual converters include automatic test equipment, programmable filters, audio and synchro applications, process control, and designs with space-sensitive requirements that could not accommodate two discrete devices. Analog Devices Ltd, Central Avenue, East Molesey, Surrey KT8 0SN. Tel: 01 941 0466.



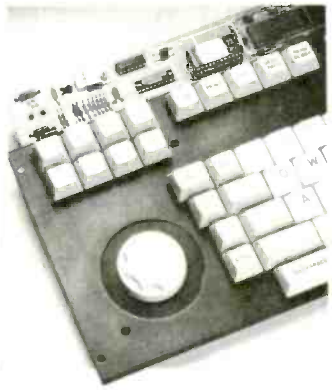
Analogue signal processor

The FX406 Unifil is a c-mos l.s.i. circuit with a variety of signal processing applications. The device consists of a switched-capacitor second-order active filter with outputs for bandpass, notch, low-pass frequency responses, together with a clock generator to provide the sampling clock frequency. The centre frequency of the bandpass and notch filters is the same as the cut-off frequency f(c) of the low-pass and high-pass filters. The filter sampling clock is derived from a multiplying phase-locked loop whose reference or input frequency is the same as the desired cut-off frequency of the filters. Facilities are provided to programme the cut-off frequency of the filters by injecting an external signal into the p.l.l, or by using the on-chip clock oscillator circuit. The filters have gain adjustment on the input and the Q is programmable to eight values between 0.54 and 8.0. A signal 5-volt supply rail and choice of d.i.l./surface mount package style make the FX406 suitable for universal analogue signal processing applications, such as programmable filters, voltage-controlled filters, sinewave oscillators, tracking filters/oscillators, f.s.k. modems, square-to-sine and pulse-to-sine converters. Consumer Microelectonics Ltd, Wheaton Road, Industrial Estate East, Witham, Essex CM8 3TD. Tel: 0376 513833.

Cursor controller

An alternative to roller balls, mice and joysticks, offered by the Cursor Disc from Alphameric Keyboards, can be incorporated into custom keyboards designed for cad/cam applications. The Cursor Disc eliminates the need to press separate keys to move in different directions, enabling users to operate it by feel. This increases ease of use since the designer's eye can be concentrated on the screen, rather than constantly having to look at the keys.

The cursor disc is the latest addition to the wide range of keyboard accessories including keytop shapes, legends and colours offered by Alphameric who produce capacitative keyboards tailored to individual requirements. Alphameric Keyboards Ltd, 6 Manor Way, Old Woking, Surrey GU22 9JX. Tel: 04862 71555.



NEXT MONTH

Spectrum analysis. Two leading manufacturers of spectrum analysers describe the functions and applications of their latest instruments. Also included are details of new analysers from other sources.

H.f. receiver development. An account of the development of a new communications receiver designed by Lowe Electronics: a discussion of the design principles, which include microprocessor assistance with alignment as well as control of circuit functions.

Image acquisition: a three-part article describing the use of a low-cost sensor as an alternative to a television camera in the capture and subsequent processing of images. The application is in computer vision used in manufacturing indutsry.

Reducing quantizing error. A description of a technique to enable analogue-to-digital converters to achieve a higher resolution that can be obtained directly from the converter. As an example, a temperature measuring device can resolve 0.1 degrees over a 110 degree range, using a 8-bit converter.

Microprocessor tone decoder. When tone-controlled, suppressed-squelch systems are used in mobile f.m. radio, the tone transmitted with the signal must be decoded in the presence of noise and fading. This article discusses the use of a microprocessor in this function.

Pulse-width-modulated power amplifiers are staging a come-back, the results of advances in mosfet technology and new circuit thinking.

Gould OS300 versus Douglas DC3

OS300	DC3
Proven worldwide	Proven worldwide
Inexpensive	Inexpensive
Rugged construction	Rugged construction
Go anywhere	Go anywhere
Piece of cake to fly	Piece of cake to fly
NATO approved	NATO approved
Two year guarantee	
U.K. design and manufacture	
Modern spec*	
Available off-the-shelf	

The Gould OS300 dual-trace 20MHz 'scope

For £342 + VAT.

Gould Electronics Ltd., Instrument Systems, Roebuck Road, Hainault, Ilford, Essex IG6 3UE. Telephone: 01-500 1000. Telex: 263785.

HIGH-FLYING TECHNOLOGY YOU CAN TRUST.

**Much as we admire the Dakota's traditional hard-working virtues, sadly its last spec. update was in 1945. The Gould OS300, on the other hand, offers 1980's features – dual-trace with true 20MHz operation, continuously variable amplifier sensitivity to eliminate loss of bandwidth over the 2mV to 5V/cm, X-Y operation, P43 phosphor and quick heat cathode for rapid set-up and brighter displays.*

GOULD Electronics

11257

ENTER 40 ON REPLY CARD

68000

DEVELOPMENT SYSTEMS

Versatile, low cost, development systems offering a choice of powerful multi-tasking disc operating systems. Available as board level, dual floppy or Winchester plus floppy configurations.

- 68000 microprocessor, 8 Mhz operation
- 512K dram, 128K eprom, 64K static ram
- 640×500 full colour graphics
- 80×24 character full colour text
- Dual 80 track dsdd floppy disc drives
- 20 Mbyte Winchester disc drive
- Two fully programmable serial ports
- Up to 48 parallel input/output lines
- Real time clock calendar – battery backed
- OS-9/68000, TRIPOS 3, CP/M-68K, STARDOS operating systems

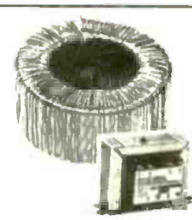
Board only – double eurocard	**£650**
Dual floppy built system	**£1195**
Winchester + floppy built system	**£1895**

Micro Concepts

2 St Stephens Road · Cheltenham · Glos GL51 5AA
Telephone: 0242 510525

ENTER 19 ON REPLY CARD

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 7.95, 30va 9.18, 50va 10.16, 80va 11.36, 120va 12.07, 160va 14.20, 225va 15.21, 300va 17.04, 500va 22.10, 625va 24.66, 750va 28.75, 1000va 44.82.
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 67 ON REPLY CARD

IN VIEW OF THE EXTREMELY RAPID CHANGE TAKING PLACE IN THE ELECTRONICS INDUSTRY, LARGE QUANTITIES OF COMPONENTS BECOME REDUNDANT. WE ARE CASH PURCHASERS OF SUCH MATERIALS AND WOULD APPRECIATE A TELEPHONE CALL OR A LIST IF AVAILABLE. WE PAY TOP PRICES AND COLLECT.

R. Henson Ltd.

21 Lodge Lane, N. Finchley, London, N12 8JG.
5 mins. from Tally Ho Corner

Telephone: 01-445 2713/0749

ENTER 16 ON REPLY CARD

NEW PRODUCTS
TEST & MEASUREMENTS

Mini portable 30MHz oscilloscope

ITT Instruments has introduced a compact, portable oscilloscope incorporating features that make it suited to heavy-duty field use. The OX709 has a large rectangular screen with 8 by 10 divisions of 8mm each. The use of a 10kV accelerating potential gives an exceptionally bright trace, so that the instrument can be used outdoors in normal daylight. In addition to an internal rechargeable lead-acid battery, the OX709 offers a choice of power sources; from 95 to 260V r.m.s. at 48 to 440Hz with no need for switching, and from 110 to 330V or 10V to 36V d.c.

The OX709 is a two-channel 30MHz-bandwidth oscilloscope, with vertical and horizontal reciprocal sensitivities from 1mV to 5V per division and a timebase, reciprocal sensitivity of 0.5µs to 0.2sec per division. Comprehensive trigger capabilities include automatic peak-to-peak triggering. The safety features, which include double isolation and the use of non-metallic BNC input connector housing and special safety probes, mean that the instrument meets the requirements of most safety standards. ITT Instruments. 346 Edinburgh Avenue. Slough, Berks SL1 4TU. Tel: 0753 82413.

Probe oscilloscope

A small hand-held oscilloscope made Lefax, makers of the Ledscope, may be used either in the manner of a logic probe or as a bench instrument, the virtue of avoiding frequent changes of view-point from probe to screen. The instrument is internally powered to eliminate leads, though the unit can accept standard scope leads. It will display most waveforms in the range 10Hz to 20Hz, and includes a voltmeter for direct voltage measurement up to 20V. Controls include gain, sweep speed, y-shift, mode and range select.

A 140-element led display is the key to the low cost of the unit (£90), which is expected to appeal to repair workshops, and educational and training establishments. Lefax Ltd, Unit 6, Genesis Business Centre, Redkiln Way, Horsham, West Sussex RH13 5QH.
Tel 0403 54135.

Hand-held capacitance meter with 0.2% accuracy

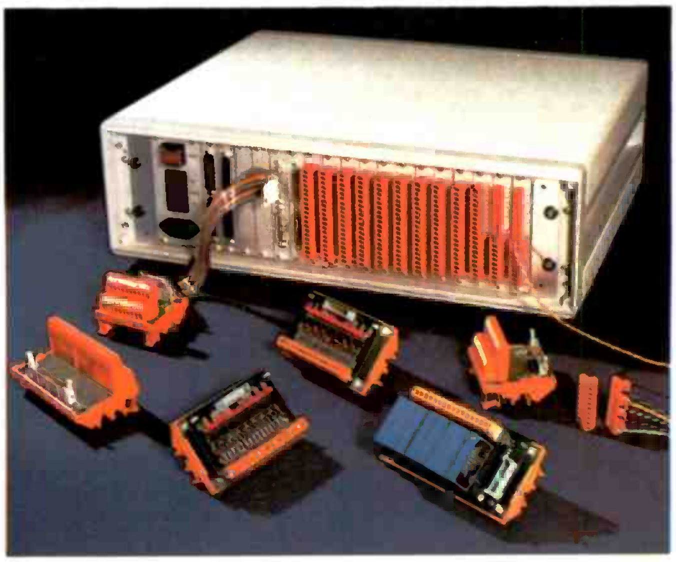
Capacitance measurements from 1pF to 20mF are possible with the Model 3000 capacitance meter from Global. It has 3.5 digits and a accuracy of 0.2% of the reading. A zero-adjust control permits the nulling of stray and incidental capacitance. Applications include sorting capacitor by value, checking tolerances, matching sets of capacitors and measuring unmarked devices. Global Specialities, Shirehill Industrial Estate, Saffron Walden, Essex CB11 3AQ. Tel: 0799 26699.

Temperature controllers

A range of temperature controllers based on Eurotherm's 800 series features RS232 or 422 communication and fast low-level a-to-d conversion. Model 818 has some built-in intelligence which allows it to 'tune' itself and adjust its programs to the conditions. It has two setpoints, two programmable logic outputs, two 4.5-digit displays, plug-in output options and display legends for all the functions. Type 818P has a 16-segment programmer and an additional display to show which segment is operating. Further indicators show the ramp, dwell and hold states, as well as the time remaining in ramp or dwell. The 815 model retains the accuracy of the 818 but leaves out some of the functions including the programmer, though it does include a programmable setpoint rate limit. Model 808 takes the minimum panel space and has fewer features, however plug-in options allow it to be adapted to the needs of the process. Eurotherm Ltd, Faraday Close, Durrington, Worthing, W. Sussex BN13 3PL.
Tel: 0903 68500.

High voltages on STE bus

Many automation and control projects involve the sensing or switching of high voltages that can be dangerous to the operator and to computer equipment. Kemitron has devised a system of conditioning cards which will sense or switch mains or d.c. of 3A or over. The boards may be mounted in a cabinet some metres away from the computer system and the 12V signals are opto-isolated at both ends to increase safety. The boards have been designed for use with Kemitron's own range of industrial STE-bus computer systems, as previously featured in these pages, but will interface with almost any digital signals. Kemitron Ltd, Hawarden Industrial Park, Manor Lane, Deeside, Clwyd CH5 3PP.
Tel: 0224 536123.

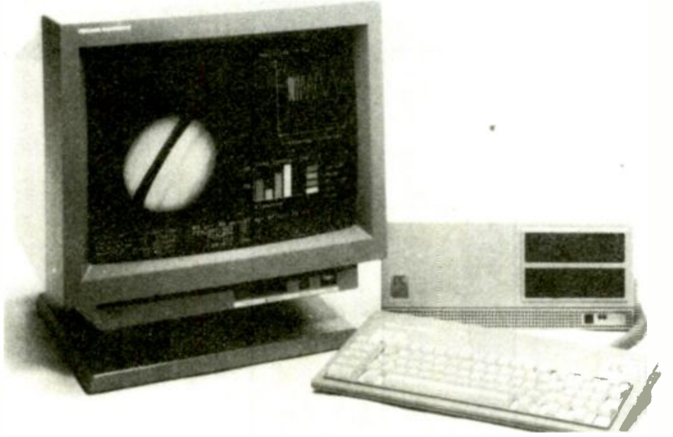


Cad plotter

New from Hi-Tek Solutions is the HP DraftPro plotter, an eight-pen drafting plotter specially designed for use with a personal cad system. The Draftpro has an RS232C V.24 interface which enables its use with a wide range of popular computers including HP Vectra, Apple Macintosh, DEC VAX, and IBM AT.

DraftPro plots on paper, vellum, or double-matte polyester film and accepts media widths from 550 to 640mm and media lengths from 400 to 1000mm. It uses fibre-tip, disposable liquid-ink, or refillable liquid-ink pens. The eight-pen carousel offers automatic pen changing and pen capping facilities. Features of the HP DraftPro include an addressable resolution of 0.025mm, a mechanical resolution of 0.013mm, and repeatabilities of 0.10mm (same pen) and 0.20mm (pen-to-pen). The plotter also has an acceleration of 2g, a pen cycle time of 100ms, and an accuracy of 0.5mm or 0.2% of the specified line length, whichever is greater.

The plotter offers the same variety of software support as other HP drafting plotters, including AutoCAD and VersaCAD. For users who write their own code, HP DraftPro supports more than 80 HP-GL (Hewlett-Packard Graphics Language) instructions to simplify graphics programming. Hi-Tek Solutions, Beadle Trading Estate, Ditton Walk, Cambridge CB5 8QD. Tel: 0223 213535.



Combined functions in cad workstation

A personal engineering workstation based on the Olivetti M245P has been produced by Densitron Computers. The DPE24 is a cad/cam graphics workstation with a fast graphics board set which is 100% software compatible with the IBM professional graphics controller. It enables the designer to access a variety of high-resolution cad packages but also provides full IBM CGA emulation for everyday engineering and business use. As the board supports both CGA and PGC modes no additional video adaptors are required and therefore only one monitor is needed for all applications.

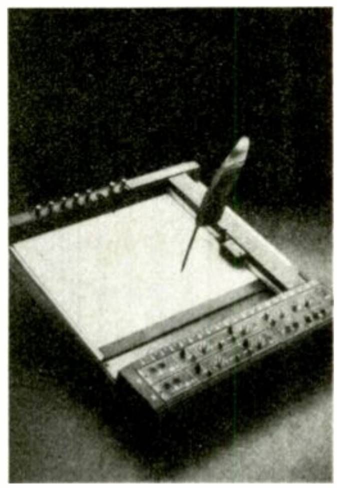
The DPE24 offers 640 by 480 resolution with 256 simultaneous colours capable of running a wide range of standard software. Drawing speeds of 35,000 vectors/s and 5,000 characters/s are possible. The high-speed operation is achieved by using a combination of the M245P, which uses an arithmetic co-processor, with the 10MHz central processor and an intelligent graphics board set. The graphics board set itself incorporates two pipelined processors, one v.l.s.i. drawing processor, the Hitachi 63484, and a 32016 display list processor. This hardware architecture is coupled with 128Kbytes of on-board firmware and 90 high-level PGC and enhanced graphic commands.

The workstation package is completed by a 20in (optionally 14in) high-resolution colour monitor. Densitron Computers Ltd, Unit 4, Airport Trading Estate, Biggin Hill, Kent TN16 3BW. Tel: 0959 76331.

...and an x-y recorder/plotter from Brown-Boveri

New to the UK is an eight-colour, flat-bed recorder that combines analogue x-y format recording and digital plotting capabilities. It is a 0.1% linearity, universal recording instrument suitable for applications in industry, research and education. Called the SE780, it has been designed to be easy to use, with an inclined plotting surface. It has a potentiometric, digital d.c. servo system with non-contact optical positioning for accuracy, claimed to be maintenance-free by the makers. Traces may be made with up to eight colours on sheet paper, roll paper or overhead transparencies in A3, A4 or ANSI A and B format, horizontal or vertical.

An RS232C interface allows the recorder to be connected to a computer and function as a stand-alone, eight-colour digital plotter. Computer data may be plotted with analogue curves and alphanumeric information combined on the same chart. The recorder has a maximum drawing area of 380 by 280mm with switchable, electronic drawing area limits and has remote-control functions: hold, frame advance,



pulse input, pen lift and chart hold.

Input modules may be exchanged to suit the application. There are currently two available: one with 18 calibrated ranges (0.05mV/cm to 20V/cm) and zero suppression, and one with nine calibrated ranges (0.5mV/cm to 1V/cm). Both have variable adjustment for intermediate ranges.

The x or y axis may be switched to timebase operation with 12 selectable sweep speeds (0.05 to 200s/cm). Pen acceleration on both axes is approximately 5g, slewing speed 1m/s, accuracy 0.3%. British Brown-Boveri Ltd, Normelec Division, Grovelands House, Longford Road, Exhall, Coventry CV7 9ND. Tel: 0952 502000.

Computerizing p.c.b. design

A small modification to a p.c.b. board which would take two days to effect by manual tape methods now takes only two hours according to Fidelity plc, who earlier this year took delivery of a Wayne Kerr Datum Artworker 2000 p.c.b. designer. The company is currently in a major design phase of its new television range, involving the designing of several new tv chassis from scratch, and in addition has an on-going programme of minor modifications to existing designs.

This increase in workload was the reason behind the decision to computerize. "With only a small team of tv designers and layout artists", explained Derek Hayes, Fidelity's technical director, "we just could not cope. With the Artworker, not only do the layout artists work on it but also the designers, thus greatly improving productivity. With the library functions of pre-defined components, it is particularly easy-to-use and they enjoy working with it."

The Artworker has shown itself to be flexible. "Most of our work involves designing boards that use a mixture of digital and analogue, which it copes with without any problems," says Hayes. "It is also good at prompting operators if they have forgotten to do something. One of the first designs came up with flashing prompts about all the points that were floating around unconnected, which puzzled us for a few moments until we realised that they were all test points!"

"We chose the Wayne Kerr Artworker because it offered us all the facilities that we required at a good price. An added benefit is that an Artworker is also used by the bureau to whom we send our overload work. We can send them a floppy disc with the schematic on it and they send it back either the finished job or finished to any stage we specify." For further information on the Artworker p.c.b. designer contact Wayne Kerr Datum Limited, Jenner Road, Fleming Way, Crawley, West Sussex, RH10 2GA. Tel: 0293 549011.

LANGREX SUPPLIES LTD

Climax House, Fallsbrook Rd., Streatham, London SW16 6ED

RST Tel: 01-677 2424 Telex: 946708 RST

SEMICONDUCTORS

AA119	0.10
AAY30	0.17
AAZ13	0.30
AAZ15	0.30
AAZ17	0.30
AC107	0.55
AC125	0.35
AC126	0.35
AC127	0.40
AC128	0.35
AC141	0.35
AC141K	0.45
AC142	0.40
AC142K	0.45
AC176	0.35
AC187	0.35
AC188	0.35
ACY17	2.25
ACY18	1.55
ACY19	1.80
ACY20	1.50
ACY21	1.55
ACY39	4.00
AD149	1.00
AD161	0.50
AD162	0.60
ADZ11	12.50
ADZ12	12.50
AF106	0.60
AF14	3.50
AF115	3.50
AF116	3.50
AF117	4.00
AF139	0.55
AF186	0.75
AF239	0.65
AFZ11	3.75
AFZ12	5.00
ASY26	1.40
ASY27	1.00
ASZ15	2.20

ASZ16	2.00
ASZ17	1.60
ASZ20	4.50
ASZ21	4.75
AUY10	3.50
BA145	0.13
BA148	0.15
BA154	0.06
BA155	0.11
BA156	0.06
BAW62	0.05
BAX13	0.05
BAX16	0.06
BC107	0.12
BC108	0.13
BC109	0.14
BC113	0.12
BC114	0.12
BC115	0.12
BC116	0.19
BC117	0.24
BC118	0.30
BC125	0.25
BC126	0.25
BC135	0.18
BC136	0.18
BC137	0.22
BC147	0.12
BC148	0.12
BC149	0.12
BC157	0.12
BC158	0.13
BC159	0.12
BC167	0.10
BC170	0.09
BC171	0.11
BC172	0.09
BC173	0.09
BC177	0.15
BC178	0.28
BC179	0.15

BC182	0.11
BC183	0.09
BC184	0.11
BC212	0.11
BC213	0.11
BC214	0.11
BC237	0.09
BC238	0.09
BC301	0.36
BC303	0.36
BC307	0.09
BC308	0.09
BC327	0.09
BC328	0.09
BC337	0.09
BC338	0.09
BCY30	3.75
BCY31	7.50
BCY32	3.75
BCY33	2.50
BCY34	2.50
BCY39	3.60
BCY40	3.00
BCY42	0.32
BCY43	0.45
BCY58	0.25
BCY70	0.21
BCY71	0.21
BCY72	0.21
BCZ11	3.50
BD115	0.35
BD123	2.30
BD124	2.50
BD131	0.42
BD132	0.42
BD135	0.27
BD136	0.27
BD137	0.30
BD138	0.30
BD139	0.30
BD140	0.30
BD144	2.00
BD181	0.75

BD183	0.75
BD237	0.35
BD238	0.35
BDX10	0.91
BDX32	2.00
BDY10	2.40
BDY20	1.50
BDY60	1.50
BF115	0.30
BF152	0.16
BF153	0.19
BF154	0.17
BF159	0.20
BF160	0.20
BF166	0.35
BF167	0.30
BF173	0.45
BF177	0.30
BF178	0.30
BF179	0.30
BF180	0.30
BF181	0.25
BF182	0.30
BF183	0.30
BF184	0.30
BF185	0.30
BF194	0.15
BF195	0.15
BF196	0.15
BF197	0.15
BF200	0.33
BF224	0.12
BF241	0.12
BF244	0.35
BF257	0.30
BF258	0.30
BF259	0.30
BF336	0.30
BF337	0.30
BF338	3.00
BFS21	4.00
BFS28	2.50
BFS61	0.30

BFS98	0.30
BFW10	1.04
BFW11	1.01
BFX84	0.28
BFX85	0.28
BFX87	0.28
BFX88	0.28
BFY50	0.28
BFY51	0.28
BFY52	0.28
BFY64	0.36
BFY90	0.65
BSX19	0.27
BSX20	0.27
BSX21	0.27
BT106	1.65
BTY79 400K	3.00
BU205	1.20
BU206	1.20
BU208	2.00
BY100	0.42
BY126	0.15
BY127	0.15
BZX61	0.17
Series	
BZY88	0.10
Series	
BZY91	8.00
Series	
BZY93	0.12
Series	
BZY95	1.64
Series	
BZY96	2.00
Series	
CRS1 40	0.60
CRS3 40	0.75
CRS3 60	0.90
GEX66	3.00
GEX541	6.50
GJ3M	3.00
GM0378A	1.75
KS100A	0.45

MJE340	0.79
MJE370	0.73
MJE371	1.05
MJE520	0.75
MJ521	0.73
MJE2955	2.25
MJE3055	2.00
MPF103	0.55
MPF104	0.55
MPF105	0.55
MPSA06	0.17
MPSA56	0.17
MPSU01	1.11
MPSU06	1.33
MPSU56	1.71
NE555	0.45
NK1401	4.00
NK1403	3.50
NK1404	4.00
OA5	1.75
OA7	0.75
OA10	0.55
OA47	0.15
OA70	0.22
OA79	0.21
OA81	0.21
OA85	0.21
OA90	0.08
OA91	0.08
OA95	0.08
OA200	0.15
OA202	0.15
OA211	1.00
OAZ200	1.50
OAZ201	1.50
OAZ206	1.50
OAZ207	1.50
OC16	5.00
OC20	6.00
OC22	4.50
OC23	10.00
OC24	3.00
OC25	1.75

OC26	1.50
OC28	5.50
OC29	4.40
OC35	4.00
OC36	4.00
OC41	1.20
OC42	1.50
OC43	1.50
OC44	1.25
OC45	0.85
OC71	0.65
OC72	2.20
OC73	1.45
OC74	1.40
OC75	1.40
OC76	1.60
OC77	2.75
OC81	0.90
OC81Z	4.00
OC82	0.95
OC83	1.40
OC84	1.40
OC122	6.50
OC123	6.50
OC139	12.00
OC140	18.00
OC141	18.00
OC170	4.40
OC171	4.40
OC200	4.00
OC201	5.50
OC202	5.50
OC203	5.50
OC204	7.00
OC205	10.00
OC206	8.50
OC207	18.00
OCP71	2.50
ORP12	2.40
R2008B	1.95
R2009	2.25
R2010B	2.00
TIC44	0.48

TIC226D	1.20
TIL209	0.29
TIP29A	0.35
TIP30A	0.36
TIP31A	0.25
TIP32A	0.25
TIP33A	0.53
TIP34A	0.60
TIP41A	0.38
TIP42A	0.42
TIP110	0.10
TIP117	0.45
TIP125	0.35
TIP130	0.45
TIP131	0.45
TIP132	0.48
TIP135	0.45
TIP137	0.48
TIP140	0.85
TIP141	0.85
TIP142	0.85
TIP2955	0.60
TIP2955T	0.45
TIP3055	0.60
TIP3055T	0.45
ZS140	0.25
ZS170	0.21
ZS178	0.54
ZS272	0.23
ZS278	0.57
ZTX107	0.12
ZTX108	0.12
ZTX109	0.12
ZTX300	0.13
ZTX301	0.14
ZTX302	0.14
ZTX303	0.14
ZTX304	0.14
ZTX311	0.13
ZTX314	0.25
ZTX500	0.14
ZTX501	0.14
ZTX502	0.14

ZTX503	0.14
ZTX504	0.20
ZTX531	0.20
ZTX550	0.25
1N914	0.03
1N916	0.03
1N4001	0.04
1N4002	0.04
1N4003	0.04
1N4004	0.04
1N4005	0.04
1N4006	0.04
1N4007	0.05
1N4009	0.06
1N4148	0.03
1N5400	0.10
1N5401	0.11
1S44	0.04
1S290	0.10
1S921	0.12
2G301	1.00
2G302	1.20
2G306	1.50
2N404	1.50
2N696	0.30
2N697	0.36
2N698	0.38
2N705	2.50
2N706	0.20
2N708	0.22
2N930	0.25
2N1131	0.35
2N1132	0.35
2N1302	1.80
2N1303	0.90
2N1304	3.00
2N1305	1.00
2N1306	3.00
2N1307	1.20
2N1308	4.00
2N1309	1.50
2N1613	0.30
2N1671	5.00

2N1893	0.30
2N2147	8.00
2N2148	2.75
2N2218	0.32
2N2219	0.32
2N2220	0.22
2N2221	0.22
2N2222	0.20
2N2223	7.50
2N2368	0.23
2N2369	0.23
2N2384	0.24
2N2646	0.75
2N2904	0.30
2N2904	0.30
2N2905	0.30
2N2906	0.22
2N2907	0.22
2N2924	0.12
2N2925	0.22
2N2926	0.12
2N3053	0.30
2N3054	0.55
2N3055	0.70
2N3440	0.60
2N3441	0.75
2N3442	1.00
2N3641	5.00
2N3702	0.11
2N3703	0.11
2N3704	0.11
2N3705	0.11
2N3706	0.11
2N3707	0.11
2N3708	0.11
2N3709	0.11
2N3710	0.11
2N3711	0.10
2N3771	1.20
2N3772	1.20
2N3773	1.60
2N3819	0.50
2N3820	0.60

2N3823	0.80
2N3866	1.00
2N3904	0.10
2N3905	0.10
2N3906	0.10
2N405X	0.12
2N4059	0.20
2N4060	0.12
2N4061	0.12
2N4062	0.15
2N4124	0.13
2N4126	0.13
2N4248	0.25
2N4288	0.15
2N4289	0.12
2N4400	0.12
2N4401	0.12
2N4402	0.12
2N5457	0.45
2N5458	0.40
2N5459	0.40
2S017	16.00
2S019	25.00
2S024	35.00
2S025	35.00
2S026	40.00
2S103	2.50
2S302	5.50
2S303	5.50
2S322	5.00
2S325	4.00
2S701	12.50
2S745A	1.75
2S746A	1.75

VALVES

A1834	9.00
A2087	13.50
A2134	17.50
A2293	16.00
A2426	35.00
A2521	25.00
A2900	15.00
A3343	45.00
AZ31	2.75
AZ41	2.60
BK448	114.90
BK484	165.00
BS90	58.00
BS810	60.00
BT5	58.95
BT17	185.00
BT19	44.05
BT29	349.15
BT69	354.80
BT95	129.90
CBL31	4.00
CL33	3.00
CY31	3.00
C1K	20.00
C3A	22.00
C3JA	22.00
DA41	25.00
DA42	18.70
DAF91	1.75
DAF96	1.75
DE122	35.00
DE124	49.00
DF91	1.75
DF96	1.75
DK91	1.75
DK92	2.00
DK96	1.75
DL92	2.00
DL94	1.75
DL96	1.75
DLS10	14.00
DLS15	12.50
DLS16	12.50
DLS19	12.50
DM70	2.00
DM71	2.00
DM160	4.75
DY87	1.50
DY802	1.50
E55L	50.00
E80CC	15.00
E80CF	11.27
E80F	14.19
E80L	13.73
E81CC	8.00
E81L	13.27
E82CC	8.10
E83CC	8.40
E86C	8.25
E88C	8.25
E88CC	10.33
E90CC	9.47
E90F	9.90
E91H	6.25
E92CC	8.75
E99F	9.10
E130L	18.50

E180CC	10.50
E180F	12.05
E182CC	13.25
E186F	11.50
E188CC	8.91
E280F	22.51
E283CC	12.00
E288CC	17.50
WX10F	35.48
EA52	32.25
EA76	2.50
EABC80	1.25
EAC91	3.50
EAF42	2.50
EAF801	2.00
EB41	4.00
EB91	1.50
EBC33	2.50
EBC41	2.50
EBC81	1.50
EBC90	1.25
EBF80	1.50
EBF83	1.75
EBF89	1.50
EBL31	10.00
EC90	1.25
EC91	8.00
EC92	1.75
EC175	462.00
ECC33	4.50
ECC35	4.50
ECC40	5.50
ECC81	1.75
ECC82	1.75
ECC83	1.75
ECC84	1.75
ECC85	1.75
ECC86	2.50
ECC88	3.50
ECC89	2.00
ECC91	8.93
ECC189	2.10
ECC807	1.75
ECC808	5.00
ECF80	1.50
ECF82	1.50
ECF86	2.50
ECH35	3.00
ECH42	2.50
ECH81	3.00
ECH83	2.50
ECH84	2.50
ECL80	1.50
ECL81	1.75
ECL82	1.50
ECL83	3.00
ECL84	1.50
ECL85	1.50
ECL86	1.75
EF37A	5.00
EF39	2.75
EF40	5.00
EF41	3.50
EF42	4.50
EF50	2.50
EF54	5.00
EF55	3.50
EF80	1.75
EF83	4.00

EF85	1.75
EF86	3.50
EF89	2.50
EF91	2.95
EF92	6.37
EF93	1.50
EF94	2.50
EF95	5.99
EF98	2.00
EF183	2.00
EF184	2.00
EF804S	12.00
EF805S	15.00
EH90	1.75
EK90	1.50
EL32	2.50
EL33	4.00
EL34MUL	4.00
EL36	2.50
EL41	2.80
EL42	2.50
EL60	18.50
EL81	5.25
EL83	6.00
EL84	2.25
EL86	3.75
EL90	3.25
EL91	7.30
EL95	2.00
EL156	30.00
EL360	8.50
EL500	3.00
EL509	10.00
EL821	13.00
EL822	13.97
EL1500	25.00
EM34	8.00
EM80	2.50
EM81	2.50
EM84	2.00
EM85	2.75
EM87	2.50
EN32	25.00
EN91	6.50
EN92	6.96
EY51	2.75
EY81	2.50
EY83	2.50
EY84	9.24
EY86	1.75
EY88	1.75
EY500A	3.00
EY802	1.75
EZ35	1.75
EZ40	2.50
EZ41	2.50
EZ80	1.50
EZ81	1.50
EZ90	3.00
FW4-500	3.50
FW4-800	3.50
G1 371K	35.00
G55 1K	12.00
G180 2M	17.50
G240 2D	12.00
G400 1K	17.50
GN4	9.00
GN4A	9.00
GN4A	9.00

GS16	16.00
G11C	25.00
GU50	20.00
GU51	20.00
GXU1	15.35
GXU2	30.00
GXU3	25.40
GXU4	44.50
GXU50	20.00
GY501	3.00
GZ32	4.00
GZ33	4.75
GZ34	4.00
GZ37	4.95
KT61	5.00
KT66	15.00
KT77 Gold Lion	12.00
KT88 Gold Lion	20.00
KTW61	2.50
KTW62	2.50
KTW63	2.50
M8079	12.34
M8080	8.25
M8081	9.82
M8082	9.69
M8083	10.25
M8091	10.43
M8096	6.80
M8097	8.10
M8098	8.15
M8099	8.00
M8100	10.30
M8136	11.75
M8137	12.25
M8140	6.00
M8141	6.50
M8142	8.75
M8144	7.50
M8149	6.50
M8161	9.35
M8162	11.75
M8163	8.25
M8190	5.00
M8195	10.85
M8196	7.50
M8204	7.05
M8212	11.37
M8223	6.00
M8224	6.30
M8225	4.50
M8248	14.03
MD200	115.00
MU14	2.50
MX119	55.00
MX123	86.00
MX145	61.50
MX151	18.30
MX152	150.00
MX161	175.00
MX163	19.50
MX164	26.40
MX166	147.00
MX168	57.00
N78	15.00
OA2	3.25
OA3	2.50
OA4	6.00

OB3	2.50
OC2	4.55
OC3	2.50
OD3	2.50
OZ4	3.50
PC86	2.50
PC88	2.50
PC95	1.75
PC97	1.75
PC900	1.75
PCC84	1.50
PCC85	1.50
PCC88	2.50
PCC89	1.75
PCC189	2.50
PCC805	1.60
PCC806	1.60
PCE82	2.00
PCF80	1.50
PCF82	1.50
PCF86	2.50
PCF87	2.50
PCF200	3.25
PCF201	3.25
PCF801	2.50
PCF802	2.50
PCF805	1.70
PCF806	1.70
PCF808	1.70
PCL82	2.00
PCL83	3.00
PCL84	2.00
PCL85	2.50
PCL86	2.50
PCL805/85	2.50
PD500	6.00
PE06-40N	45.00
PFL200	2.50
PL36	2.00
PL81	1.75
PL81A	2.00
PL82	1.50
PL83	2.00
PL84	2.00
PL504	2.50
PL508	5.50
PL509	6.00
PL519	6.00
PL801	6.00
PL802	6.00
PY33	2.50
PY81	1.50
PY83	1.50
PY88	2.00
PY500A	4.00
PY800	1.50
PY801	1.50
QF451	82.50
QQV02-6	38.00
QQV03-10	26.25
QQV03-20A	48.38
QQV06-40A	46.00
QQV07-50	76.65
QQZ06-40A	62.20

QU37	12.50
QV03-12	6.80
QV04-7	3.50
QV08-100	197.40
QY3-65	63.24
QY3-125	78.48
QY4-250	74.00
QY4-400	87.20
QY5-500	208.00
QY5-3000A	566.80
QZ06-20	46.00
R10	6.00
R17	3.00
R18	3.00
R19	9.24
R20	2.50
RG3-1250	59.50
RG3-250A	32.68
RG3-1250	59.00
RG4-1250	61.60
RG4-3000	99.45
RR3-250	40.00
RR3-1250	45.75
SHF12	65.00
SI30	6.00
SI30P	6.00
STV280-40	14.00
STV280-80	21.00
SU41	5.00
SU42	10.00
TD03-10	35.00
TD03-10F	35.00
TT15	50.00
TT21	37.50
TT22	37.50
TT100	60.00
TY2-125	78.75
TY4-400	88.20
TY4-500	124.26
TY5-500	272.50
TY6-800	231.00
TY6-5000A	632.20
TY6-5000B	395.00
TY6-5000W	523.00
TY7-6000A	632.00
TY7-6000W	579.00
TZ40	25.00
U18/20	3.50
U19	13.75
U25	2.50
U26	2.50
U37	12.00
UABC80	1.25
UAF42	2.50
UB41	3.00
UBC41	2.25
UBF89	1.50
UCC84	1.75
UCC85	1.85
UCF80	2.00
UCH42	2.50
UCH81	2.50

UCL82	1.75
UCL83	2.75
UF41	2.00
UF42	2.10
UF80	1.75
UF85	1.75
UF89	2.00
UL41	5.00
UL84	1.75
UM80	2.00
UY41	2.25
UY85	2.25
VLS631	15.00
XG1-2500	100.00
XG5-500	30.00
XG2-6400	185.00
XR1-1600A	53.75
XR1-3200	110.00
XR1-3200A	
XR1-6400	165.00
YD1120	395.00
YD1240	588.00
Z803U	25.00
Z759	25.00
ZM1001	8.00
ZM1020	9.00
ZM1021	9.00
ZM1022	9.00
ZM1023	9.00
ZM1040	19.36
ZM1041	16.66
ZM1042	17.77
1B3GT	3.00
1B24	25.00
1B35A	48.00
1B63	64.00
1R5	1.75
1S5	1.75
1T4	1.75
2AS15	11.50
2C39A	60.00
2C43	70.00
2D21	3.25
2E26	8.25
2J42	98.00
2J55	245.00
2J70A	383.00
2J70B	336.00
2K25	125.00
3400Z	115.00
3500Z	100.00
3A5	3.00
3B24	11.00
3B28	15.35
3B29	20.05
3B240M	17.50
3B241M	17.50
3C23	25.00
3C24	12.00
3CX100A	47.00
3E29	45.00
3S4	2.00
3V4	1.75
4-65A	60.00

4-125A	60.00
4-250A	80.00
4-400A	87.00
4B32	20.00
4C35	120.00
4CX250B	58.00
4CX350A	105.00
4X150A	60.00
4X150D	56.00
5B254M	35.00
5B255M	35.00
5C22	160.00
5J180E	2500.00
5R4GY	5.50
5U4G	3.00
5U4GB	2.50
5V4G	2.50
5Y3GT	2.50
5Z3	4.00
5Z4G	2.50
5Z4GT	2.50
6-30L2	1.75
6AB4	1.75
6AB7	3.00
6AC7	3.00
6AH4A	4.25
6AG7	3.00
6AH6	6.00
6AK5	5.99
6AK6	2.50
6AL5	1.50
6AM4	4.00
6AM5	9.69
6AM6	6.02
6AN5	4.75
6AN8A	3.50
6AQ5	3.25
6AS6	8.60
6AS7G	8.75
6AT6	1.25
6AU5GT	5.00
6AU6	2.50
6AV5GA	4.50
6AV6	1.50
6AX5GT	3.00
6B7	3.25
6B8	3.25
6BA6	1.50
6BA7	5.00
6BA8A	4.00
6BC4	4.00
6BE6	1.50
6BH6	2.50
6BJ6	3.25
6BK4	3.50
6BL6	125.00
6BL7GT	4.50
6BM6	115.00
6BN6	2.00
6BQ7A	3.50
6BR7	6.00
6BR8A	3.50
6BS7	6.00
6BW6	6.00
6BW7	1.50
6BX7GT	5.00
6BZ6	2.75
6C4	1.25
6CB6A	2.50

6CD6GA	5.00
6CG7	2.50
6CH6	13.00
6CL6	£3.75
6CW4	8.00
6D2	1.50
6DK6	3.00
6DQ6B	4.75
6EA8	3.00
6EB8	2.50
6EW6	2.25
6F6	3.00
6F23	1.60
6F28	1.60
6F33	33.50
6H1	14.00
6H3N	2.75
6H6	3.00
6J4	5.50
6J6	8.93
6J7	4.75
6JE6	7.50
6K4N	2.50
6K6GT	2.75
6K7	3.00
6K8	3.00
6KD6	8.00
6L6G	3.50
6L6GA	3.50
6L6GC	5.75
6L6GT	3.00
6L7	2.50
6N2P	2.50
6N3P	2.50
6N7	3.00
6P25	4.00
6Q7	3.75
6R7	3.25
6RHH8 6KN8	10.00
6SA7	3.00
6SC7	2.75
6SF7	2.50
6SH7	3.00
6SJ7	3.25
6SK7	3.25
6SL7GT	3.00
6SN7GT	3.00
6SQ7	3.40
6SR7	2.75
6SS7	2.75
6U5G	3.50
6U8A	2.25
6V6GT	4.25
6X4	3.50
6X5GT	1.75
7B7	2.50
7C5	4.00
7C6	2.50
7H7	4.00
7R7	4.25
7S7	3.50
7Y4	2.25
7Z4	2.00
12AH8	5.00
12AT6	1.50
12AT7	1.75
12AU6	2.50
12AU7	1.75

12AV6	2.50
12AW7	3.50
12AX7	1.75
12AY7A	4.00
12B4A	3.50
12BA6	2.50
12BE6	2.50
12BH7	2.75
12BY7	3.00
12E1 11	28.00
12E14	65.00
12E1	20.00
13E1	170.00
19H5	47.50
24B9	67.25
30C15	2.00
30C17	2.00
30C18	2.00
30F5	1.60
30FL1 2	1.38
30FL12	1.38
30FL14	2.00
30L1	1.50
30L15	2.00
30L17	2.00
30P4	2.50
30P19	2.50
30PL1	3.00
30PL14	1.80
30PL15	2.00
35W4	1.50
50C4	1.50
75B1	6.05
75C1	4.50
85A1	7.50
85A2	6.45
90AG	20.00
90AV	20.00
90C1	6.00
90CG	14.54
90CV	15.45
92AG	20.00
92AV	20.00
95A1	8.45
150BA	6.50
150B3	8.35
150C2	3.25
150C4	6.00
211	35.00
723AB	125.00
803	25.00
805	45.00
807	3.75
811A	18.33
812A	47.50
813 valve	65.00
833A	193.16
866A	35.03
872A	20.00
922	6.00
931A	18.50
1624	4.00
1625	3.50
2050	7.50
4212E	300.00
4212H	300.00
5544	110.00
5545	150.00
5551A	120.00

5552A	165.00
5642	9.00
5654	3.00
5651	4.45
5670	4.50
5675	28.00
5687	6.00
5696	4.50
5718	7.50
5725	5.50
5726	11.37
5727	7.05
5749	2.50
5751	4.00
5763	4.50
5814A	4.00
5840	4.00
5842	12.00
5876A	31.50
5879	5.00
5886	17.50
5963	2.50
5965	3.50
6005	2.25
6021	4.50
6057	12.25
6058	12.34
6059	6.00
6061	6.00
6063	3.75
6064	10.25
6067	11.75
6072	6.00
6080	14.00
6097A	235.00
6097B	200.00
6146A	12.00
6146B	12.00
6159B	19.00
6189	9.50
6201	11.40
6442	20.00
6550	8.00
6883B	12.50
6973	7.50
7025	4.50
7027A	8.10
7551	6.25
7586	15.00
7587	23.00
7609	56.00
7868	6.00
7895	12.00
8068	16.50
8136	2.50
8417	6.00
18042	11.53
18045	10.49
18046	11.53

Tested Ex-Equipment
4CX250B 8.50
CV Devices
Large stocks
Prices on application

BASES

B7G Unskirted	0.40
B7G Skirted	0.50
B9A Unskirted	0.40
B9A Skirted	0.50
B9D	0.55
Int Octal	0.40
Loctal	0.55
Novistor base	2.00
Valve screening can all sizes	0.30

CRTs

2AP1	8.50
2BP1	9.00
3BP1	20.00
3DP1	5.00
3EG1	10.00
3FP7	6.00
3GP1	6.00
3JP1	8.00
3JP2	8.00
3JP7	10.00
3KP1	15.00
3RP1	35.00
3WP1	20.00
5ADP1	55.00
6CP1	10.00

5CP1A	40.00
5P15A	15.00
5UP7	25.00
DG7-5	63.32
DG7-31	58.07
DG7-32	58.07
DG7-36	65.00
DH3-91	56.83
DH7-11	113.12
VCR138	12.00
VCR138A	12.50
VCR139A	8.00
VCR517B	10.00
VCR517C	10.00

CRT sockets
Prices on application

I/C sockets
Texas
low profile

8	pin	10p
14	pin	10p
16	pin	10p

INTEGRATED CIRCUITS

7400	0.16
7400	0.35
7401	0.36
6402	0.36
7403	0.36
7404	0.42
7405	0.42
7406	0.48
7407	0.55
7408	0.36
7409	0.36
7410	0.36
7411	0.40
7312	0.42
7413	0.36

7416	0.48
7417	0.48
7420	0.48
7422	0.36
7423	0.36
7424	0.36
7427	0.36
7428	0.36
7430	0.36
7432	0.36
7433	0.55
7437	0.36
7438	0.36
7439	0.36
7440	0.36

7441	0.48
7442	1.25
7450	0.30
7451	0.30
7453	0.30
7454	0.30
7460	0.30
7470	0.48
7472	0.30
7473	0.48
7474	0.36
7475	0.65
7476	0.48
7480	0.32
7483	0.48

7484	0.72
7486	0.54
7490	0.72
7491	0.36
7492	0.54
7493	0.54
7494	0.78
7495	0.65
7496	0.60
7497	3.90
74100	0.84
74107	0.36
74109	0.54
74110	0.48
74111	0.51
74116	1.50
74118	1.20
74119	1.50

74120	0.75
74121	0.54
74122	0.70
74123	0.60
74125	0.60
74126	0.54
74128	0.55
74136	0.70
74141	0.46
74143	1.30
74145	0.72
74147	1.50
74148	1.40
74150	1.60
74151	0.36
74154	1.40
74155	0.60
74156	0.48

74159	1.75
74170	1.20
74172	4.00
74173	0.72
74174	0.60
74175	1.00
74176	1.00
74180	1.48
74190	1.20
74191	1.20
74192	1.10
74193	0.60
74194	1.10
74195	0.72
74196	1.00
74197	1.00
74198	2.20
74199	2.20

TAA570	1.75
TAA630S	1.75
TAA700	3.00
TBA480Q	1.50
TBA520Q	1.50
TBA530	1.50
TBA550Q	1.75
TBA560Q	1.75
TBA673	1.75
TBA700	1.50
TBA700Q	1.75
TBA750Q	1.50
TBA800	1.00
TBA920	1.75
TBA990Q	1.50
TCA270Q	1.00
TCA760A	1.25

Terms of business: CWO. Postage and packing valves and semiconductors 50p per order. CRTs £1.50. Prices excluding VAT, add 15%.
Price ruling at time of despatch.
In some cases prices of Mullard and USA valves will be higher than those advertised. Prices correct when going to press.
Account facilities available to approved companies with minimum order charge £10. Carriage and packing £1.50 on credit orders.
Over 10,000 types of valves, tubes and semiconductors in stock. Quotations for any types not listed. S.A.E.

Telephone: 01-677 2424/7
Telex: 946708
E. & O.E.
Open to callers Monday–Friday 9 a.m. – 5 p.m.

WW

ENTER 10 ON REPLY CARD

NEW PRODUCTS
AUDIO & VIDEO

Music synthesizer improved

A new version of the Music 500 (now the Music 5000) music synthesizer for the BBC micro adds many new facilities to turn what was rather user-unfriendly into a fully professional and easy-to-use system.

Based on its own programming language (Ample) and some clever hardware, the Music 5000 offers 16 channels, organized into up to eight voices, spread as required over the stereo output. Waveform and envelope synthesis is included as well as ring, frequency, amplitude and phase modulation to produce almost any sound as well as simulating 'real' musical instruments.

Ample is a language using nested words so that a whole program is ultimately contained in a single instruction. Its internal compilation is interactive, like Logo, and this allows words to be redefined in real time without recompiling the whole programme. The nucleus of Ample is now contained in a rom and there is a suite of utilities provided on disc which supplement the functions.

The staff editor, one of the disc utilities, enables the music to be entered directly on a musical staff presented on the screen, complete with clefs, key signatures, bar lines, dotted notes, tied notes etc. Above the staff is space to add instructions, such as changing the tempo, or mixture. Notes are entered, lengthened or shortened, dotted or tied by very simple cursor controls; it is not necessary to know the name of the note so it is quite straightforward to copy music from a score.

The real-time mixing desk, another module on the disc, presents a screen simulation of a mixing desk with faders, stereo pan pots, tempo and tuning controls, even a fast wind. This is also controlled by easy cursor manipulation and it is possible to substitute a different instrument or change the stereo position or tempo "on the fly" and listen to the effect immediately.

A number of waveforms, envelopes and instruments are already set up and by judicious substitution of a different preset wave or adding vibrato, channel frequency offset and/or modulation, it is possible to creat a great number of different sounds without needing to study harmonic synthesis of waveforms, although this is to be added later.

The system is designed to be modular and further hardware and software, including a keyboard, Midi-interface and other facilities are being developed.

The hardware, enclosed in a disc drive sized box, remains essentially the same as the Music 500, although there have been some timing changes to make the system compatible with the BBC Master series. It has its own power supply and needs to be plugged into a stereo amplifier (preferably of good quality) to hear the results. The system works on a sampling rate of 47kHz, which is faster than that used on compact disc. The complete system is available from the designers and manufacturers, Hybrid Technology, in Cambridge. Tel: 0223 316910.

Signal strength meter for tv signals

Built-in monitors are included in the Unaohm range of EP741 tv field strength meters, used typically for aerial and distribution cable installation. All the features necessary for detecting and evaluating tv signals are included: signal level measurement between 20 and 130μV, frequency readout on a four-digit l.c.d, zooming on the monitor for closer inspection of reflections or disturbances, band spectrum analysis around the tuned frequency with close-up inspection of selected parts of the spectrum, and monitoring of frame/line sync and chroma bursts.

Channels may be preset as on a tv receiver. Provisions are also made for voltage measurements on the devices associated with aerials and distribution systems. A sound output duplicates the field strength measurement so that it is possible to monitor the signal without looking at the instrument, while orienting an aerial, for example. The instrument operates on mains power or from an internal 12V rechargeable battery. An f.m. version adds the measurement of f.m. and i.f. signals and there is another model that can also decode teletext. Advid-Unaohm, 17A Mill Lane, Welwyn, Herts.

Microvoltmeter for a.c.

Audio measurements are the special province of the TM3B microvoltmeter which offers a wide frequency range and a variable bandwidth, high sensitivity and low noise level. The instrument has ranges from 15μV to 500V and +50dB, with an input impedance of 10MΩ in parallel with $<$20pF on ranges above 50mV. Maximum bandwidth is 1Hz to 3MHz but a pass band switch provides other ranges within that band. 1000h of use can be obtained from a PP9 battery; power unit for use on the mains is an optional extra. Levell Electronics Ltd, Moxon Street, Barnet, Herts EN5 5SD. Tel: 01-449 5028.

Synthesized receiver

A microprocessor-controlled synthesized receiver from Lowe Electronics seems to be the first British-made unit in its price range for many years. Coverage is continuous from 30kHz to 30MHz. Operating modes are a.m., s.s.b. and c.w.; an optional detector board adds f.m. plus a synchronous demodulator for enhanced a.m. reception. The design is intended to give excellent r.f. performance as well as convenience in use; image and spurious response rejection is said to be better than 80dB and dynamic range greater than 90dB at 50kHz from the tuned frequency (both intermodulation distortion and reciprocal mixing). Features include 30 battery-backed memories, a noise-blanker, four switchable filter bandwidths and a 400Hz audio filter for c.w. Further options are a plug-in keypad for frequency control and an internal nickel-cadmium battery pack, charger and active whip aerial for portable use. Basic price is £375. Lowe Electronics Ltd, Chesterfield Road, Matlock, Derbyshire DE4 5LE. Tel: Matlock 0629 2817.

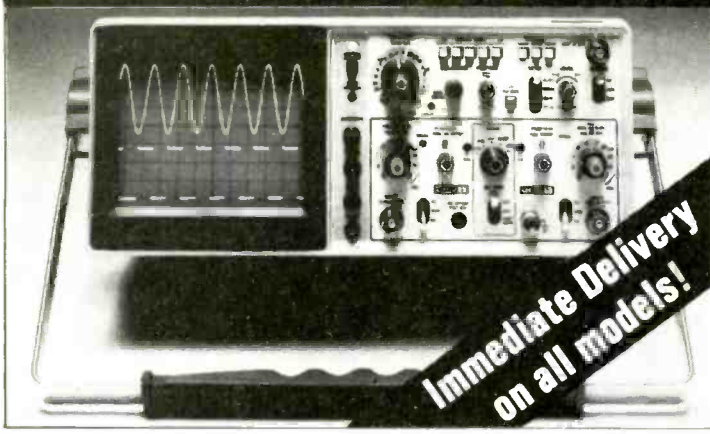
Surface mount integrated circuit mixer

A symmetrical mixer i.c. designed by Siemens for receivers, converters and modulators of a.m. and f.m. signals with frequencies up to 200MHz is now packaged in a surface-mounted version, the TBB042G, supplied in a SO14 miniature package. In its new package, the TBB042G can still be operated either from an external source or via its internal oscillator, in line with the requests from manufacturers of radio sets and of all kinds of remote-controlled models; mobile radio is also an important future application area for the s.m.d mixer.

Unlike the dip package with pins through the printed-circuit board, the new s.m.d. mixer is suitable for double-sided board production. Samples of the TBB042G are available ex-stock. Siemens Ltd, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS. Tel: 09327 85691.

Hitachi Oscilloscopes

leading the way in performance and pricing! **from £299 +VAT**



The highest quality
The Hitachi name is synonymous with quality and reliability and is backed by a 2 year or 3 year warranty on every oscilloscope.

The keenest pricing
With prices starting at only £299 for a 20MHz dual-trace model Hitachi's price-performance ratio can not be bettered.

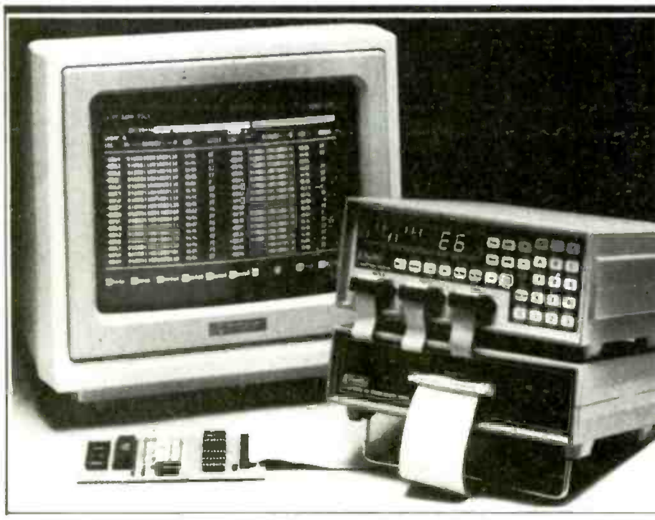
The largest range
Now totalling 18 models the Hitachi range covers bandwidths from 20MHz to 150MHz and digital storage models to 60MHz.

The fastest service
We can supply any Hitachi 'scope immediately from stock and we back it with full calibration and after-sales service.

For colour brochure giving specifications and prices ring **(0480) 63570**
Thurlby Electronics Ltd., New Road, St. Ives, Cambs. PE17 4BG

ENTER 64 ON REPLY CARD

low-cost logic analysis



Today's digital circuitry can't be debugged with just a logic probe and oscilloscope. A logic analyser has become an essential tool.

The Thurlby LA160 system puts logic analysis within the reach of every engineer with a wide range of options to suit many different applications.

- Prices from £395 plus vat
- 16 or 32 data channels
- IBM-PC interface options
- Data pods for random logic
- Personality modules for uPs
- Microprocessor disassemblers

No other logic analyser system approaches the value for money of the Thurlby LA160. Contact us now for full technical data.

Thurlby
designed and built in Britain

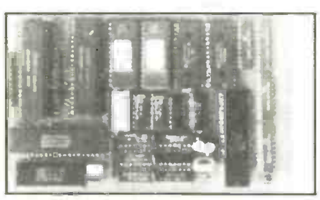
Thurlby Electronics Ltd
New Road, St.Ives, Huntingdon, Cambs.
PE17 4BG, England. Tel: **(0480) 63570**

ENTER 65 ON REPLY CARD

Z80 ■ CONTROL ■ Z80

CARDMASTER CPU

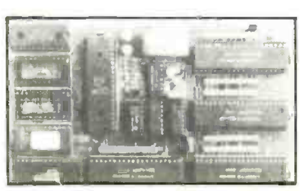
- 4/6 MHz Z80 CPU
- CP/M compatible
- User transparent MULTI-TASKING
- Up to 32K EPROM & 16K RAM
- Watchdog crash protection
- RS232 & RS422 Comms
- 2 * Z80a PIO (one uncommitted)
- On board bus buffering
- Power-on jump hardware
- Euro-card construction



NOW FROM £124 + VAT

CUB MICROCONTROLLER

- Z80 CPU
- 4 x Z80a PIO's (64 I/O lines)
- Z80a CTC
- 4K Battery backed RAM (2K sup.)
- 4K EPROM (2K MCV2.0 sup.)
- Powerful monitor (MCV2.0)
- Eurocard construction



NOW FROM £108 + VAT

STARBURST V1.31

A CROSS ASSEMBLER FOR CP/M80 covers four major families of single chip uP's and uC's

- 8048 inc. 8741/2 8748/9/50
- 8051 inc. 8031/2 8751 8744
- 6801 inc. 6800/1/2/3 68701
- 6805 inc. 68705 63705

Supplied with a complete set of demonstration files.

STARBURST V1.31 £95.00 + VAT
Requires Z80 CPU

CMR16 NOW FROM £199.00

Bare PCB's Available

	1+	10+
C/M CPU	28.50	25.65
C/M I/O	28.50	25.65
CUB	23.50	21.15
CMR16	40.00	36.00

Manuals on request

GNC ELECTRONICS
Little Lodge, Hopton Road, Thelnetham, DISS IP22 1JN.
Tel: 0379 898313

ENTER 47 ON REPLY CARD

KESTREL ELECTRONIC COMPONENTS LTD.

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

'Exclusive of V.A.T. and Post and Package'

	1+	50+		1+	50+		1+	50+
74LS00	0.13	0.10	6821	1.40	1.00	2764-25	2.30	2.20
74LS04	0.13	0.10	6502	3.30	2.80	27128A-25	2.40	2.35.
74LS08	0.13	0.10	6522	3.30	2.80	27128-25	3.50	2.30
74LS21	0.15	0.12	74S00	0.20	0.15	27256-25	3.20	3.00
74LS37	0.13	0.10	74S04	0.35	0.30	6116LP-3	1.30	1.20
74LS74	0.13	0.10	74S138	0.30	0.25	6264LP-15	2.30	2.00
74LS86	0.13	0.10	74S240	0.30	0.25	43256-15	12.00	9.00
74LS122	0.20	0.18	8085A	1.40	1.20	4164-15	0.90	0.80
74LS244	0.40	0.32	8255	1.40	1.25	41256-15	2.20	2.00
74LS245	0.44	0.32	4 meg Crystal	0.30	0.25	Z80ACPU	1.40	1.00
74LS367	0.23	0.17	LM324	0.25	0.20	Z80ACTC	1.40	1.00
74LS373	0.40	0.30	LM339	0.25	0.20	Z80AP10	1.40	1.10
74LS374	0.40	0.34	LM386	0.70	0.60	8253	1.40	1.25
74LS399	0.30	0.20	LM556	0.35	0.25	6845	1.90	1.30

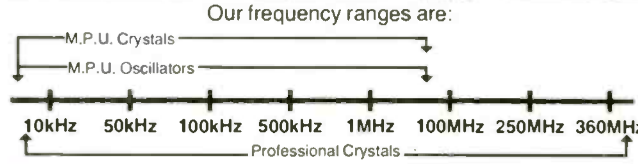
All memory prices are fluctuating daily, please phone to confirm prices.

ENTER 34 ON REPLY CARD

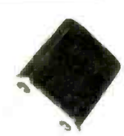
178 Brighton Road,
Purley, Surrey CR2 4HA
Tel: 01-668 7522

QUALITY QUARTZ CRYSTALS QUICKLY

Our frequency ranges are:



We also supply quartz crystal filters, oscillators of all types and communication antennae.



Webster Electronics
ILMINSTER, SOMERSET TA19 9QA, ENGLAND
TEL: (046 05) 5166 TELEX: 46571 FRQNCY G
FAX (046 05) 5865

ENTER 28 ON REPLY CARD

Digital image processing – – an overview

Digital processing of images for data compression, enhancement or restoration – a major area of application of two-dimensional digital signal processing – has spurred a great deal of work in the analysis of random fields.

A. S. KWABWE, R. N. GORGUI-NAGUIB and R. A. KING

Digital images are frequently formed by spatially sampling points of a continuous image. The digital image representation consists of an array of numbers which correspond to the intensities of the image at the sampling points. Digitization involves sampling the grey level at each picture point and quantizing it so that it takes on open of the number of specified values in the range of grey levels. Both the number of samples taken within a given scene and the number of levels to which they are quantized affect the quality of the digital image.

The question of the optimum number of sample points and the quantization strategy are often addressed in terms of the sampling theorem and optimum quantization.

Given a bandlimited picture, one can determine a sampling strategy in the picture plane and an interpolation function such that the picture is reconstructed without error from the samples.

The sampling theorem indicates that samples taken at rate of $f_c/2$, where f_c is the spectrum of the image, would be sufficient. Considering the images as samples of a random field, one can find an optimum set of orthonormal functions that minimize the sampling error. Such a set is the Karhunen-Loeve function for the minimum mean square error (m.m.s.e.) criterion.

Optimum quantization was developed by Max[1]. For a given number of output levels, the values of the output levels and the decision levels are determined such that the mean square quantization error is minimum. For an optimum quantizer, the decision levels are located midway between the output levels. Thus an array consisting of element intensities is produced from the analogue image.

There are perhaps more interesting ways of forming a digital image that do not involve sampling an existing analogue image. In the various modalities of tomographic scanning, for instance, a digital image is reconstructed from projections taken at various angles of an object.

In the majority of applications of interest, the digital image array is then processed by a digital computer and another array of numbers is produced to reconstruct a continuous image for viewing.

The processing may take a variety of forms depending on the requirements of the application at hand, and these are reviewed in this article.

Image processing may consist of coding, filtering, enhancement, restortation, analysis and recognition of images, and it is important to differentiate between the various terminologies that are used in this area. For the purposes of this overview, the term image processing refers to operations that transform images into other images. This must be differentiated from image recognition which maps images into non-image descriptions, and from computer graphics which deal with the computer synthesis and manipulation of images that are specified by descriptions. Apart from digital methods, there are other analogue methods of image processing – optical for example – but these are not covered here.

IMAGE CODING REDUCES STORAGE

Digital image coding, or compression, is performed to minimize the number of bits that are needed to represent or transmit an image without introducing visually unacceptable degradation.

The need for compression may be illustrated by considering a standard digital television image: for acceptable representation, one normally needs 512 by 512 samples per frame, each quantized to 50 grey levels. This is a total of approximately six bits per sample or 1.5 million bits in all.

Obviously, if no compression is performed, an overwhelmingly number of bits would be needed to send tv images, imposing an unacceptable burden on the transmitting network.

The other major application for image coding is in image storage. With the increasing use of images in remote sensing, astronomy, atmospheric physics and medicine, large amounts of image data are being acquired and it is essential that the amount of storage used be minimized.

Many different approaches to image coding have been extensively investigated, but a few general classes are outlined here. The first step is to decorrelate the data. One basic approach is to apply an invertable transform to the given image, approximate the transform by truncating some of its components and then reconstruct the image by inverting the transform. The transform is designed so that it can be approximated using many

Fig.3. Cosine transform coding performed at 0.8bit/element (c) results in a better image quality reconstruction than predictive coding at 1bit/element (b). Original image at (a).

fewer bits and minimizing the errors in the reconstructed image when it is inverted. Compression ratios of up to 10:1 can be achieved using transform coding and a variety of orthogonal transforms can be used[2] e.g., Fourier, Hadamard, Harr, KLT.

The forward unitary transform of an N_1 by N_2 image array $f(n_1,n_2)$ is an N_1 by N_2 transformed array defined by

$$F(m_1,m_2) = \sum \sum f(n_1,n_2)A(n_1,n_2,m_1,m_2),$$

where $A(n_1,n_2,m_1,m_2)$ is the forward transform kernel. The inverse transformation from the transform domain to the space domain is defined by

$$f(n_1,n_2) = \sum_{n_1} \sum_{n_2} F(m_1,m_2)B(n_1,n_2,m_1,m_2),$$

where B is the inverse transform kernel. A and B must satisfy orthonormality conditions.

Unitary transforms have found wide application in image processing, particularly in image coding. They provide a spectral decomposition of an image into coefficients that tend to isolate certain features of this image. For example, the first spectral component is proportional to average image brightness and the higher sequency components are measures of the image edge content. The block diagram of a transform coding system is illustrated in Fig.1.

Another approach is predictive coding. Here, rather than coding the image samples, one codes the difference between successive image samples.

Because successive picture elements are correlated, it is possible to form a prediction $\bar{f}(m,n)$ for a given element, $f(m,n)$, in terms of the rest of the image. The difference

$$e(m,n) = f(m,n) - \bar{f}(m,n)$$

is the estimation error for that element, and is also called the differential signal.

Although the best estimate (for m.m.s.e. criteria) is generally a non-linear function of the elements, a simple linear estimate is often used in which the prediction is formed as

$$\bar{f} = a_1 f(m-1,n) + a_2 f(m-1,n-1) + a_3 f(m,n-1)$$

where the coefficients a_1, a_2 and a_3 are chosen to minimize $e(m,n)$ and are functions of the autocorrelation. Compression is achieved because quantizing and coding the differential data rather than the pixel intensities requires fewer bits.

Because of the high correlation between successive samples, the differences will have a non-uniform probability density, peaked at zero (see Fig.2) and thus can be quantized acceptably using relatively few quantization levels. The differences may be either spatial (intraframe coding) or temporal (interframe coding) and further compression may be obtained by making the process adaptive.

A difficulty with this approach to compression is that when the image is reconstructed from the differences by summing them any errors will tend to propagate causing an unwanted distortion.

Fig.4. Histograms equalization can be used to enhance an image, remove blurring or correct geometric distortions. Applied to image (a) it results in subjective improvement (b).

Fig.3 shows transform and predictively coded images at various bit rates.

Another group of techniques combines the two classes discussed above. In hybrid coding, the image is first transformed, then adaptive prediction is applied to the transform samples. Here, the image quality obtained is often superior to that obtained from either predictive or transform methods.

Many other coding techniques, such as contour coding, run-length coding, interpolative coding, have been proposed and used. Some of the more interesting coding problems being addressed today consider motion estimation and compensation techniques for coding of moving-image sequences. There are interframe techniques that try to exploit the redundancy between consecutive frames and only code the moving parts of the frames.

Immediate applications of such techniques are found in videoconferencing where there is extremely little movement between frames, but good motion estimation techniques should widen their applicabilities to more general scenes.

Also, to evaluate or compare different coding methods, one has to determine the least number of bits needed to represent a picture, given that a certain level of distortion is acceptable, or conversely if only a certain bandwidth (number of bits) is available, which of the above techniques would minimize distortion?

In principle, this question is answered through rate distortion theory[3], which deals in quantitative terms with the concept of redundancy and its reduction to achieve data compression. A measure of the degradation is also needed as well as a model of the image being encoded.

Rate distortion theory may be used to derive absolute bounds for relatively simple error criteria and image models which may be useful, but it does not provide simple solutions when non-stationary image sources or complex error criteria are assumed.

IMAGE ENHANCEMENT

Some enhancement techniques – operations on the image that give rise to a subjectively improved image – are conceptually very simple and only involved pointwise modifications of the image. For example, one can analyse the grey levels in the neighbourhood of each image point, determine a grey-scale transformation that stretches these levels over the full display range, then apply this transformation to a given point. The class of histogram modification techniques based on this principle include equalization and hyperbolization techniques.

Image enhancement is often necessary when the observed image has undergone degradation, impairment or is the output of some processing system.

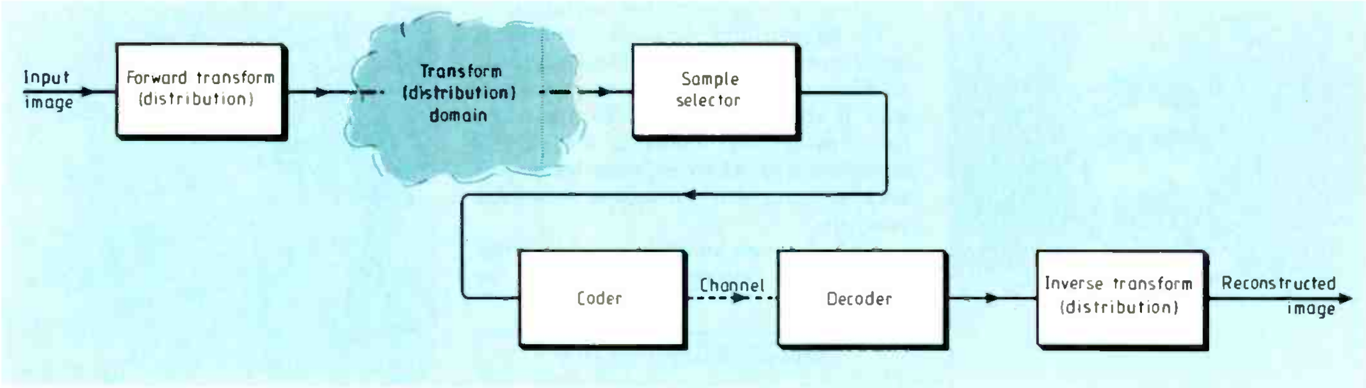
The methods discussed in this section differ from those of image restoration (see later) in the sense that they are basically simpler and do not explicitly attempt to model the degradation process or estimate the actual error, but only apply modifications to the given intensities to produce an image free of some general degradations.

The enhancement methods generally include contrast enhancement, smoothing, deblurring and correcting geometric distortion. The simplest enhancement techniques, however, involve grey-level correction where any obvious errors in the intensities are corrected: for example, any negative element intensities may be set to zero and any intensities outside the range of display set to the maximum intensity.

Another contrast enhancement technique, useful when some knowledge is available about the nature of the degradation function, is grey-level modification. For example, if a function of the non-uniform illumination under which the image was formed is known, then intensities may be modified to cancel the effect of the function.

If we assume that a function $p(z)$ denotes the relative frequency with which grey-level z occurs in f for all z in the grey-level range $[z_1,z_k]$ of f, then $p(z)$ is the histogram of the image and it can provide useful information about how to segment f into parts and as a basis for measuring certain textural properties of f.

In other words, histogram modification transforms a picture's grey scale so as to give the picture a specified histogram. Such modification may be useful if the type of histogram for a good image in that class is



known. Given an image with poor contrast, it can be transformed into one with the same histogram as a 'good' image.

A commonly used technique to achieve this purpose is histogram equalization, where the new element intensity is

$$x(m,n)=\frac{K-1}{M\times N}\sum_{i=1}^{k}p_i$$

where M×N is the dimension of the image array, K is the total number of levels to which the image is quantized, k is the old intensity of the element at location (m,n) and o_i is the number of elements that have a given intensity i (i.e., a bar of the histogram).

Averaging and smoothing operations generally lead to a more pleasing image if the original image has high frequency noise, whose effect is then reduced by smoothing.

Gradient and differential operators may also be used for sharpening or edge enhancement (discussed later). Fig.4 shows some enhancement results on images.

IMAGE RESTORATION

There are also image operations that differ from enhancement by the fact that they operate on degraded images and attempt to undo the effects of degradation. A model of the degradation is essential and it is customary to use additive combinations of blurring and noise operations, where the blurring is a weighted sum or integral operation applied to the image and the noise is uncorrelated with the ideal image.

There are a number of approaches to image restoration[4]. Pseudoinverse techniques define a blurring operator that yields the best approximation to the ideal image in the expected least squares sense. Kalman filtering yields least squares estimates of an ideal image corrupted by additive noise.

Closely related to image restoration is image reconstruction. For example, three-dimensional objects can be reconstructed from sets of projections, e.g. x-rays taken at many angles. Much work has recently been done in this area.

Even though the image formation process is often non-linear, the model below is valid in many cases:

$$g(x,y)=\sum h(x,y,x',y')f(x',y')dx'dy'+U(x,y)$$

where f(x,y) is the input image, g(x,y) the degraded image, h(x,y,x',y') a degradation function, also called the point spread function (p.s.f.), and U(x,y) the random noise that may be present.

Fig.1. In a transform coding system, input image is first transformed from the time domain to the transform domain representation. Samples from this domain are then selected and coded for channel transmission. At the receiving end, reverse operations take place, i.e. decoding the samples and inverse transforming them reproduces the reconstructed image.

This model is much simplified and real life degradations which are much more complex require modifications to the above model.

The simplest restoration method is inverse filtering which is aimed at removing the effects of blur and ignores the presence of additive noise. The estimate $\bar{f}(x,y)$ is

$$\bar{f}(x,y)=h^{-1}(x,y)*g(x,y)$$

where $h^{-1}(x,y)$ is the inverse of the degrading factor. However, h(x,y) may not be invertable or it may have zeros at which the calculation would be impossible.

Another method explicitly takes the presence of additive noise into the account and tries to find an estimate that minimizes the noise. This is the Wiener filter and it chooses the estimate as the minimum mean square estimate:

$$\min_{\bar{f}}\left[(f-\bar{f})^T E(f-\bar{f})\right]$$

Here, x^T denotes the transpose of x and E(x) is its expected value. If we assume gaussian statistics, the optimal estimate is obtained as

$$\bar{f}=PH^T(HPH^T+R)^{-1}.g$$

where $P=E(ff^T)$, $R=E(uu^T)$ and $E(fu^T)=0$.

The Wiener filter overcomes some of the problems of the inverse filter but is not optimum because it is based on the m.m.s.e. criterion which is not well suited to the way the human visual system works. Stationarity assumptions made to make the calculation

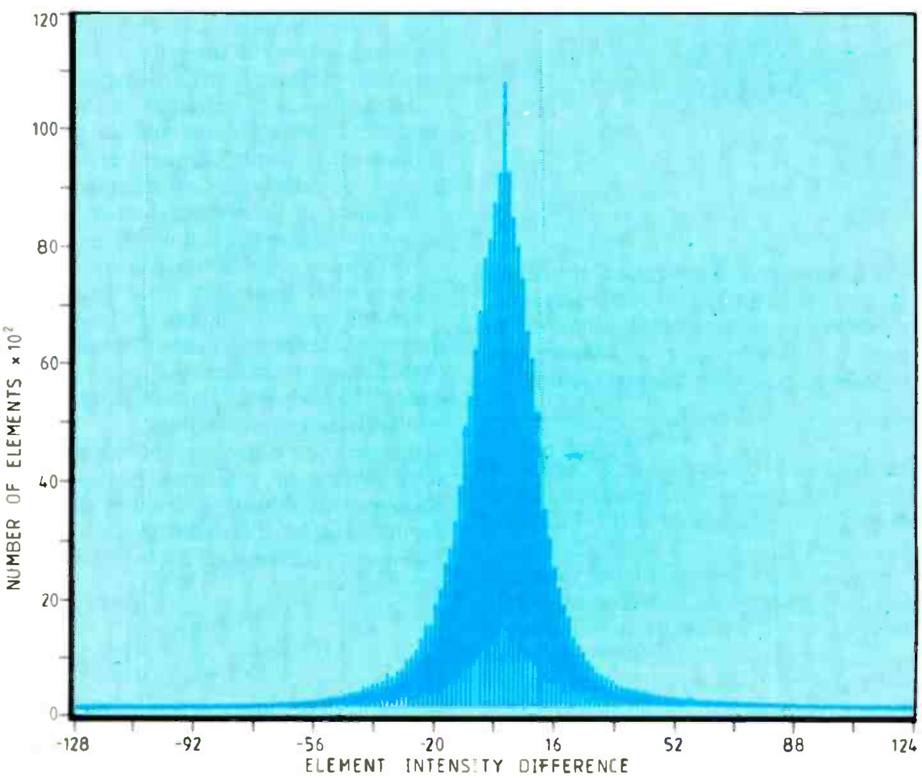


Fig.2. Histogram of difference signal for a predictive codec shows probability density is maximum at zero element intensity difference, and that successive samples result, overall, in a non-uniform probability density.

Fig.5. Intentional degradation of image at (a) by linear blurring (b) tests subsequent restoration by Wiener restoration (c). Image is filtered using a Wiener filter, regaining some of its original features.

feasible lead to the smoothing of edges and the reduction of contrast. It also requires too much *apriori* information on the statistics of the image.

Several other schemes have been proposed to overcome the short comings of the Wiener filter. These include the constrained least squares filter, parametric Wiener filter and a geometric mean of the inverse and Wiener filters. These are all non-recursive methods with high computational burden.

Research emphasis is now geared toward developing recursive restoration methods with computational advantages. The drawback is that more complex models are needed and, in this respect, several methods have been proposed using Kalman filters.

The Kalman filter, like the Wiener filter, is based on m.m.s.e. criteria and consequently sacrifices resolution for noise suppression as well. It also requires a detailed model and may not be very robust in the case of modelling error. However, many techniques have been proposed to overcome both these problems.

Fig.5 shows an image degraded by linear blur and its restored version using the Wiener filter.

IMAGE SEGMENTATION

Images are often composed of regions that have different values of some chosen property. For example, the regions may have a different range of grey-level intensities or a different texture, and in many applications, such as robotics, machine vision and pattern recognition, it is frequently necessary to process a given image or scene and delineate these regions.

An image may be segmented by examining its grey-level (or local property) histogram for the presence of peaks corresponding to the ranges, and using thresholds to single out individual regions.

If an image consists of an object and background, then its histogram will be bimodal and a threshold selected between the peaks of the histogram will segment the image into object and background. This is a conceptually simple segmentation method but unfortunately it is not always successful because many image histograms are not bimodal and some images are taken under such illumination conditions that a single global threshold is not sufficient for good segmentation.

More elaborate thresholding schemes are available such as multiple threshold selection, where the histograms and thresholds are computed over sections of the image that have reasonably uniform illumination.

Segmentation by selection of single or multiple thresholds does not in general perform satisfactorily. Some better methods use an edge-detection or enhancement technique prior to threshold selection, which gives a stronger region definition.

While many edge-detection operators and segmentation algorithms have been proposed and used, they do not always give all the essential edge information that correctly characterizes the image. Most useful techniques give a fairly good approximation to the ideal with few extraneous lines.

Simple linear edge-detection methods involve performing a discrete spatial differentation. Often this is achieved by convolving the image function with a gradient mask. A commonly used mask is the Laplacian edge detector:

$$H=\begin{vmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{vmatrix}$$

The new image intensity g(x,y) is formed from the image f(x,y) by using this mask to give.

$$g(x,y)=f(x+1,y)+f(x-1,y)+f(x,y+1)+f(x,y-1)-4f(x,y).$$

Other masks may be used to give maximum

Fig.6. Image resulting from edge enhancement and thresholding techniques has sharpened edges (b). Though not ideal, the edge information gives a good approximation to the edge characteristics of the image (a).

response to a preferred direction.

Non-linear edge detection systems use non-linear combinations of elements over a limited window area. Examples include Roberts' operator where the edge image is formed by cross-operations:

$$g(x,y)=\{[f(x,y)-f(x,y+1)]^2+[f(x,y+1)-f(x+1,y)]^2\}^{1/2}.$$

Other operators that have been widely used include Sobel, Kirsh and the Marr-Hildreth operators.

Segmentation of texture differs from intensity segmentation because texture edges sometimes occur where there is no marked change in intensity level and thus would not be detected by grey-level methods.

Several methods have been used both to measure texture quantitatively and for segmenting texture images. Quantitative texture measures include Fourier spectrum texture analysis, spatial autocorrelation functions and co-occurence matrices.

The use of region growing with split and merge algorithms has been found to give some reasonable segmentation when suitable texture measures are used to determine whether regions should be merged or not. Fig.6 shows some results using these methods.

References

1. Max, J. Qunatizing for minimum distortion *IRE Trans. Inf Theory*, vol. IT-6, 1960, pp. 7-12.
2. Pratt, W. Digital Image Processing, Wiley, 1978.
3. Berger, J. Rate Distortion Theory, Prentice-Hall, 1971.
4. Andrews, H.C. and Hunt, B.R. Digital Image Restoration, Prentice-Hall, 1977.

RADIO BROADCAST

H.f. quarts in pint bottles?

Pressure for an early World Administrative Radio Conference to revise frequency allocations, particularly within the h.f. spectrum of 3 to 30 MHz, is likely to surface at the WARC for the planning of the h.f. bands allocated to the broadcasting service, of which the second session is currently being held at Geneva.

The prime purpose of this session is to agree the plan of using a central computer at Geneva to allocate or share channels within the bands agreed at the 1979 WARC, at which h.f. broadcasters failed to gain access to several bands of frequencies they sought, although a number of extensions were agreed. Since then the continued expansion of external broadcasting, the installation of more powerful transmitters and the constraints of the present sunspot-minimum period, plus the world-wide effects of the mainly-Russian jammers, have caused further serious congestion and increase of interference to h.f. broadcasting.

In a recent broadcast, John Tusa, managing director of BBC external broadcasting, emphasized that this year's meetings cannot make new frequencies available for broadcasting, but added: "I think this session may concentrate people's minds on the need to expand frequencies".

He emphasized that there is no point in making programmes if "reception is so bad that it needs dedicated or skilled listeners to tune into them".

At the first session of the h.f. broadcasting WARC, an elaborate central planning system of the International Frequency Board was proposed and the current session has as one of its main tasks to agree whether to adopt this system.

It is clear, however, that theoretical studies have resulted in serious doubts whether the IFRB planning procedures can deliver the required service areas. It is considered that interference levels would be so high that only part of the designated service areas would receive satisfactory service. EBU special groups concluded last year that "It is believed that results achieved in practice are not as poor as those suggested by theoretical analysis. While the fundamental reasons for this need to be examined further, one implication is that an automated planning system (based on the same propagation prediction model and the same protection ratios) which is required to give service areas which are protected, can only do so by suspending a large number of the notified requirements."

In other words, even the most optimistic forecasts show that with so many countries now attempting to provide virtually world coverage by means of relay bases and with multiple transmissions of the same broadcasts on more than the two frequencies recommended by the ITU to cope with variations in h.f. propagation, h.f. broadcasting seems set to degrade still further under the sheer power and number of transmissions. While broadcasters see this as a reason for expansion of their bands, other spectrum users are likely to suggest that h.f. broadcasting needs first to put its own house in order, to modify its demands for world coverage and to reach agreement on the reduction, if not elimination, of intentional jamming.

Pre-echo problems

Although distribution of programmes to overseas h.f. relay bases has brought about a major improvement in technical quality, it has given rise in a few areas to serious degradation in the form of a pre-echo, with the main signal received a fraction of a second after a weaker echo signal. It has been found that this form of interference is even more disturbing than a conventional echo signal.

The situation arises where a distant overseas base, for example Singapore, uses the same channel as a UK transmitter not intended to serve the same area (for example parts of the Indian sub-continent) but nevertheless on some days providing an audible signal in the target area of the Singapore transmitter radiating a signal delayed by the satellite distribution link.

The problem can be largely overcome by artificially delaying the UK transmission, but the BBC have been reluctant to adopt this technique since it would destroy the accuracy of the time signals from its UK transmitters. But would it not be possible to arrange automatically to switch out the delay for the time pips?

Waiting for R-DAT?

Most consumer electronics appear on the market at the earliest possible opportunity – indeed, it could be argued that too much of it appears well in advance of the system being standardized, with consequent format rivalry.

This is clearly not the case with digital tape recordings for which an agreed specification, R-DAT (Rotary-head Digital Audio Tape-recorder) has been in existence for some time. Meanwhile the consumer industry rumbles with forebodings or denials of forebodings about the potential impact of digital tape on the compact disc industry, particularly since the CD boom has been suffering its first slight upset following increases in the price of the discs. The cost of software is seen by the trade as having more influence on the long-term future of audio recordings than the hardware costs. The availability of a tape system that could produce excellent quality recordings off-air or from CD discs – and subsequently re-used for different material – is worrying to an industry that has seen the lack of enthusiasm for high-quality video discs in the face of the video cassette tape recorder. Much money has been invested in setting up plants for the production of CD records. Yet in practice, disc and tape have existed together for many years and there is no proof that R-DAT machines would kill the CD industry or even seriously dent its growth.

Details of the basic R-DAT specification and performance measurements made using metal particle and Ba-ferrite particle tapes have been presented by Toshiba engineers in *IEEE Transactions on Consumer Electronics*, November 1986, pages 707 to 712.

Pirate interference

Although illegal broadcasting in the UK fell away dramatically during the period when it was anticipated that community radio licenses would soon be authorized, by the end of 1986 many pirate stations were active again not only in the London area but in the provinces and in Northern Ireland. The Government has not rushed to publish its Green Paper on the future of radio broadcasting, originally promised by the end of 1986, although some inspired leaks have emerged. From these it appears that what may have been published by the time these notes appear will be more in the nature of election manifesto promises than intended for immediate action. It also seems doubtful whether the proposals will do much to encourage quality broadcasting but rather lean heavily on market forces in pursuit of what appears to be a long-term aim of cutting BBC and Independent Radio down to size.

It is often claimed by the pirates that they cause little or no interference to the authorized broadcast services. This is not, however, the experience of those of us living anywhere near to "pirate alley" located on the high ground of the Crystal Palace area. For some months it has become increasingly difficult to receive Radio 3 programmes from Wrotham without at least some splatter (and often capture) by the strong local signals of one or more pirate stations.

It was widely assumed that the extra powers given to the Radio Investigation Service of the DTI by the Telecommunications Act would serve as a powerful deterrent to pirates, few of whom can be realistically considered as falling within the scope of what many of us conceived as true community radio, for which a strong case can be made.

Radio Broadcast was written by PAT HAWKINS.

TELEVISION BROADCAST

Educating video discs

Despite the good technical quality of video discs, the system, lacking the record facility of video tape cassette machines, has so far proved to have little appeal to consumers. The disc, however, may well come into its own as a means of storing enormous amounts of visual information as, for example, in the much-publicized "Domesday Project" and in interactive form as a powerful educational tool.

It is, admittedly, always dangerous to predict the influence of new technology on the world of talk and chalk. Closed-circuit television and computer-aided instruction have never had the predicted impact on education. Computer-aided instruction using conventional graphics presented on a visual display unit has proved too often too impersonal to hold the attention of students. But interactive laser-disc systems are being promoted as offering the "action" of recorded television images with the interactive facilities of computer-aided instruction, thus marrying the emotional and visual power of television to the speed and intelligence of the computer.

A small US company, Interactive Medical Communications, headed by Jim Mason, a former writer and broadcaster, has recently landed a contract to provide an interactive video disc educational system to provide health and safety training for the 400,000 employees at the 147 sites of General Motors.

The workforce is being trained to appreciate safety hazards by using a touch screen to answer questions as they watch training videos. The system has been designed to keep track of each worker's progress by assessing incorrectly answered questions and generating individual review programmes. Each worker-student thus trains individually at his or her own pace and without being intimidated or ridiculed when failing to answer questions correctly. The system comprises a colour touch-screen monitor, a microcomputer with 640K of random-access memory and a 20-megabit hard disc together with a laser-disc player. The branching software used to create revision programmes adapted to progress can generate up to a million paths.

The company stresses that it is essential to produce the video disc material to a standard comparable to television broadcasting, claiming it took eight months to develop the single disc plus software for the General Motors health and safety training programme.

A similar training system designed to reduce adult illiteracy has also recently been developed by IBM, who claim that it is achieving very positive test results.

Pirate decoders

The introduction last year of scrambling of programmes distributed by satellite to US cable systems decimated for a time the sale of the 4 GHz C-band television receivers to home viewers. There are now upwards of eleven channels using the Video Cipher II system and General Instruments have received some 75,000 orders for decoders, authorized through the programme companies, outstripping production. Another 20 channels are also planning to adopt Video Cipher II.

However it is clear that a number of viewers are endeavouring to avoid paying programme subscription charges with a number of companies now marketing "pirate" decoders or offering to modify decoders to permit owners to receive additional programmes without payment. The Video Cipher marketing people claim this to be "in violation of state and federal law".

The number of subscribers to UK cable systems is now approaching 200,000 although a large majority of these are still connected to the older "upgraded" systems offering a limited choice of channels. With the number of "homes passed" by cable now over 1,100,000 the ratio of subscribers to homes passed fell slightly, from 16.4% to 15.9%, in the third quarter of 1986. The Cable Authority has reminded Ulster Cablevision and Merseyside Cablevision, both of which were in the first batch of franchises awarded more than three years ago, reminding them that the Authority could not be expected to wait indefinitely for construction to begin.

Amer-connector standardized

The US Electronic Industries Association has standardized a 20-plus-shield pin connector for providing a baseband (audio/video) interface between NTSC television receivers and peripheral devices. The socket is basically similar to the Peritel/SCART Euro-connector now being fitted to an increasing number of PAL and SECAM receivers but with some differences in the facilities provided and in the connections to the pin numbers. Known as the EIA IS-15 Amer-connector, the concept is similar to Peritel in Europe and is seen as providing an interface for pay-tv descramblers etc., as well as improving the technical quality available from video cassette recorders by elimination of the modulator/demodulator degradation.

Cable television has had a significant impact on American receiver design with some 40-million "cable-ready" receivers sold and with about two-thirds of current production in this category. As in Europe there has been a growing need for a standard interface permitting connection of RGB and/or composite video and to facilitate the use of a television receiver with an external stereo audio system.

As noted in the February issue, it has been proving extremely difficult to establish teletext services on either American broadcast or cable channels. But, in addition to the "Electra" teletext service described in that issue, there is at least one cable "subscription" teletext service providing a "Market Watch" service of financial information and available on the Financial News Network channel on cable. This is run by the Data Broadcasting Corporation of Vienna, Virginia, a firm founded in 1984 by the Financial News Network and Biotech Capital Corporation but currently having the large Merrill Lynch brokerage house as majority owner.

Market Watch promises virtually instant quotations on either 8000 stocks and indices or on up to 20,000 stocks, indices and options at a cost to the subscriber ranging from about £25 to £60 per month. However, it faces strong competition from various Radio Teletext (SCA) services of financial information carried on v.h.f./f.m. broadcast stations as planned to be introduced shortly in the London area.

Market Watch was launched in April 1986 and is currently carried on about 120 cable systems that serve about 2.5 million homes with its basic channels. But by December 1986 there were just 650 subscribers to the Market Watch teletext service mostly located in Texas, Florida and California, and the company are not predicting at what rate it hopes to penetrate an "emerging market".

The IBA offer of a three-channel d.b.s. contract last December to BSB did not include any satellite teletext services for which a separate contract was advertised last April. This attracted an application from Direct Business Satellite Systems Ltd who proposed a broadcast message service, akin to electronic mail, but intended for multiple addresses in the form of text, data, facsimile or digitized voice. DBSS have commented that the satellite-teletext award is subject to further discussion of the regulatory position which at present appears to forbid "closed user group services" but permits encrypted subscription teletext. It would seem that there requires to be a more precise definition of where the line needs to be drawn by existing legislation between a broadcast service and a telecommunications service.

Television Broadcast was written by PAT HAWKER.

RADIO COMMUNICATIONS

Telecomms privacy

The attempt by the US government to strengthen the privacy of American telecommunications services by the introduction of a new "Electronic Communication Privacy Act" appears to have ground to a halt, at least for the time being. This is despite the fact that a watered-down version of the original draft Bill, as S-2575, received unanimous approval from the Senate Judiciary Committee last September. But when S-2575 reached the Senate in October, it failed to be sent for ratification by President Reagan. This means that S-2575 automatically died on December 31, 1986 in accordance with US legislatory practice. Unless a new Bill is introduced to Congress and is duly ratified, protection against unauthorized interception of radio traffic or telephone "bugging" looks like being constrained only by the relatively mild provisions of such current legislation as the Communications Act, 1934.

This Act does not attempt to forbid listening to radio transmissions of any services or on any frequencies although it does, nominally, make it an offence to use or disclose the contents of private messages.

Strong opposition to the US Electronics Communications Privacy Act, even in its modified form, came from various bodies representing short-wave listeners and enthusiasts and by radio amateurs on the grounds that it gave the US Government the right to forbid listening on frequencies not used for broadcasting or other public services.

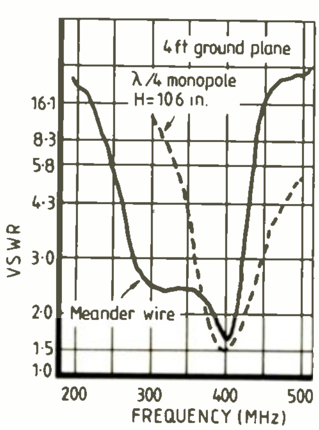
Various amendments exclude from the original provisions the monitoring of any radio communications "for the use of the general public" or those "readily accessible to the public" thus excluding cordless telephones, marine and aircraft transmissions, law enforcement and public safety services (police and fire services) etc.

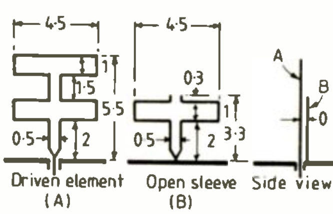
In this watered-down version it was expected to become law during 1986 but was strongly attacked by the influential columnist Jack Anderson as being motivated in support of the cellular radio-telephone industry.

In the UK, the privacy provisions of the Wireless Telegraphy Acts were further strengthened last year by the "Interception of Communications Act" which came into force in April 1986, making it a criminal offence for any person intentionally to intercept a communication in the course of its transmission by post or by means of a public telecommunications system. While no prosecutions under this Act have been reported, three men were charged during January 1987 following the discovery in November 1986 of a listening device buried in a tin and connected to the telephone line of a director of the electrical and electronics firm Comet. The charge in this case (conspiring to intercept a public communication) was brought under the 1977 Criminal Law Act.

Compact broadband monopole

The use of very closely spaced parasitic elements as "open sleeves" in order to extend the bandwidth of driven antenna elements has been used in a number of novel designs in recent years. Jimmy Wong and Howard King of The Aerospace Corporation have described (*IEEE Transactions on Antennas & Propagation*, May 1986, pages 716-7) a height-reduced meander zigzag broadband monopole developed to provide a performance comparable with a quarter-wave monopole but over a 3:1 bandwidth and with a height of under one-third wavelength at the lowest operating frequency.





Use no. 12 wire

Dimensions in inches

Their report describes results achieved with model wire antennas constructed from 12-gauge wire and with measurements made over the range 250 to 750 MHz. The antenna is being developed for use in a spacecraft operating over 50 to 80 MHz and 100 to 150 MHz. It has been shown that, with proper choice of design parameters, this antenna could be operated over two widely-separated bands with little or no change in pattern performance relative to a resonant quarter-wave monopole. The diagram shows the v.s.w.r. of a meander monopole with one open sleeve. For dual-band operation, two open sleeves are used. The single-band model operates over 250 to 400 MHz and is compared with the bandwidth performance of a 7.06-in straight-wire monopole with a resonant frequency of approximately 400 MHz. Overall height of the meander is 5.5 inches (a tuned monopole for 250 MHz would require a wire length of about 11 inches). Measured radiation patterns were presented showing that when a meander monopole is used in conjunction with a suitable ground plane the basic quarter-wave monopole pattern characteristics are preserved over a 3:1 frequency range.

Military packets

The possibility of using "packet-radio" systems for military communications networks, including battlefield "Combat Net Radio", has been under active investigation by a team of the Royal Signals and Radar Establishment since 1983, when a decision was made to build a five-station research demonstration system. Military mobile systems pose particular problems in having to be able to operate in hostile electromagnetic environments resulting from enemy jamming and the siting of units behind hills out of sight of the enemy.

The RSRE demonstration system has initially been based only on single-address "acknowledged datagram" service and unlike more recent civilian and US military systems does not use an ISO "open system interconnection" model. Instead it has been based on the US Defence Advanced Research Project Agency (DARPA) internet architecture, transmission control and internet protocols for end-to-end and internet working respectively. More recently the US Department of Defense has endorsed ISO rather than DARPA standards. However the RSRE team has been able to link their demonstration equipment into the US ARPANET and also demonstrated to NATO in 1985 interworking with a more complex US Packet Radio demonstrator.

Digital transmission with packet-switching techniques is possible with current military v.h.f. transceivers such as the Clansman VRC353, Jaguar V and Scimitar V in conjunction with an RSRE in-house data interface unit and DEC-11/33 station processor with RSRE software.

The RSRE is continuing design work with a view to developing a production specification model. There is need to refine the demonstration system by providing protection against spoofing and additional interfaces, gateways, etc. for services other than single-address datagrams.

In a recent report on RSRE work on Packet Radio, Major R.D.M. Graham and Dr B.H. Davies noted that future use of this technique for a variety of roles in military communications raises a number of important management issues that have not yet been tackled, in particular the question of achieving the necessary degree of operational control within a mix of battlefield systems co-ordinated by senior communication managers and their staffs.

Radio Broadcast was compiled by PAT HAWKER.

PINEAPPLE SOFTWARE

Programs for the BBC models 'B' with disc drive with FREE updating service on all software

DIAGRAM

Still the only drawing program available for the BBC micro which gives you the ability to draw really large diagrams and scroll them smoothly around the screen stopping to edit them at any time if required.

Pineapple's unique method of storing the diagram information on disc means that the size of diagrams is limited only by the free space on disc, and not the amount of computer memory you have available. (A blank 80 track disc will allow up to 39 mode 0 screens of diagram).

The superb print routines supplied with the program enable large areas of the diagram to be printed in a single print run in a number of different sizes and rotated through 90 deg. if required. Full use can also be made of printers which have a wider than normal carriage available.

The program is fully compatible with the Marconi Tracker ball described below.

PLEASE STATE 40 or 80 TRACK DISC & WHETHER STANDARD BBC or MASTER VERSION IS REQUIRED

PRICE £25.00 + VAT

DIAGRAM UTILITIES

A suite of six utility programs which add additional features to the 'Diagram' drawing program. The utilities include the saving and loading of areas of diagram to and from disc. The ability to display the whole of your large diagram on the screen at one time (in either 4★4 or 8★8 screen format). The addition of borders and screen indents to diagrams, and the ability to shift a whole diagram in any direction.

PRICE £10.00 + VAT

MARCONI TRACKER BALL

This high quality device comes with it's own Icon Artmaster drawing program and utilities to enable it to be used in place of keyboard keys, joysticks, or with your own programs.

PRICE £60.00 + VAT p&p £1.75

PRICE INCLUDING 'DIAGRAM' SOFTWARE £79.00 + VAT p&p £1.75

TRACKER BALL for MASTER series

The Pointer ROM is supplied instead of the Icon Artmaster disc and enables the Tracker ball to work directly with the MASTER series computers. (e.g. to use with TIMPAINT etc.). Prices are the same as for the standard tracker ball.

POINTER

The Pointer Rom is available separately for people already owning tracker balls, and comes with instructions for use with the MASTER computer.

PRICE £12.50 + VAT

PCB

This new release from Pineapple is a printed circuit board draughting aid which is aimed at producing complex double sided PCB's very rapidly using a standard BBC micro and any FX compatible dot-matrix printer.

The program is supplied on EPROM and will run with any 32k BBC micro (including Master series). Also supplied is a disc containing a sample PCB layout to demonstrate the programs features.

By using an EPROM for the program code the maximum amount of RAM is available for storing component location and ASCII identification files etc. (Up to 500 components and 500 ASCII component descriptions may be stored for a given layout). These is no limit to the number of tracks for a given PCB, although the maximum size of board is restricted to 8" * 5.6".

Using a mode 1 screen, tracks on the top side of the board are shown in red, while those on the underside are blue. Each side of the board may be shown individually or superimposed. A component placement screen allows component outlines to be drawn for silk screen purposes and component numbers entered on this screen may be displayed during track routing to aid identification of roundels.

The print routines allow separate printouts of each side of the PCB in a very accurate expanded definition 1:1 or 2:1 scale, enabling direct contact printing to be used on resist covered copper clad board.

This program has too many superb features to describe adequately here, so please write or 'phone for more information and sample prinouts.

PRICE £85.00 + VAT

CONVERTER LEADS

Converter leads to enable the Trackerball to run mouse software and the mouse to run trackerball software (inc. DIAGRAM). Please state which way round when ordering.

PRICE £8.00 + VAT

MICROSPICE

A new addition to our range of engineering software. Microspice is a very powerful DC and AC analogue circuit simulator package for any model BBC computer.

As well as all the usual facilities available with this type of program, non-linear effects, small signal, noise measurements and sweeps may be performed. Component values may be swept, allowing component tolerances to be investigated as well as thermal performance etc. Comprehensive transistor modelling is incorporated using a 20 parameter Ebers Moll description. The program is supplied on disc with a very comprehensive 49 page manual.

Please write or 'phone for more information.

PRICE £99.00 + VAT P&P FREE

ALL ORDERS SENT BY RETURN OF POST

39 Brownlea Gardens, Seven Kings, Ilford, Essex 1G3 9NL. ☎ Tel: 01-599 1476

ENTER 23 ON REPLY CARD

★ FREEPOST YOUR ORDER OR ENQUIRY TO US ★

No Stamp Needed

74LS00	21	74LS40	21	74LS126	36	74LS174	40	74LS279	48
74LS01	21	74LS42	47	74LS132	50	74LS175	40	74LS280	150
74LS02	21	74LS48	90	74LS133	45	74LS190	70	74LS283	70
74LS03	21	74LS54	21	74LS136	35	74LS191	60	74LS290	40
74LS04	21	74LS73	30	74LS138	35	74LS192	60	74LS293	39
74LS05	21	74LS74	24	74LS139	36	74LS193	60	74LS295	130
74LS08	21	74LS75	34	74LS145	86	74LS195	60	74LS298	100
74LS09	21	74LS76	34	74LS151	65	74LS196	70	74LS299	210
74LS10	21	74LS78	34	74LS153	40	74LS197	65	74LS348	200
74LS11	21	74LS83	50	74LS154	90	74LS221	57	74LS353	120
74LS12	24	74LS85	52	74LS155	45	74LS240	65	74LS363	180
74LS13	34	74LS86	30	74LS156	55	74LS241	65	74LS366	48
74LS14	35	74LS90	45	74LS157	30	74LS242	65	74LS367	40
74LS15	24	74LS92	40	74LS158	39	74LS243	70	74LS373	60
74LS20	21	74LS93	40	74LS160	55	74LS244	60	74LS374	60
74LS21	21	74LS95	50	74LS161	50	74LS245	60	74LS375	68
74LS22	21	74LS96	67	74LS163	50	74LS247	60	74LS378	94
74LS27	21	74LS107	37	74LS164	50	74LS249	90	74LS393	60
74LS28	21	74LS109	34	74LS165	74	74LS251	35	74LS395	100
74LS30	21	74LS112	36	74LS166	74	74LS253	52		
74LS32	21	74LS114	35	74LS168	95	74LS257	43	XTALS	
74LS33	21	74LS123	51	74LS169	70	74LS260	45	100kHz	390
74LS37	21	74LS124	90	74LS170	90	74LS266	30	1.000MHz	260
74LS38	21	74LS125	36	74LS173	80	74LS273	60	1.843MHz	190

Add 70p P&P + 15% VAT

TURBO INTERNATIONAL FREEPOST
LONDON SW16 2BR

Also: Cmos, Linear, Micro, Memory, Crystals. Send for details! Phone: 01-769 1639

ENTER 73 ON REPLY CARD

TRANSFORMERS EX-STOCK

MAINS ISOLATORS
Pri Sec 120V × 2 OR
240 to 415/440V
(60-1000VA Tap Secs)

VA	£	P&P
20	7.06	2.18
60	11.51	2.31
100	13.43	2.59
200	19.03	3.10
250	23.01	3.24
350	28.46	3.40
500	35.45	3.66
1000	64.28	4.62
1500	82.92	5.85
2000	99.76	6.36
3000	139.89	OA
6000	298.89	OA

50V	25V	£	P&P
0.5	1	5.01	1.76
1	2	6.09	1.90
2 A	4	10.84	2.20
3 M	6	12.54	2.25
4 P	8	17.16	2.58
6 S	12	21.84	2.79
8	16	30.89	3.15
10	20	36.66	3.60
12	24	43.87	3.80

30/15V or 15.0-15V
2 × 15V Tap Secs, Volts

30V	15V	£	P&P
0.5	1	3.86	1.41
1	2	5.24	1.70
2	4	8.47	1.92
3	6	9.82	2.10
4 A	8	11.72	2.20
5 M	10	14.49	2.31
6 P	12	16.40	2.55
8 S	16	21.95	2.60
10	20	25.32	2.84
12	24	28.07	2.95
15	20	31.66	3.51
20	40	43.22	5.95

60v	30V	£	P&P
0.5	1	5.69	1.85
1	2	8.67	1.91
2	4	11.15	2.20
3 A	6	16.12	2.34
4 M	8	18.38	2.55
5 P	10	23.23	2.78
6 S	12	26.50	3.02
8	16	37.25	3.65
10	20	43.37	3.99
12	24	49.98	4.65

PLEASE ADD 15% VAT TO ALL ITEMS AFTER P&P

24/12V or 12-0-12V
2 × 12V Secs. Pri. 240V

12V	24V	£	P&P
0.3 A	0.15	2.92	1.10
0.5	0.25	3.08	[illegible]
1	0.5	3.70	1.60
2	1	5.15	1.70
4	2	5.94	1.90
6 A	3	9.31	2.05
8 M	4	10.89	2.10
12 P	6	13.20	2.25
16 S	8	15.73	2.60
20	10	21.17	3.04
30	15	26.31	3.10
40	20	37.56	[illegible]
60	30	53.92	4.90
83	41	62.09	5.65

INVERTERS
12/24V DC to 240V AC
100W to 4kW

WINDING SERVICES
3VA TO 15KVA
Single or 3-phase
Plus Toroidals
Stock items by return

CONSTANT VOLTAGE TRANSFORMERS 1%
Spike-free stable mains

AUTOS
105,115,220,230,240V
For step-up or down

VA	£	P&P
80	5.86	1.70
150	6.49	1.85
250	10.34	1.98
500	16.12	2.68
1000	21.79	3.25
1500	34.17	3.68
2000	51.09	4.62
3000	86.88	5.72
4000	112.78	O/A
5000	131.33	OA
7500	202.71	OA
10KVA	239.53	OA

CASED AUTOS
240V Cable Input
115V USA socket outlets

VA	£	P&P
20	8.34	1.76
80	11.33	1.87
150	14.67	2.20
250	17.87	3.02
500	29.32	3.19
1000	40.29	4.34
2000	73.33	5.28
3000	105.26	OA

Full range AVO's, Meggers, Fluke, Edgecumbe
ALSO VALVE MAINS OUTPUT & MATCHING TYPES

Unit 211, Stratford Workshops, Burford Road, London E15 2SP

BARRIE ELECTRONICS LTD
Tel: 01-555 0228 (3 lines)

ENTER 35 ON REPLY CARD

HI-FIDELITY
WITH SOUND PRINCIPLES

Complete Hi-Fi kit for less than £140

- 40 watts RMS per channel into 8Ω watts into 4Ω
- High current output, stabilised PSU for power amps
- Minimum capacitor passive equalisation design
- MM/MC with infra cut, CD, Rad, Tape 1 & 2 inputs
- Rugged TO3 complementary output & PSU transistors
- Comprehensive instructions, quality components

Much is said about amplifier design. Specification and technical performance alone no longer rules supreme. Concepts such as musicality are regarded as sacred by the Hi-Fi fraternity. The state of the art is for amplifiers to have high output current capability, high overload margins, be "neutral sounding yet articulate and dynamic". High feedback designs are definitely out, capacitors and cables affect the sound.

Where does the engineer stand in all this? We think you would like an amplifier with real state of the art features, but not over the top in insignificant design details. You are unhappy at paying for a mass produced product. You appreciate a top class system but cannot justify the price of more exotic products. Building your own to an exclusive and well engineered design has a definite attraction.

GATE ONE utilises the latest audiophile techniques in its design. Great attention is given to the layout with separate signal and component earths. RIAA equalisation and tone controls (with in/out switch) are of a passive design. A low lift switch lets you tailor response to compensate for loudspeaker defficiency. A unique volume control circuit increases overload margin and optimises S/N ratio. All power transistors are TO3 type. The PSU is fully regulated, including the supply TO THO O/P transistors.

You can buy a GATE ONE in kit form for £139.61 inc. or a GATE MONITOR ONE stereo power amp with 3 line inputs for £114.85 inc. Both have a professionally finished case and include all components. Both are available fully assembled and tested. Order now or send for further comprehensive details.

GATEHOUSE AUDIO (WW)
PO Box 6, Evesham, Worcs. WR11 4NP

Money back guarantee if kit returned unused

ENTER 24 ON REPLY CARD

Editorial Feature List

APRIL 1987

Spectrum analysers. Advances in the application of microprocessors to these instruments have opened up a wider area of use. Those on the UK market are listed and new techniques examined.

MAY 1987

Logic analysers are clearly indispensable to those working on digital system design or maintenance. This feature presents the characteristics of those available and discusses applications.

JUNE 1987

Batteries. Recent developments in battery design mean that an investigation into the new types available is needed. We discuss design and applications and characterize the types on the market.

For further advertising details please ring Ashley Wallis on: 661 8641

68020 display processing

With its large address range and some special instructions, the 68020 can control text and graphics display as well as performing the main processing tasks.

DAVID BURNS AND DAVID JONES

Although the 68020 is a 32-bit general-purpose microprocessor, it can handle many more specific tasks, such as display processing. In bit-mapped displays for example, using this processor can remove the need for a dedicated controller.

Advantages of using the 68020 for display processing are threefold. The device has a linear address space large enough to allow a substantial display bit plane to be implemented in memory. Secondly, this display memory is addressed contiguously from least-significant to most-significant locations, i.e. the bit plane is stored in memory as it will be represented on a terminal. Thirdly, the processor has a group of instructions which is specially designed for addressing and manipulating individual bits or blocks of memory.

Take for example a simple text processing application. Typically, characters are stored in rom and each character is defined as a matrix of, say, eight-by-twelve dots, Fig. 1. Looking after a system like this is not too difficult. Each character is a single byte wide, assuming one bit per pixel, and so movement of these elements is easy provided that the base address of the character rom is known.

In this situation, the character set could be stored contiguously in rom so that each character falls on a 12-byte boundary. You can see from the following example of pseudo code that extraction of the character could simply involve moving bytes by automatically incrementing addresses.

```
FOR D0 EQ #0 TO #11 D0
    MOVE.B letter B(A0)+,D0*linesize(A1)
ENDF
```

In this example, the variable 'letterB' indicates the byte offset of the character within the character rom, which is 12 bytes in this case. Address register A0 holds the base address of the character rom.

By automatically incrementing register A0, it is possible to read the 12 bytes that make up the character 'B'. The destination address for this move is held in address register A1 and this will be altered on each line scan with respect to the line length of the display bit plane.

Length of the scan line in the final display bit plane is represented by the variable 'linesize'. Inclusion of this variable allows the final character to be correctly lined up in the final image, Fig. 1(a).

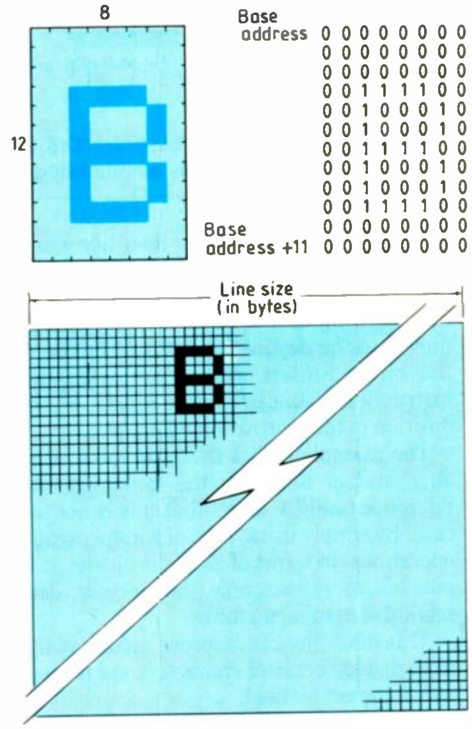


Fig.1. Display characters are normally stored in rom and defined as a matrix like this one (a) of eight-by-twelve dots. Characters can be located anywhere in the bit-plane memory map (b). Since the character is defined as a matrix, each horizontal character dot is exactly one line size away from the dot directly underneath it.

Fig.2. Within a microprocessor, data can be defined in various forms to suit the kind of manipulation required. The 68020 has a data form called a bit field which is especially useful for character and graphics-element manipulation. Bit fields allow any size of data block to be placed at any bit offset in memory.

Flexible as this system may appear, the limitations start to become obvious when you consider character fonts that do not conveniently take up a byte of storage as with, for example, a character in a ten-by-16-bit matrix. Further problems arise when you consider the possibility that the character, or graphics primitive, may have to be moved to a non-byte boundary within the destination bit plane.

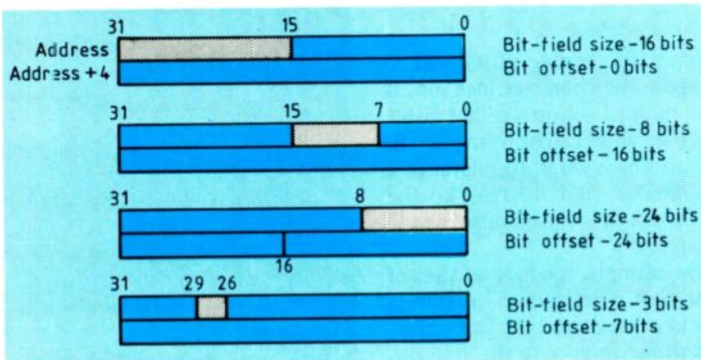
With the 68020 this problem can be circumvented using a new data form called bit fields, Fig.2. These fields can be any size from one to thirty-two bits and they can be located on any bit boundary, i.e. you are not restricted to accessing bytes, words or long-words.

To accompany this new data form, a new range of instructions is available for manipulating bit fields. Functions of these new instructions are change bit field, clear, extract, find first one, insert, set and test.

Figure three illustrates an immediately apparent use for these new instructions. In this example, character fonts are stored in sequential form whereby they are adjacent in terms of scan lines, that is scan line #0 for letter 'b' follows scan line #0 for letter 'a'. This method of storing character fonts makes it impossible to use the previous method of moving bytes. In this situation, bit fields have to be used.

Firstly, consider a situation where the character 'b' needs to be moved from character rom into the graphics bit plane. Address A holds the first scan line of the character but this scan line is situated at an offset of ten bits. Subsequent scan lines are located at addresses corresponding to the offset of the line length, Fig. 3(a). Bit-field instructions can be used to extract this information.

With the bit-field-extract instruction it is possible to extract a bit field ten bits wide with an offset of ten bits from the base



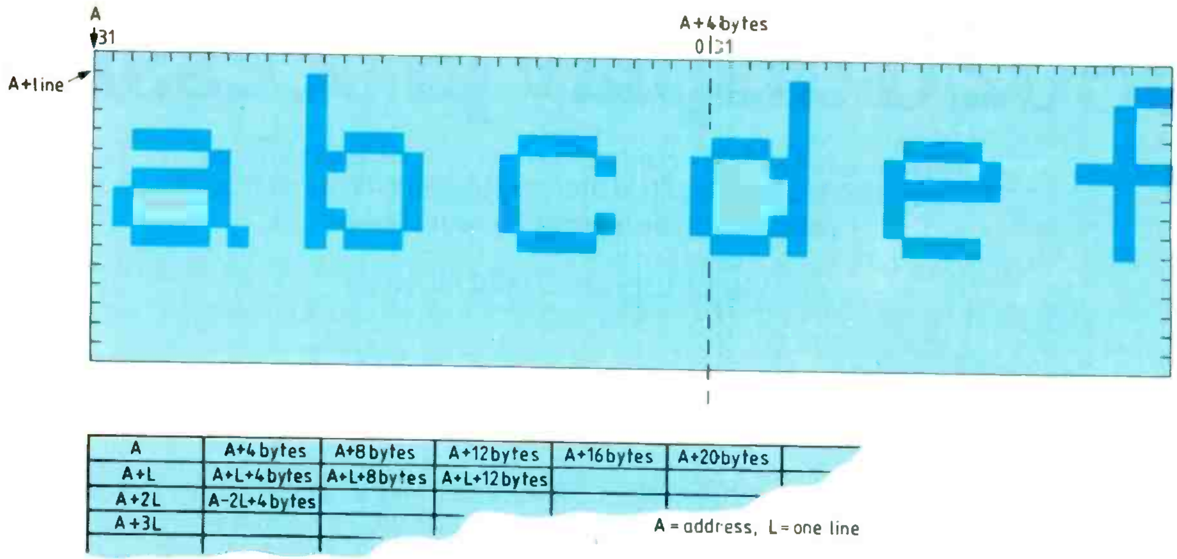


Fig.3. Characters are stored sequentially in memory and can easily be extracted using bit fields and dynamic bus sizing. Even characters on a 32-bit data-word boundary, like the letter d here, are easily manipulated because of 68020 dynamic bus sizing.

address held in register A0. For the next scan line, the base address can then be found by adding the line length of the character rom to the present base address.

The next scan line of character 'b' is found at the same bit-field location, i.e. at a bit offset of ten and a bit field width of ten. Again this bit field can be extracted using the bit-field extract instruction. By now sequencing down through all the scan lines of the character, 16 in this case, the whole character can be moved simply.

In this example, letter 'b' is contained completely within one memory location, that is none of the scan lines crosses a long-word boundary. Letter 'd' however does cross a boundary and could present problems. To deal with this, the 68020 dynamic bus sizing mechanism can be used.

Letter 'd' is located at a bit offset of 30 from the character base address and with a bit-field width of ten bits it is contained primarily in two adjacent memory locations. When presented with this type of situation, the 68020 uses its dynamic bus sizing mechanism in order to extract the relevant bit field. This is done automatically by the processor and the programmer need not worry about data-alignment problems.

Pseudo code for this data movement is as follows.

```
FOR D0 EQ #0 TO #15 D0
   BFEXTU D0*linesize(A0)
      {offset:width}.D1
   BFINS D1,D0*linesize(A1) {offset:width}
ENDF
```

For this example the variable 'offset' will be enough to specify the character location. If the offset is contained within a data register then the range of values can be from -2^{31} to $2^{31}-1$ which will be enough to reference a very large character rom; to refer to the character 'q' for example the bit offset would be 160.

In the above example, the base address of the character rom is contained in address register A0 and subsequent scan line accesses are made with reference to the 'linesize' variable and the associated scan-line number which will be contained in data register D0. Data extracted from the character rom is now held in data register D1 and can be moved to the destination bit field by use of the bit-field-insert instruction. With this instruction, data can thus be located at any position in the destination bit plane.

The example makes the assumption that all character fonts are the same size but reference to Fig.4 shows that this is not the case. By simply using a set of equate pseudo operations, in terms of width and offset, it is possible to extract only the relevant data section of a character font.

This flexibility can improve quality of the final display because characters are located in the correct bit field.

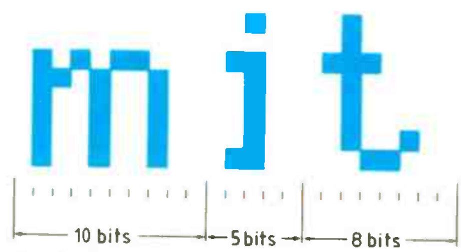
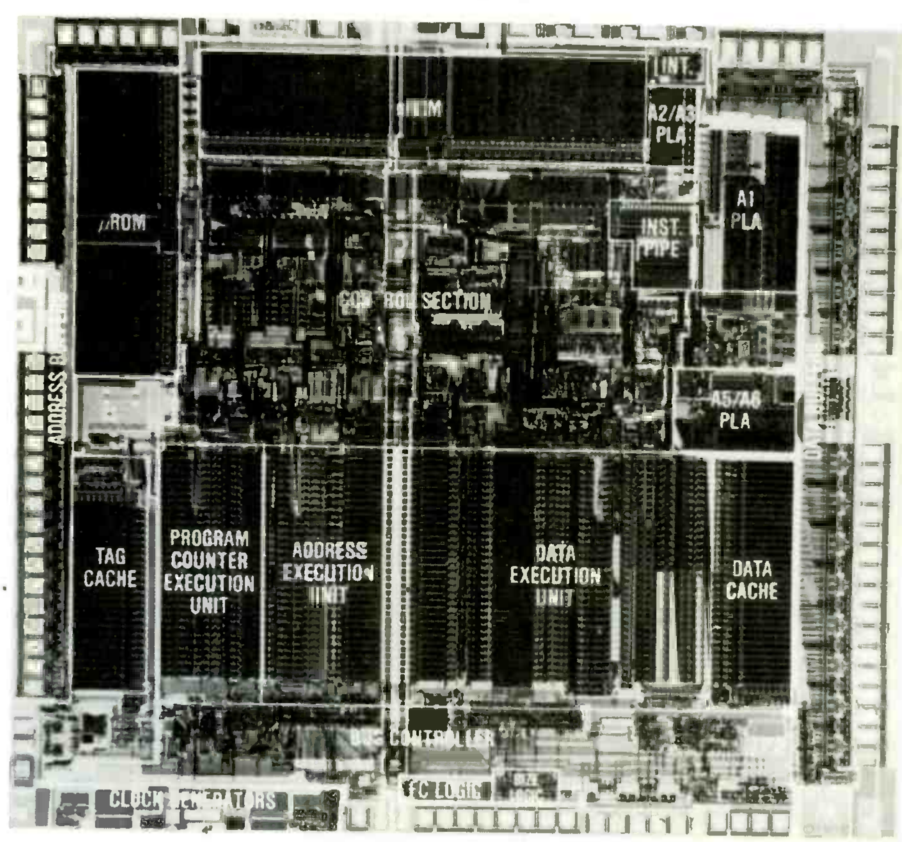


Fig.4. Proportionally-spaced characters like these make a professional display but they are difficult to control unless you have access to a facility like the 68020's bit-field manipulation feature.

David Burns and David Jones are applications engineers at Motorola's East Kilbride plant.



Dolby a.d.m. system for tv distribution

A consortium of independent Australian tv broadcasters together with Dolby Laboratories and Graham Patten Systems of the USA have been working jointly to develop a distribution system for vision and multichannel sound, for television programme interchange. The digital audio system has been ordered by the commercial Networks 7, 9 and 10 in Sydney and is expected to become the standard for the interchange of programmes on the Satellite Programme Service by all commercial television networks in Australia.

The system uses a video-audio multiplex process using adaptive delta modulation developed by Dolby Laboratories, known as Vamp/adm and described on page 286 of this issue. Based on a 6.6MHz subcarrier, it is designed for use in both satellite and terrestial links. The system employs differential quadrature phase shift keying (q.p.s.k.) at 750ksymbols/s to compress the subcarrier signal to about 1MHz bandwidth. For use in Australia, the 6.6MHz q.p.s.k. signal is combined with a PAL video signal for transmission.

At the heart of the four-channel system are two Dolby DP85 a.d.m. encoders (pictured on page 289) and a newly developed bit-stream multiplexer/demultiplexer. The new format operates at an aggregate bit rate of 1.500 Mbit/s and provides capacity for up to four broadcast-quality digital audio channels, although a two-channel mode at half the data rate is available as an option.

The system makes provision for scrambling of the transmitted data if required using a seed key set at the encoder site. At the decoder, the key may be either preset or received as part of the transmitted data. The system includes an additional 50kbit/s scrambled auxiliary data stream, a portion of which is used to convey video re-synchronization information. Future developments may enable each decoder to be addressed individually.

The Vamp/adm approach provides excellent audio performance at a significantly lower cost per station in the network than other available digital systems. Transmission packages for vision and four-channel sound cost about $25,000 for the encoder and $2,500 for the decoder (US dollars). Dolby Laboratories are at 346 Clapham Road, London SW9 and at 100 Potrero Avenue, San Francisco.

Winning graphics

A computer graphics design system from a young British company has won a British Design Award. The 6000 series from Sigmex combines high-speed, high-resolution graphics with ease of use, attractive styling and a carefully considered range of peripheral devices. It is the result of a design and development programme spanning more than three years.

Development of the 6000 series began with the need to create a graphic display system that could make the best use of the new international graphics standard, Graphical Kernel System (GKS).

The system utilizes advanced technology and incorporates a high-speed processor to ensure the fastest response to all operations. The clarity and the complex quality of the graphic display is enhanced by firmware which was developed by Sigmex in line with GKS objectives. The system's capability has now been extended beyond GKS to give extra performance features to enhance ease of use, give added speed, provide multiple viewports and special image modes: all without violating basic GKS principles.

The result of this development work is a range of equipment that satisfies more than 90 per cent of all two and three-dimensional applications using fast, clear graphics for purposes as diverse as slide presentations and air traffic control. The availability of a variety of peripheral devices: including joystick, trackerball, dials and mouse, ensures that the 6000 series is easy to handle and simple to control. The system is flexible and can be upgraded easily.

Ken Sadler Associates were the consultant industrial designers and transformed the original functional metal boxes in to the present external design.

Floating point Transputer

A new version of the Inmos transputer has been developed which is claimed to be the world's fastest 32-bit processor. The TMS T800-20, available soon, can sustain over 1.5M floating point operations per second (miflops) while the T800-30, available towards over 2.25 miflops.

The new devices have been developed as part of the European Esprit programme to construct a supercomputer from a reconfigurable collection of transputers. This is part of an investigation of parallel processing architecture in computers. The first transputer, TNS T414, has found applications in system simulation, robot control image synthesis and digital signal processing. All of these applications have used concurrency: running several transputers in parallel. One application has been found in computerizing the finger-printing identification system of the British police. It has increased the speed of processing by 25 times and cut the cost of one tenth.

Pin-compatible with the earlier devices, the T800 retains their capabilities, while incorporating an on-chip floating-point unit, more on-chip memory and new instructions to support graphics. It also doubles the data rate on the communications link. However, it is thought that it is particularly suited to high-speed, high-definition colour graphics, and is claimed to be "a complete high-performance scientific computer on a single chip."

Link with industry

The Government has announced another scheme to link university, government and technological research projects with industry. The 'Link' initiative has earmarked £210M to support up to half the cost of collaborative programmes between the scientific community and industry. Overall, the initiative will generate expenditure by government and industry of at least £420 million over the next five years. Provided industry matches the Government funding, Link will consist of a range of programmes, each in a strategic area of science and technology. They will cover the entire spectrum of science based technology from molecular electronics to transport systems, materials technology to food process engineering. Link will have a steering committee of industrialists, Government officials, representatives of the academic community and the research councils, chaired by an eminent industrialist. All government departments that have a significant research and development programme are involved in Link.

The scientific input to Link projects will mainly come from the Research Councils and from higher education in which a considerable proportion of Link expenditure will be invested.

Recent reports suggest that underfunding of universities and underpayment of lecturers and research staff is promoting another 'brain drain' to North America.

Telephone network code

A provisional Network code of practice (NCOP) for the design of private telecommunication branch networks suitable for connection to public Switched Telephone Networks (PSTNs) is being published by Oftel, following consultations with the public telecommunication operators and representatives from TEMA, TMA, BEITA and members of the appropriate BSI standards committees.

The Code of Practice will allow private branch networks to take maximum advantage of the proposed relaxation of routing restrictions under the revised Branch Systems General Licence (BSSL) whilst continuing to protect the integrity of the PSTNs, and ensure that the public operators can continue to meet the UK's international obligations through the CCITT.

The NCOP specifies the design criteria which should be met if a network is to provide satisfactory telephone service. It includes design parameters for safety, call addressing, call control, call progress indications, call path transmission quality, traffic handling capacity and network management. In particular it specifies requirements for private network telephone calls which are also routed over the PSTNs. These requirements are to be made mandatory by the director general of telecommunications in the revised BSSL and other licences issued under Section 7 of the Telecommunications Act 1984, when the Code of Practice is issued in final form.

These mandatory requirements for public network traffic and the related recommendations for non-public network traffic refer to call impairments which include loss, delay, quantizing distortion and cross talk. The NCOP also includes direct dialling inwards (DDI) calls, because networks can be designed to route these over many hops. The NCOP recognises that good network design depends largely on the suitability of all the links, switches and terminal apparatus to work together. The parameters included are designed on the basis that the collective result of the degradations of performance of each element in a call path will not result in unsatisfactory overall call quality.

Taking advantage of the flexibility offered by the proposed relaxation of routing restrictions may entail changes to private networks and it is likely that only the most up-to-date, fully digitalk multi-hop networks will be able to meet the code of practice requirements in full. To be fully usuable, the NCOP requires information on all port-to-port impairments of PBXs and other call routing apparatus. The necessary ports requirements are not yet available as part of BS 6450, and CRA are therefore not able currently to gain approval for switching PSTN traffic over tandem circuits within a private network.

In conjunction with the NCOP, Oftel is therefore producing a set of interim ports requirements for CRA, the first of which should be available early in 1987. BT is making similar provisions in BTR 1050. A final Code of Practice will be issued when work on these ports' requirements is complete.

Video game for the forces

Those expensive aerial war games that cost millions, tie up thousands of men and hundreds of aircraft, could well soon be a thing of the past with the introduction of a new computerized training system from Marconi Radar. Called the Force Management Trainer, the new system could be described as the ultimate video game: it enables the top brass to develop and maintain their tactical command skills inexpensively and without the 'other side' watching.

The system can simulate the functions and interactions of the lower echelons in the face of an attack – the bit that costs the money. Senior commanders will be able to hold any number of war games and play them through to their likely conclusions.

The Force Management Trainer is based on a commercially available computer and can be used by people with little or no knowledge of programming.

To set up an exercise, the controller first provides the system with information on the 'battlefield' and sets the environmental conditions such as day or night, weather, etc. He/she then allocates to the defender resources such as radars, aircraft and weapons. Finally he determines the size and nature of the threatening forces.

When the exercises is running, the commanders are able to 'deploy' and commit their resources as the threat develops; the system decides on the effectiveness of their response based on the numbers and comparative performance of the various weapons and weapons platforms used by both 'sides'. The commander's ability to make those decisions is assessed at each stage.

Institutions united

The Institution of Electrical Engineers and The Institution of Electrical and Electronic Engineers are to merge. A 97% vote by members of both institutions set the seal on the combined institution to meet the future needs of the profession.

Work will start today to implement the proposals which will take full effect on 1 October 1988. The new body will retain the long established title "The Institution of Electrical Engineers" and will be the largest of the UK chartered engineering institutions having more than 100,000 members, nearly 25% of them being resident overseas.

The new Institution will cover the art, science and practice of electrical, electronic and software engineering activities in such fields as power, control, instrumentation, broadcasting, radio, telecommunications, computers and information systems.

The Institution, whose members range from students to chief executives, will act as the voice of the electrical and electronics engineering profession in all matters of public concern. It will also speak with greater authority to government and other influential bodies, both in the UK and overseas. The merger of the two institutions will also lead to an enhanced and broadened range of learned society activities and the adoption of common standards for professional qualifications. The need for technical standards and professional updating in fields of fast-moving technology will be more readily met and the vital work of encouraging young people to enter the profession will also be strengthened. Other benefits of scale and rationalization are anticipated.

The decision to merge comes after nearly three years of extensive negotiations and discussions during which time care was taken to seek the views of the membership before finalizing the terms of the agreement. This approach has been amply justified by the result of the votes.

The move will be seen as a strengthening of the profession at a time when the need for high technology engineers has never been greater.

C.r.t. drivers for high-resolution tubes

Principles, requirements and design using the Motorola MRF542 and MRF543

PETER BISSMIRE

This article discusses the design of transistor high-speed, high-voltage amplifiers for driving high-resolution colour cathode-ray tubes. It will become evident that once the problems of driving a colour tube have been solved, the drive of a monochrome tube is simple.

GENERAL REQUIREMENTS

A c.r.t. driver is required to work with input signals which lie within the supply voltage range of typical signal-processing circuitry – usually 5V to 10V. The output voltage must be of the order of 100V. The brightness of each picture element has to be continuously controlled, which requires a stable, defined d.c. response, and to set adjacent elements to different brightnesses, high speed is needed.

The design of picture tubes is a compromise between conflicting elements, which among other effects means that there is little variation in input characteristics in spite of the wide range of tube types available for consideration.

For each primary colour channel, the c.r.t. driver effectively 'sees' a vacuum triode with a grid/cathode capacitance of 15 pF. It has become normal practice to make these tubes with a common connection to the three grids and also to the first three anodes. It is therefore necessary to use cathode drive and to include in the drive voltage a correction for the differences in cathode voltage at cut-off between the three guns, amounting to about 40V.

Drive voltage can be estimated. For a given accelerating voltage and gun exit dimensions, the density of electrons in the spot is limited. As phosphor triad spacing diminishes, the spot size must keep step to realise the available screen resolution. The maximum current therefore varies as the square of the triad spacing. The transfer characteristic of the tube is usually quoted as

$$I = V^{gamma}$$

where V is the voltage difference between cutoff and beam current I. We have

$$I = k \times d^2$$

where d is the triad spacing, from which

$$V = c \times d^{(2/\Gamma)}.$$

Putting $\Gamma = 2.8$

gives $V = c \times d^{0.7}$

This voltage swing must be increased by 10% or so to allow for brightness control, which must pass through the signal drivers to maintain colour balance, and the 40V differential referred to above must be added to find the total output swing required. Starting from the standard tv tube, which is known to be difficult to focus beyond 80V drive, the following table emerges for a selection of pitches (triad spacings).

pitch (mm)	voltage swing (V)
0.82	128
0.62	112
0.43	96
0.31	85
0.21	74

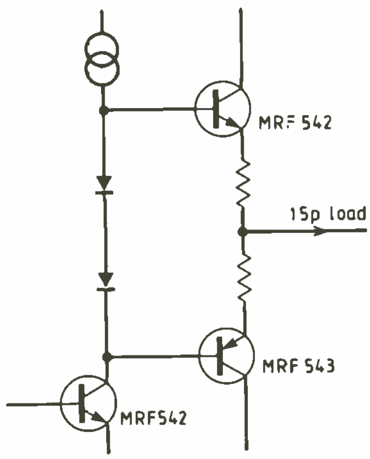


Fig.1. Basic output circuit, using MRF542/543 as a pair of emitter followers. Their input capacitance is considerably less than the 15pF of the tube.

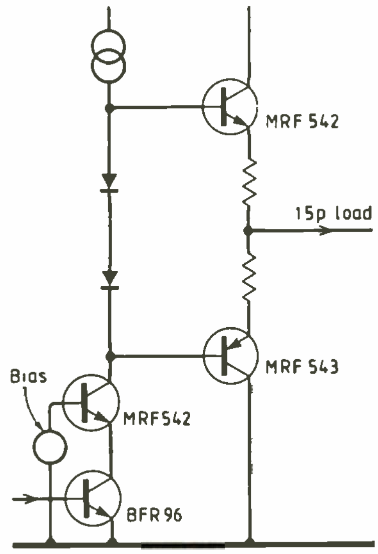


Fig.2. Addition of cascode input completes basic amplifier.

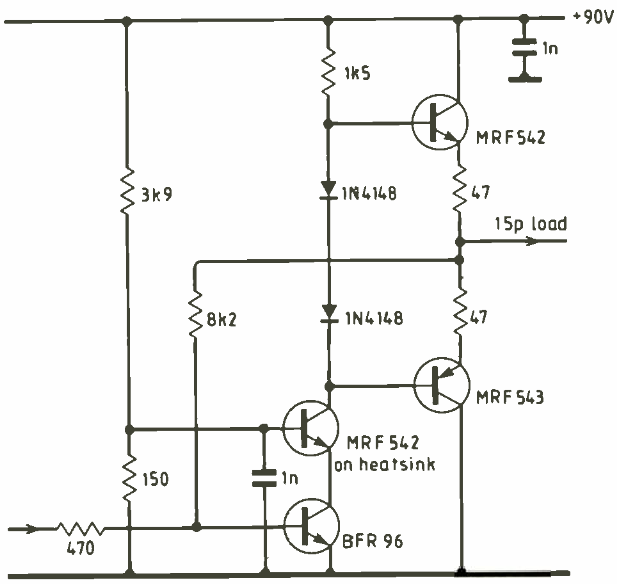


Fig.3. Complete low-cost version of amplifier, using a resistive collector load.

DEVICES

It is most helpful to concentrate on the most challenging end of the scale – tubes with pitches of 0.31mm or less. The Motorola transistors MRF542 and MRF543 (n-p-n and p-n-p respectively) are high-voltage r.f. devices in a power macro-X package. They are capable of operating with a supply voltage of 90V and allow a peak-to-peak dynamic range of 85V to be realised, thanks to their high-frequency saturation performance.

The key parameters of these devices are summarized below.

parameter	n-p-n	p-n-p	units
collector/base breakdown, V_{CBO}	>120	>100	V
collector/base capacitance, C_{CB}	1.5	2	pF
transition frequency, f_T	>1.1	>1.1	GHz
current gain, h_{FE}	>15	>15	

PERFORMANCE SPECIFICATION

The points of interest in a c.r.t. driver are its response at high frequencies and its ability to retain this response at high amplitudes. It is common practice to quote rise time, but the amplitude at which it applies is often vaguely specified or, in some cases, not at all. By quoting slew rate, one can incorporate these two linked elements into a single parameter. Furthermore, slew-rate limitation is of direct practical importance. It is rarely symmetrical so that, when it occurs, not only is the amplitude response curtailed, but the alternating part of the signal is partially rectified. In visible terms, an area of picture containing high frequencies shows errors not only in the amplitude of the high-frequency component (contrast and accutance) but also in mean brightness. This effect is only absent if the amplifier is able to respond sinusoidally or symmetrically to the required frequency, a limitation which may be up to three times more severe than that seemingly implied by risetime. In addition to small-signal bandwidth to show how well the amplifier responds at small output amplitudes, it is also necessary to consider slew rate, to indicate the response at high output amplitudes.

AMPLIFIER DESIGN

A transistor amplifier with voltage gain and a high output voltage must clearly be collector loaded. Bandwidth and slew-rate performance will be limited by capacitance at this collector.

If the input capacitance of a push-pull pair of emitter followers is less than the 15pF of the tube, it is interesting to add them between the amplifier transistor and the tube cathode. With the MRF542, 543, the difference is considerable, leading to a basic configuration shown in Fig.1.

At the input side, if the amplifier transistor is driven in grounded-emitter, the current in the collector/base capacitance of the device, which we already have to cope with at a high-voltage point, flows also at the input (Miller feedback). Grounding the base avoids this problem. Since a flat frequency response is needed, a further transistor in grounded-emitter is introduced, the BFR96 being used. This arrangement gives the cascode configuration shown in Fig.2.

The essential factor in arriving at a practical circuit is the choice of a replacement for the theoretical current source shown in Figs. 1 and 2.

Low-cost design. The simplest choice is a resistor. Compromising between operating current and the additional capacitance of a heat sink leads to the circuit shown in Fig. 3.

The maximum dissipation in the amplifier transistor is 1.35W. For an ambient temperature of 60°C a heat sink of 42.5°C/W is required. This can be furnished by a simple copper tab of about 5cm^2 which can be oriented to contribute a capacitance of about 4pF. Further increase in dissipation is not very interesting, as the capacitance of the additional heatsink required totally absorbs the additional available current.

To examine the performance of the circuit, 2pF is allowed for the capacitance of any interconnection, leading to a total capacitance of

$$1.5 + 2 + 2 + 4 + 2 = 11.5\text{pF}$$

driven upwards by 1.5kΩ and downwards by the transistor. The capacitance therefore takes a current of +0·67mA per volt across the resistor for upward slewing and 100mA minus the current in the resistor in the downward direction. This leads to a slewing rate which depends on the output voltage level, as shown in Fig.4.

The small-signal bandwidth is almost impossible to estimate, since most of the major determining factors are in the physical layout.

A prototype amplifier has been made in several versions and the results agree very closely with the graph in Fig.4. Small-signal bandwidth (10V p-p output at low frequency) reached 75MHz at –3dB.

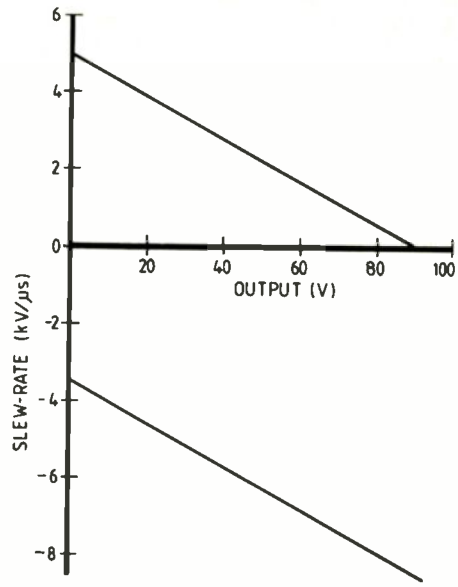


Fig.4. Slewing performance of low-cost circuit.

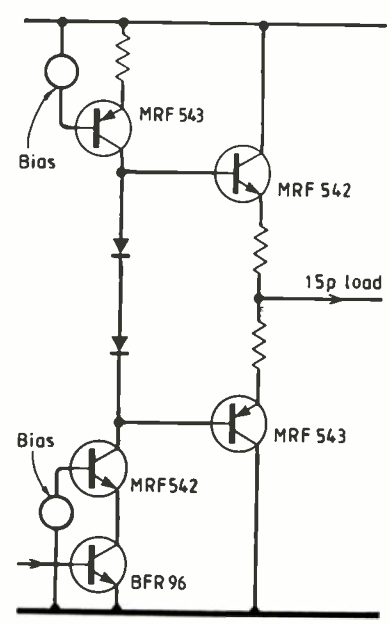
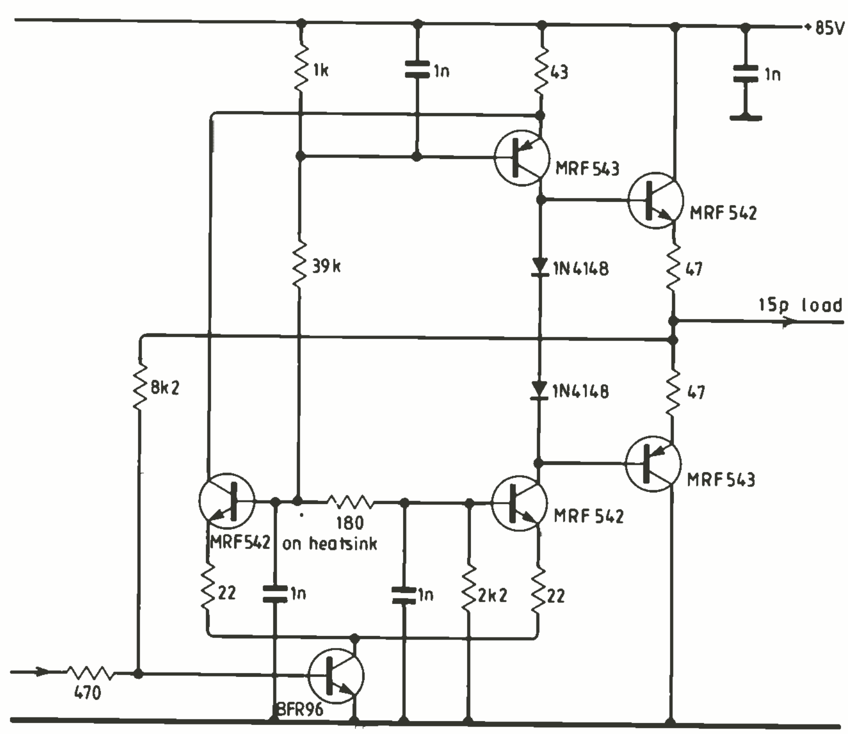


Fig.5. Constant-current source as collector load reduces differential slewing.

Fig.6. Complete high-performance circuit, with current-source modulation.



High-performance design. It has been remarked that, for the type of amplifier discussed above, the slewing rate is variable, as can be seen in Fig.4. This can be a disadvantage in a colour monitor where, due to tube spreads, there can be an appreciable difference in the d.c. levels of the three cathodes. The consequent differential slewing would lead to colouration of fast edges. This can be improved by using a transistor to make the current source of the basic configuration constant, as shown in Fig.5.

Unfortunately, there is a complication with this solution. If one tries to match the mid-range performance of the Fig.3 amplifier by setting a current of 30mA, the transistors must support this current at nearly the full supply voltage. The consequent dissipation of 2.7W requires a heat sink whose capacitance is intolerably high on both the amplifier and current source collectors. A solution is to modulate the current source so that these two collectors are operated in class AB and shift the dissipation to a collector where the signal voltage level is low. The penalty that yet another high-voltage r.f. transistor is needed: the benefit is that no heat sink at all is necessary on the high-voltage node. The resulting practical circuit is shown in Fig.6.

This arrangement sets a quiescent current of about 5mA in the amplifier stage, while the peak current available is 35mA for upward slewing and higher for the downward direction. The total capacitance at the amplifier collector is about 9pF, giving an upward slewing rate of 3.9kV/μs. The greater complexity of this current limits the small-signal bandwidth to around 60MHz. Figure 7 shows the slewing performance of this circuit compared with that of the low-cost solution. The gain in slew-rate/voltage area is considerable. As in the low-cost case, the performance of this design has been confirmed by the construction of prototypes.

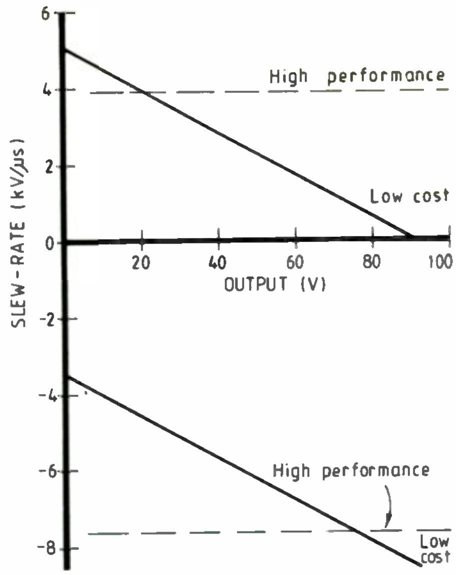


Fig.7. Slewing performance of the two circuits.

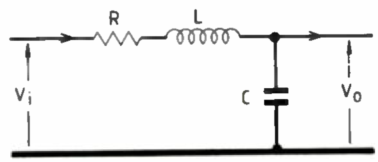


Fig.8. Series resonant compensation.

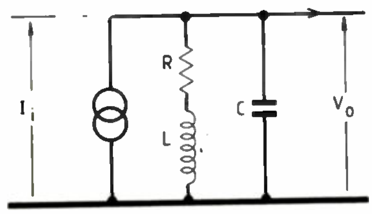


Fig.9. Series/parallel compensation.

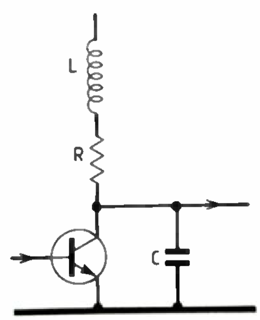


Fig.10. Typical application of series/parallel compensation.

GAIN

In both of the designs presented, the amplifier gain is determined by a feedback resistor. This configuration is that of a transresistance amplifier (current in, voltage out), the 470Ω resistor serving merely to ease testing with a signal generator as source. The approach offers particularly good temperature stability when current-driven, as the output temperature is −2mV/°C due to the V_{BE} of the input transistor. A further advantage of taking feedback from the amplifier output is that it gives excellent power-supply rejection. In the case of the high-performance design, this is the only possibility as, open-loop, the circuit has an extremely high low-frequency gain and the output d.c. level is indeterminate.

In the case of the low-cost design, the feedback resistor could be replaced by a resistor in the emitter of the input device. For thermal stability this would require drive from a source having a V_{BE} temperature coefficient to compensate that at the input. This would not, however, deal with transient drift due to local temperature differences, for example warm-up drift. The output dynamic range would be slightly reduced by the voltage drop across this resistor and additional measures would be needed to maintain the high-frequency response.

COMPENSATION

A number of techniques can be used to improve or control the high-frequency behaviour of wide-band amplifiers.

Resonant compensation is often applied with success and consists of the addition of inductors which combine with the unwanted capacitance to form a resonant circuit. The object is to produce a low-pass filter structure which can be adjusted to give a more or less flat response below cutoff. Normally, this compensation is second-order and the two most useful configurations are series and series-parallel.

Series compensation. The circuit is as shown in Fig.8. The response of this circuit is given by

$$\mathcal{L}(V_o/V_i) = \frac{R+sL}{1+sRC+s^2LC}$$

from which natural frequency is

$$\omega_n = 1\sqrt{LC}$$

and damping factor

$$\zeta = 1/2R\sqrt{C/L}$$

Thus

$$L = \frac{1}{\omega_n^2 C}$$

where ω_n is the chosen natural frequency and

$$R = \frac{2\zeta}{\omega_n C}$$

Frequency response for

$$\zeta = 1/\sqrt{2}$$

is maximally flat, giving

$$R = \sqrt{2}/(\omega_n C)$$

The most interesting position for this type of compensation is between the amplifier output and the tube cathode. C would be the cathode itself and L and R would be additional components. The presence of a resistor at this point is usually considered obligatory. Putting $\omega_n = 377 \times 10^6$ (60MHz) gives L = 0.47μH and R = 250Ω.

A word of caution here. When driving an uncompensated capacitor, the amplifier delivers zero current on voltage peaks. This means that if the amplifier is overdriven the transistors tend to saturate with low collector current even at high frequencies. The impedance of a compensated load is resistive at resonance, so current and voltage are in phase. The consequence is that compensation improves the overall frequency response up to resonance, but degrades the high-frequency saturation behaviour of the amplifier.

Series/parallel compensation. The basic circuit is seen in Fig.9.

The response is given by

$$\mathcal{L}(V_o/V_i) = \frac{R+sL}{1+sRC+s^2LC}$$

As before,

$$L = \frac{\ }{\omega_n^2 C}$$

and

$$R = \frac{2\zeta}{\omega_n C}$$

As R and C frequently exist already, it is interesting to rewrite

$$\omega_n = \frac{2\zeta}{RC}$$

Figure 10 shows an example of this type of compensation, from which one can see that it could be used in the low-cost design. Putting R = 1.5kΩ and C = 11.5pF gives ω_n = 82(13MHz). Such a low value for the resonant frequency throws considerable doubt on the usefulness of this type of compensation in these amplifiers.

The author is senior Staff Engineer at Motorola Semiconductors European headquarters, Geneva.

TELECOMMS TOPICS

British Telecom's local network goes opto

BT has started on a major programme to introduce optical fibre into its network in the City of London. This optical-fibre network, currently being installed at a cost of £50million, extends from King's Cross in the north to the Elephant and Castle in the south as well as from Covent Garden and Wapping in the west and east respectively.

It will use single-mode fibre, initially operating at either 8 or 34Mbit/s transmission rate. About 100 Dealerinterlink customers will shortly be the first to use this network. Dealerinterlink was set up about a year ago as part of BT's support for the all-electronic trading "Big Bang" on the London Stock Exchange. Customers rent groups of circuits which are all connected to a central point. This enables a private speech circuit to be set up with any other Dealerinterlink user within 24 hours. Other services will then be progressively provided through optical-fibre connections including telex, packet switched data lines, private circuits, Kilostream and Megastream (64kbit/s and 2Mbit/s circuits). These optical-fibre links can also be used by customers to connect to the Public Switched Telephone Network (PSTN).

IDD to China

International direct dialling (IDD) is now available to China via the Indian Ocean satellite, a new ground station at the capital Beijing (Peking), and BT's Goonhilly earth station. It will initially serve three of China's major cities: Beijing, Shanghai, and Guangzhou. According to British Telecom International, these cities account for 85% of the calls from the UK to China. For the time being, calls to other areas must still be made via the operator.

During the initial period in which China is still modernizing its exchanges, the service will be on a trial basis. It is intended to

extend this facility to other cities and areas as soon as possible.

With a population of over 1,000 million, China only has one telephone per 100 of the population as compared with the UK's 50 per 100. The number of phones in China is expected to double by the end of the decade and rise to more than 30 million by the year 2000.

British army goes digital

The first phase in what will be the largest and most advanced private digital telecommunications network has been completed. It is the start of re-equipping the British Army's entire fixed telecommunications network in the UK with a system that has been designed to evolve into an ISDN has been completed. British Telecom has provided, at a cost of £13million, Fastnet 1, which is the higher order network of primary, minor, transit and satellite switches together with provision for a network manufacture structure.

This first phase covers the Army's 50 largest sites. The exchanges and their digital interconnections will form a single integrated system, handling voice, data, fax and teleprinter traffic.

A total of 72 Merlin DX digital p.a.b.xs (Plessey ISDXs) have been installed under the contract. They are linked by 119 wideband digital leased circuits with signalling being carried out by d.p.n.s.s. (digital private network signalling system). This will allow specialized user features (such as call transfer and ring-when-free) which will work across the entire network.

Fastnet 2 and 3, the subsequent phases, will respectively provide the terminal exchanges and the data overlay to the speech network. These phases will add a further 200 smaller switches and provide a data and office automation overlay together with the network management facilities. They have not yet reached the tendering stage but, when they are implemented, will provide an ISDN facility roughly 20 years in advance of the public network.

Channel Islands back-up

The directors of telecommunications of channel islands, Jersey and Guernsey, are having discussions with representatives of British Telecom and the French PTT with the objective of setting up an alternative path between the Islands and the UK mainland. This will be of major importance when the planned digital optical-fibre cable between Guernsey and Dartmouth in South West England comes into service in 1989. It is believed that this 150km cable will be the longest unrepeatered submarine cable to be installed.

It is expected that the back-up will take the form of a microwave link between Jersey and France, a distance of less than 30km, and then via the recently installed digital microwave link across the English Channel. This will provide higher capacity and lower cost per channel than could be obtained by means of satellites. Both Jersey and Guernsey have opted for System X and are planning for major telecommunications growth.

British Telecom buys LaserCard licence

British Telecom has bought a licence to sell credit-card sized "memory-bank" cards, known as LaserCards, from the Drexler Technology Corporation of California. Up to 2Mbytes of data can be imprinted by photographic techniques on the cards at the time of manufacture or subsequently by low-cost lasers. They are claimed to be intrinsically secure and difficult to corrupt, either accidentally or deliberately.

Mr Ron Back, managing director of BT Business Services, said: "The agreement with Drexler Technology opens the way for a range of service and equipment products which will extend the already comprehensive offerings that British Telecom is able to make to its customers, especially in the health, financial and network security areas."

British Telecom is negotiating with a major London hospital which is considering the use of LaserCards for holding maternity records. It anticipates that the combination of the secure personal data record with the facilities of communications networks will lead to even more effective solutions to many of the requirements of information technology users. It will also supply the equipment for recording and reading data on the cards. Currently, the cards and the recording equipment are made in the USA and Japan but, should customer demand warrant, there is a possibility of local manufacture.

Siemens h.p.as for ESA

Siemens design and development group at Congleton, Cheshire is to supply high-power amplifiers (h.p.as) for use by the European Space Agency. It has been awarded a contract worth some £750,000 for the supply of 30GHz, 350W amplifiers for installation in three advanced transportable earth stations that will be used for teleconferencing and business communications experiments via ESA's Olympus satellite. The prime contractor for the £3million ($4.5m) project is Marconi Defence Systems.

The h.p.as. which can be used in either dual-carrier uplink or single-carrier redundant modes, use Siemens own travelling wave tubes (t.w.ts).

Satellite communications is one of the key areas of the Congleton group. It has also supplied state-of-the-art microwave equipment for BT's Goonhilly Down ground station. Similar systems have also been designed and supplied to the West German and the Dutch PTTs and for installation in Saudi Arabia.

BTI circuit control contract to STC/ICL

STC and ICL have won an £8million contract from BT International to develop, supply and install four automatic digital distribution frames. These are computer-controlled systems to connect and test international telecommunications circuits. They will allow faulty circuits to be isolated without any service interruption.

Each system wil consist of solid-state crosspoints operating from 140 down to 2Mbit/s. The systems will be managed by ICL Series 39/30 mainframes and DRS 300 distributed microcomputers, using ICL network management software. The first system will be ready for operation early next year.

UK s.l.c. production for APT

AT & T and Philips Telecommunications (APT) is to set up a manufacturing facility for subscriber loop transmission equipment at Malmesbury, Wilts. It is investing £17.5 million on the venture. This includes purchase of the site (previously used by Philips Telecommunications TMC Ltd which is moving to Bishopbriggs near Glasgow) and the expenditure on new buildings and plant.

It will be manufacturing a 30 channel version of the 24-channel subscriber loop carrier (s.l.c.) equipment developed by AT & T in the USA. To be known as SLC120, it will be marketed in the UK, the rest of Europe and elsewhere in the world that 2Mbit/s trunks are used.

In addition, the factory will act as an overflow for production of APT transmission equipment developed in The Netherlands.

British Telecom quality of service

National Utility Services (NUS) and the Office of Telecommunications (Oftel) have both reported on the quality of British Telecom's services.

A survey by NUS of 200 top UK companies revealed that 37% think that BT's services have improved, 24% say no-change and 39% are of the opinion that they have deteriorated since privatization. The Oftel report indicated that the results of the recent surveys were broadly similar to those carried out from 1969 onwards. It also noted that 12% of consumers thought that the telephone service has improved since BT was privatized, 10% thought it had deteriorated and 72% thought it had remained the same. This latter concentrated on the residential telephone service and call boxes and made use of surveys carried out by 1600 members of Oftel's Telecommunications Advisory Committees.

According to NUS, its survey also revealed that over 90% believe that the level of service must improve as competition increases. However, only 13% of respondents were considering replacing BT with Mercury as their network supplier and of these all said they would only use Mercury partially rather than for all network services.

The Director General of Oftel in his report, which mainly covered residential services, stressed that he regarded BT's obligation to provide a universal service as meaning that the service must be of acceptable quality and that any deterioration in services would be the same as a price increase.

BT's managing director of Inland Communications responded to the Oftel report and said that it was encouraging to note that it rejects any suggestion that there has been general deterioration in the quality of service. He pointed out that, over the last few years, there had been a marked increase in customers' expectations. Nevertheless, despite this, and the rapid expansion in the size of the network and the services on it, BT was "keeping pace".

He pointed out that BT is well into a £160million programme to modernize all its payphones – both public and privately rented. By August, all public boxes will have been fitted out with modern equipment. He went on: "We are wholly committed to improving the quality of service we provide to all our customers. We are continuing to make substantial investments in modernizing our network. Soon, the local network will begin to show improvements as more local digital exchanges come into service.

"Mega" project developments by Philips and Siemens

Two years into the Mega project, the Siemens new semiconductor plant at Regensburg, West Germany has produced its first 1Mbit dynamic random-access memories (drams). These chips will use 1.2 micrometre geometry, while the 4Mbit memory chips will use 0.8.

In addition, the company will shortly be opening a new mask centre and a further processing line in Munich for very high-speed, bipolar, logic circuits. They will deal primarily with e.c.l. (emitter coupled logic) gate arrays for c.p.us and for super-fast communications circuits. A third 'logic' project is a design centre, scheduled later this year, for application-specific integrated circuits (asics) and custom c-mos circuits for communications, data technology etc.

Also as part of the Mega project, Philips has opened a new integrated circuit R & D centre at its Eindhoven headquarters.

The Mega project was launched in 1984 by Philips and Siemens as a joint research effort aimed at a quantum leap in semiconductor technology – one of the key areas in electronics. It has a projected cost of some $700million (nearly £500million) with the companies investing one-third each and their governments (Netherlands and West Germany respectively) contributing the rest.

British Telecom majors in viewdata

British Telcom has announced two viewdata-based information services aimed at vertical markets; BT Travel Service (BTTS) and Optionline from BT Insurance Services.

The former is a comprehensive information service for the UK-based travel industry, based on BT's Prestel Travel Service which is already taken by 90% of the UK travel agents. This new service will allow a wide choice of screen-based methods of on-line communications so that standard videotex terminals may be used or, through automatic switching controlled by BTTS, on dual-purpose terminals.

Optionline, also based on Prestel, provides a customized videotex service for the insurance and financial services sector. To date the Halifax building society, with over 700 branches, and a further 5 major building societies have signed to put a total of nearly 3,000 of their branches online to the service. It provides building societies, banks and larger brokerages with the facilities of an in-house network and displays comparative information to assist clients when taking decisions on mortgages.

The Halifax has been providing quotations on the Prestel network for over a year and has seen a 24% increase in total customer take-up of insurance-linked mortgage loans.

Telecomms Topics was written by Adrian Morant.

Low-resistance measurement

Attention to the nulling of lead resistances enables measurement down to 100 micro-ohms.

D.J. HAIGH

Low-ohms meters have many uses in varied fields such as reliability testing of switches and relays, measurement of the diameter of fine wire, and testing electrical installations. This article describes an instrument suitable for these and many other applications where an accurate reading of low resistance is required.

Measurement of low resistance requires a special technique to null test lead and contact resistances. This technique entails the use of two pairs of test leads, called force and sense leads. One pair is used to apply a stimulus to the resistor under test in the form of a current, and the other pair to sense the voltage across the resistor (see Fig. 1). If the current in the sense leads is kept small, so that the voltage dropped across the contact and lead resistances is small compared with that across the resistor under test, then a measurement of V will give an accurate value for R_x by ohms law

$$R_X = \frac{V.}{I_F}$$

Conventional low-ohms meters use this technique, but usually suffer from one or two drawbacks. One is the joining of force and sense leads before they make contact with the resistance under test (see Fig. 2), which will eliminate the resistance of the leads, but not that of the test probes, or their contacts with the resistor under test. The use of four completely independent test leads easily solves this problem. A second drawback of conventional meters is that measurement is often performed with a direct current, and amplification of the sensed voltage is at d.c.. Amplifier offset voltage then puts a limitation on the measurement, and a zero control must be provided and frequently adjusted.

The meter described in this article does not suffer from either of these limitations. Four test leads are provided, and the measurement is made at a.c.. A block diagram of the meter is shown in Fig. 3.

R_X is supplied by a current from the a.c. current generator and the voltage across R_X is sensed by the differential amplifier. A differential amplifier was used to ensure attenuation of any common-mode signal due to lead and contact resistances of the force leads. The resulting single-ended signal is amplified by a factor of 10, and any out-of-band noise eliminated by a band-pass filter. The signal is then amplified further by a switched-gain amplifier, which sets the full scale reading of the meter. A synchronous detector is then used to mix the signal to d.c. so that a moving-coil meter can be driven. Each component of the block diagram is described in more detail below.

A.C. CURRENT GENERATOR

The a.c. current generator applies a square-wave variation in current to the resistor under test of between 0 and 100 mA. A circuit diagram is shown in Fig. 4.

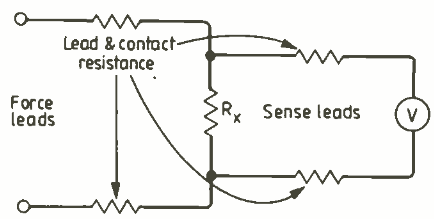


Fig.1. Conventional arrangement of test leads for low-R measurement.

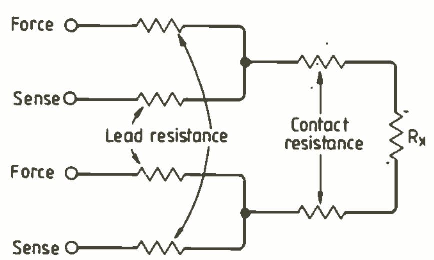


Fig.2. Arrangement of Fig.1 does not eliminate resistance of contacts to unknown R.

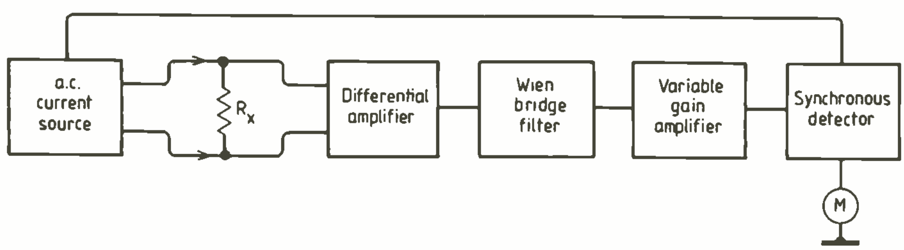


Fig.3. Block diagram of the low-ohms meter, in which four separate leads are used.

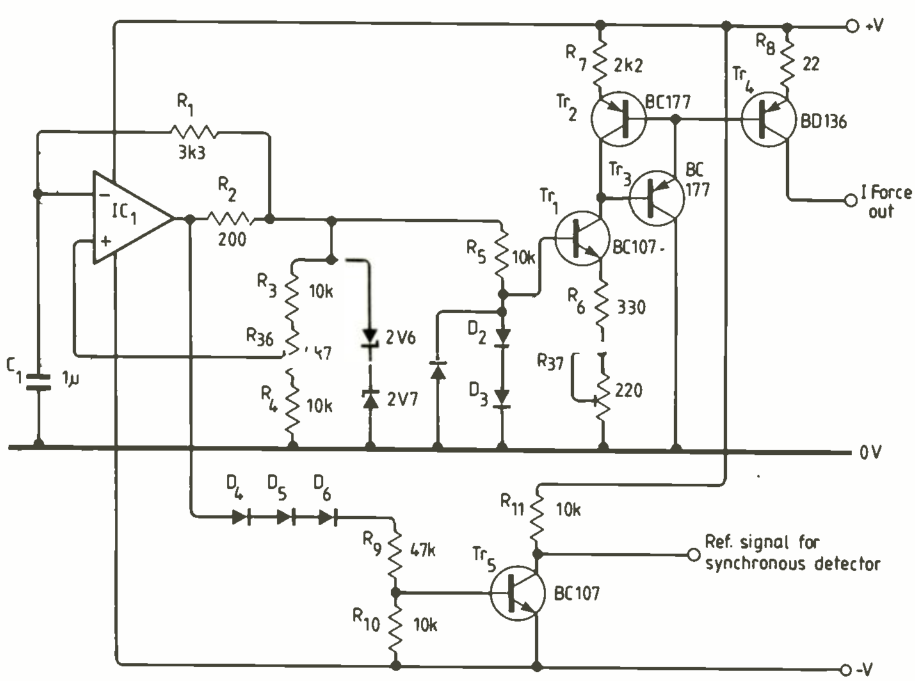


Fig.4. Alternating current force generator, providing a square-wave output, and a reference waveform for the synchronous detector.

IC_1 is configured as a square-wave generator with its frequency (approximately 130Hz) set by R_{36}. The square-wave generator drives Tr_1 via R_5, D_2 and D_3. The high-level collector current of Tr_1 is set by its emitter resistance, and low-level collector current is zero, as the base emitter junction of Tr_1 is reverse biassed. Diode D_1 prevents breakdown of this junction. Transistors Tr_2, Tr_3 and Tr_4 are configured as a current mirror with a ratio of 1:100, R_{37} being used to adjust the high-level I_{out} to about 100mA. Transistor Tr_5 provides a reference signal for the synchronous detector.

If the resistance under test is grounded at one end, the resistance of the ground lead will produce a common-mode signal which must be rejected by the differential amplifier (see Fig. 5). To avoid the use of an unduly complicated differential amplifier, the circuit shown in Fig. 6 is employed. This circuit reduces the common-mode signal due to the lead resistances by a factor of the open-loop gain of IC_2, at the frequency of I_{FORCE}. The voltage at A is adjusted so that the instantaneous voltage across R_X is centred about ground potential. Thus, the voltage across R_x is put into the differential mode, although some common-mode signal will persist due to mismatching of R_{13} and R_{14}. It is important that the ground reference required by IC_2 is taken at the differential amplifier to prevent errors due to ground track resistances.

DIFFERENTIAL AMPLIFIER

The next part of the circuit is a differential amplifier, which eliminates any remaining common-mode signal and transforms the voltage across R_X to a single-ended signal referred to ground. The circuit is shown in Fig. 7, in which the differential amplifier is the standard, single operational amplifier configuration, with unity gain and a common-mode rejection ratio limited by the matching of the ratios Rw_{15}/R_{16} and R_{17}/R_{18}.

BANDPASS FILTER

This is simply a Wien-bridge oscillator with its loop gain set to less than that needed for oscillation. The circuit is shown in Fig. 8. Centre frequency is set to 130Hz to ensure rejection of mains harmonics, whilst keeping the signal well within the bandwidth of the following amplifiers. The bandpass filter serves three functions: it attenuates harmonics of the signal so that the switched-gain amplifier is not required to amplify signals outside its bandwidth; it attenuates most of the noise so that the switched-gain amplifier is not saturated at high gains; and it acts as a preamplification stage.

SWITCHED-GAIN AMPLIFIER

Following the bandpass filter is a cascaded pair of non-inverting operational amplifiers forming a switched-gain amplifier, the circuit being shown in Fig. 9. The amplifier provides switched gains from 1 to 10000 in decade steps. At the frequency of 130Hz, the amplifiers have ample open-loop gain to perform their required function. The amplifier is arranged to give full-scale readings of 1Ω, 100mΩ, 10mΩ, 1mΩ and 100μΩ.

SYNCHRONOUS DETECTOR

The final stage of the circuit is the synchronous detector — a solution which was considered preferable to simple rectification, since a rectifier would produce erroneous results if the noise level were comparable to the signal level. The circuit for the synchronous detector is shown in Fig. 10, and works by multiplying the signal alternately by +1 and −1 at the signal frequency. This gives a d.c. component exclusively to the required signal, so that low pass filtering of the output will remove almost all undesirable effects, such as noise and mains hum. Operation of the circuit is simple: when the analogue switch is closed the amplifier is in the inverting configuration with a gain of −1, and when the switch is open the inverting gain is −1 and the non-inverting gain is +2. This results in an overall gain of 2−1=+1. The output of IC_5 drives a moving coil meter via R_m, which should be calculated to give a full-scale deflection of 0·5V. The mechanical damping of the meter gives adequate low pass filtering.

POWER-SUPPLY CONSIDERATIONS

The instrument requires a split supply of about ±6V, a mains supply being used in the prototype to avoid frequent battery replacement. If it is desired to use batteries, it would be wise to reduce the maximum force current to 10mA, and employ a test switch so that the meter is only on when a measurement is required. The complete circuit diagram shows a suitable modification to reduce the maximum force current to 10mA. With battery operation the range of full scale measurement is 1mΩ to 10Ω.

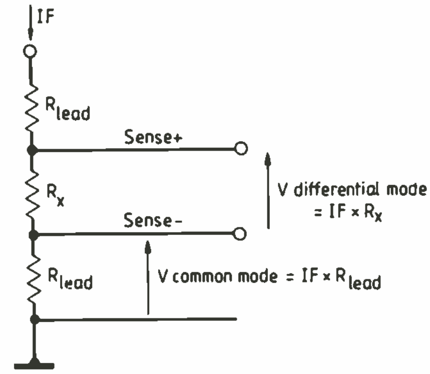


Fig.5. Grounding one end of R_X results in a common-mode voltage.

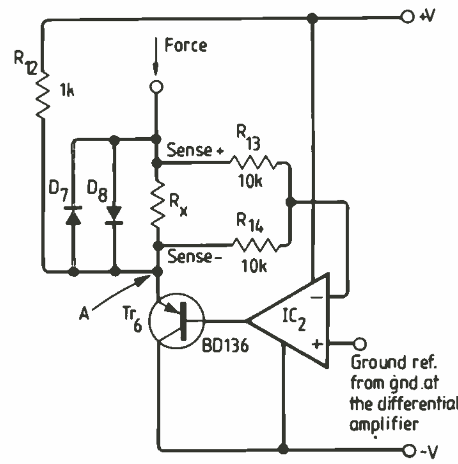


Fig.6. To reduce the common-mode voltage, R_X is connected in a feedback loop, centering the voltage about ground and rendering it a differential-mode signal.

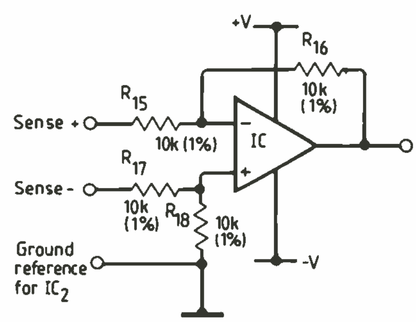


Fig.7. Differential amplifier.

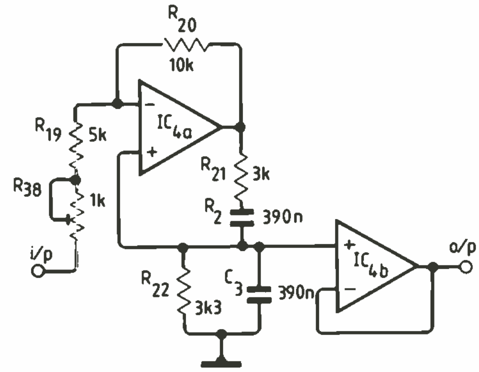


Fig.8. Bandpass filter, using Wien-bridge circuit with feedback less than that for oscillation.

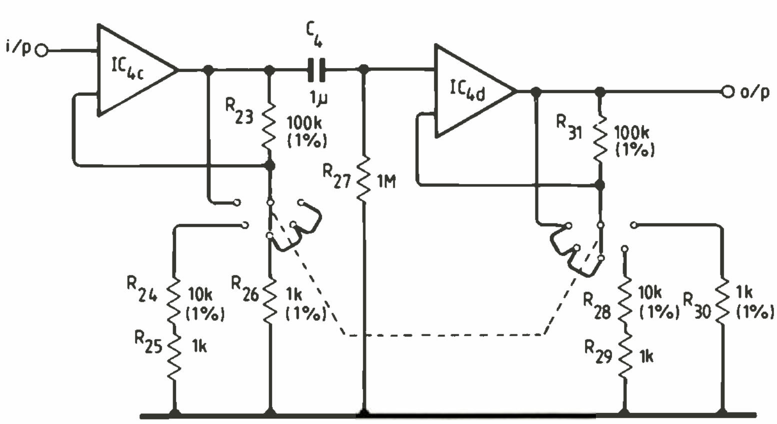


Fig.9. Switched-gain amplifier.

CONSTRUCTION

Figure 12. shows the complete circuit diagram. The prototype was built on unclad Veroboard, and connections were made on the underside of the board with fine, single-strand copper-wire. This method of construction was found to be quite satisfactory, and there is no advantage in using a printed-circuit board, though anyone wishing to do so should find that the layout is non critical except for the following:

- separate boards, or sections of a single board, should be used for the force and sense circuitry, to minimize pickup;
- the ground reference voltage for IC_2 should be taken directly from the ground connection of R_{18};
- current in the ground leads of the sense circuitry, and particularly at R_{18} should be minimized;
- the leads to and from the switch must be screened.

SETTING UP

Setting up the low ohms meter is not difficult. A 22Ω resistor should be obtained, and the instrument wired up to measure it. The range switch should be set to minimum sensitivity, and the power switched on. The voltage across R_8 should be measured to give a d.c. reading of 1V. R_{38} is then adjusted to its maximum value to ensure that the Wien-bridge filter does not oscillate. R_{36} can then be adjusted to give a maximum output, using the range switch to give a sensible reading. The 22Ω resistor is then exchanged for a 1Ω, 1% resistor, and R_{38} adjusted for full-scale deflection, with the range switch set to minimum sensitivity. If the battery option is used, a 10Ω resistor must be used instead of 1Ω.

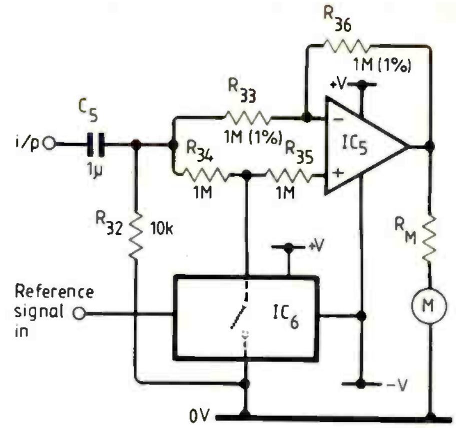


Fig.10. Synchronous detector and meter driver.

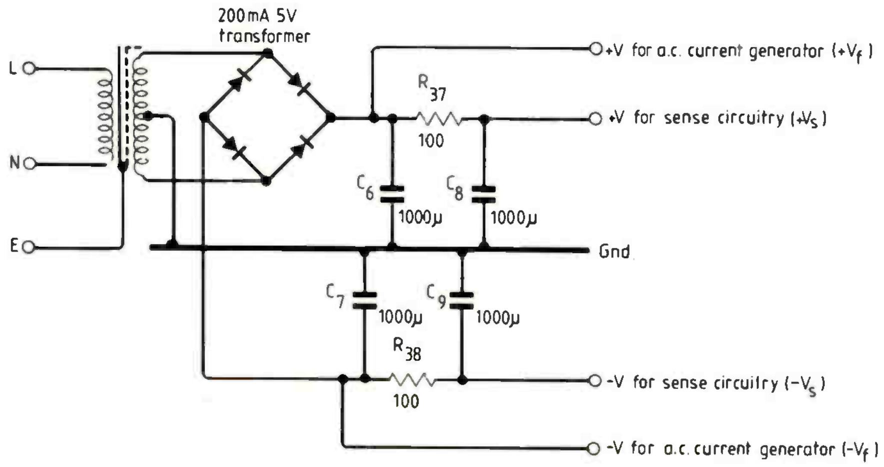


Fig.11. Mains power supply.

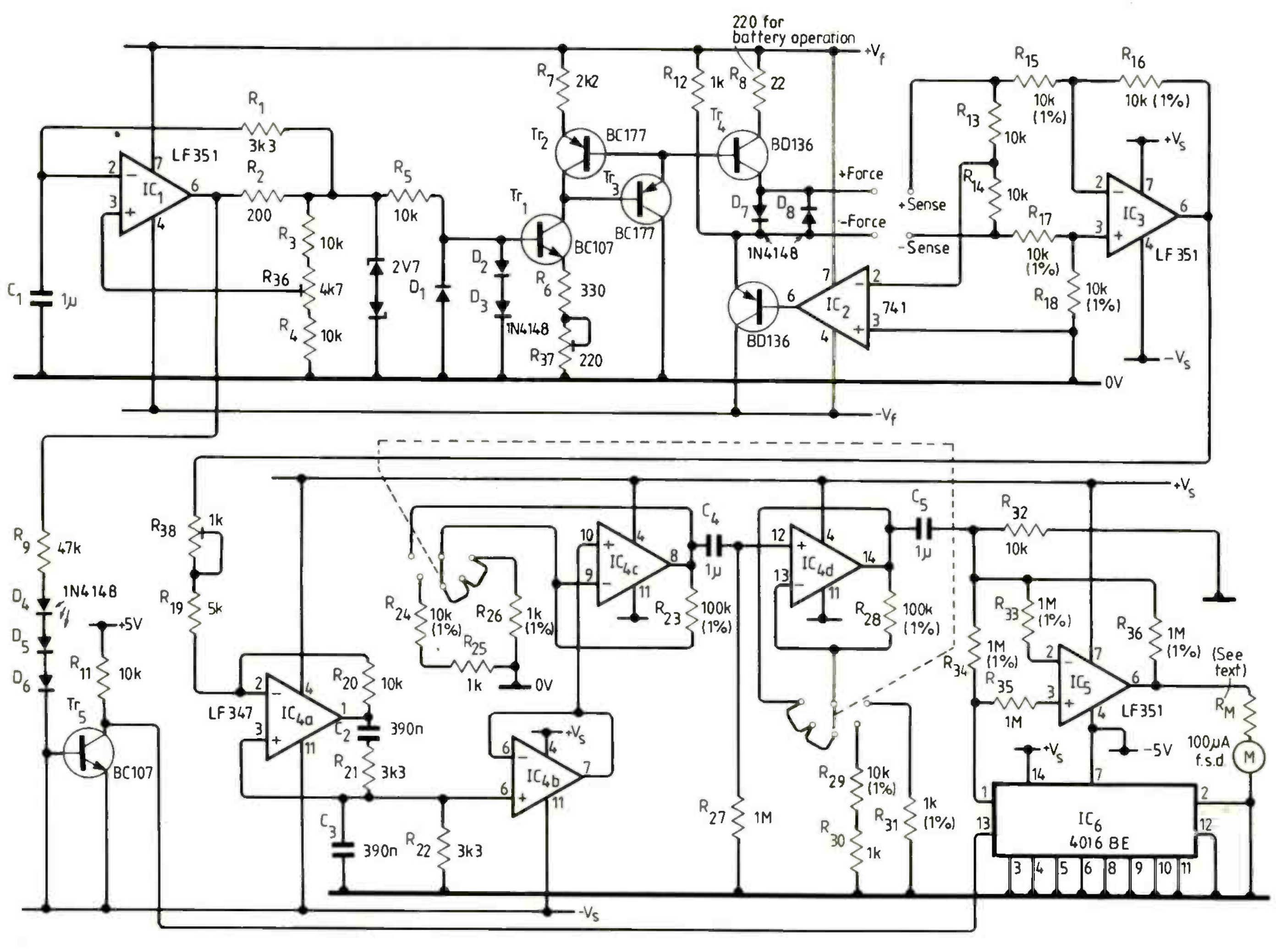


Fig.12. Complete circuit diagram.

WORKFILE

Audio Engineers

If you want good audio engineers you need to train them yourself – or take them from the BBC, so the current wisdom seems to go. If good engineers seem to be hard to come by, then so are the jobs. "Jobs for audio engineers are very few and far between," said Keith Darlig of Castle Recruitment, "but it's even harder to get the people."

This sentiment is widely echoed in the education world. Tim Whitely from B/TEC said their courses were very much demand orientated. "If there was more demand from industry for audio courses we would promote them (these courses) more widely among our students and in the community at large." Whitely said the lack of demand for highly skilled technicians is partly due to advances in technology. "The whole thing has become deskilled," Whitely pointed out. "There is not a great need any more for diagnostically skilled technicians. People now want the cheapest possible person to change the bit."

At present, there are few courses offered in audio engineering. B/TEC does organize a National Certificate in audio, television and radio. The course runs for two years with most entrants having 'O' level or CSE passes in maths, physics and English. There is a core of basic electronics and maths and audio engineering subjects. This B/TEC course is on offer, among other places, at Wigan College in Lancashire. Roy Hesford, who runs the course, said there is no shortage of students. He said this is largely due to the high reputation of the college and the degree of marketing carried out by the staff. Perhaps even more important, Hesford said there is no lack of takers for his pupils after their studies. "About half our young people get jobs quite quickly," said Hesford. "In the present industrial climate it just takes longer to get jobs. Most succeed though if they persevere."

To combat the lack of an overall training approach the Association of Cinematography, Television, and allied Technicians (ACTT) has joined together with employers and trainers to try and come to grips with the requirements of the film, television, radio and video industries. The newly formed training federation has held three meetings in its attempt to assess the training needs and provisions in these fields. In the cinema, the ACTT has also been involved in a scheme called "jobfit". The two-year programme would give freelance technicians an ACTT card and would train them to work in the film industry. ACTT training officer Ann Rawcliffe-King said this course is the first of its kind.

Different employers in the field may have different recruitment needs, but certain similarities seem to run through the market. A premium is set in the business on experience. "As a general principle it's difficult to get adequate training at college. You need on site training coupled with classroom training – the classroom on its own is not enough," said Roger Francis from the London Broadcasting Company.

There seems to be two types of recruitment in the market. People are taken on either at an operator level, or as graduate entry engineers. At an operator level most people come to their employers straight out of school.

The BBC is a large employer of young people and sets quite exacting criteria. A "good standard of education" is requested, to include 'O' levels in Maths, Physics and English. However, education is not the only quality needed for entry into the BBC's three year training scheme. "Other factors are equally important," said recruitment officer Ray Seymour, "we need the right personality, interest in the job at hand, and a high degree of motivation."

This emphasis on personal development is equally important at Abbey Road recording studios – part of the Thorn EMI group. Personnel officer Barbara Rotterova said most of the vacancies are at entry level. Promotion tends to be from within and the majority of staff stay at Abbey Road for quite a large part of their careers. Rotterova said recruitment centres on 17/18 year olds with good 'O' levels in maths, physics and English. Again, a keen and flexible approach is the key to success. Rotterova was quick to point out the scarcity of opportunities at Abbey Road. "People do write in to us. We keep the letters on file but at the moment it's unlikely we would take them on as we only employ two to three extra staff a year – and that's in a good year!"

According to Whitely, fewer skilled audio technicians now exist because more young people are going into general electronics, where there is "more demand for their skills and intelligence." With more people going on to general electronics degrees the competition for these graduates is becoming ever more intense. As graduates train in digital equipment they are courted actively by companies in communications, ultrasonics, and other related fields. The Ministry of Defence is another primary employer of new talent. This is, perhaps, mirrored at the second level of recruitment for audio engineers where employers are principally interested in electronics graduates. Again, the BBC has a large role to play and recruits graduates for its 12-18 months training course. All directorates are represented from television/radio to research and maintenance support. Even the BBC finds it difficult to find such a high-calibre intake. "It's getting more and more difficult as time goes by," noted Seymour. "Two years ago it was a lot more straightforward. It's a common problem now... we're competing for that same group of highly qualified staff."

The BBC has found it so difficult to recruit engineering graduates it has started to run graduate conversion courses – for those who got it wrong the first time around!! This conversion course has proved so successful – almost 3,000 applications for 30 places – the BBC said it is set to continue.

Graduate recruitment for other employers is a lot less structured. At Abbey Road they are experimenting with music graduates who show an "aptitude for electronics." The Independent Broadcasting Authority (IBA) employs engineers both at the specialist level and for its 18 month training courses. These positions are general in nature and largely deal with u.h.f. transmitter design and maintenance. The IBA employs 21/22 field teams responsible for this work. It also works with a limited number of audio engineers in the quality control field.

At the London Broadcasting Company there are three grades for audio engineers – L1, L2 and L3. Most engineers, according to Roger Francis, start at L3 and work their way up the ladder internally. "Broadly speaking, we're looking for people with 2/3 years experience as a sound technician on local radio, at the BBC, or in recording studios," said Francis. The salary for an L3 grade engineer is around £11,500 rising to £15,000 for an L1 grade. These wages include money for shiftwork, and again, the need for flexibility is underlined.

Audio engineers are also at a premium in the broadcast-equipment manufacturing sector. One leading supplier told me it employs engineers in both its service and product management support teams. The role of the latter is to give technical and marketing support to new products. The team shows people how to get the most out of the equipment they have just bought – be it a camera or a complete recording studio. A personnel spokesman said they prefer to employ people with three to five years experience. The engineer can then progress from a technician grade, through system engineering to management. The company prefers experienced engineers but finds these hard to come by because of its stringent requirements and the lack of skilled people in the market place. "If we're that desperate I'll take a graduate," the spokesman said.

Francis is quite optimistic concerning future demand for audio engineers. He said the expansion of ITN, the introduction of satellite direct broadcasting, along with a continued drive from the BBC, should provide a ready source of jobs for qualified people. Indeed, Francis is not worried about increased automation. As jobs become more specialized he said there will remain a strong need for well qualified and highly skilled maintenance engineers in all fields.

Workfile is written by Stephen Horn, Employment Editor, Electronics Weekly.

APPOINTMENTS

Advertisements accepted up to 12 noon February 27 for April issue

DISPLAYED APPOINTMENTS VACANT: £23 per single col. centimetre (min. 3cm).
LINE advertisements (run on): £5 per line, minimum £40 (prepayable).
BOX NUMBERS: £11 extra. (Replies should be addressed to the Box Number in the advertisement, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS).
PHONE: SUSAN PLATTS, 01-661 3033 (DIRECT LINE)

Cheques and Postal Orders payable to REED BUSINESS PUBLISHING and crossed.

---

ecm

JOBSEARCH TECHNOLOGY

FREE CASSETTE!

HARDWARE, SOFTWARE & SYSTEMS APPOINTMENTS

£10,000 - £30,000

- With the most successful companies and consultancies - both large and small - throughout the UK & Europe: Offering first class salary/benefit packages (several include co. car) with excellent career advancement opportunities.

Experience in any of these fields would be a particular plus:
HIGH SPEED SIGNAL PROCESSING: REAL-TIME 16/32BIT, ARRAY, PIPELINE OR BIT SLICE ARCHITECTURES; SOFTWARE - C, PASCAL; ADA; ASM-VMS/UNIX etc: A I & EXPERT SYSTEMS: IMAGE & GRAPHICS PROCESSING: LASER/FIBRE-OPTICS: SONAR: RADAR: COMMUNICATIONS: CUSTOM VLSI DESIGN: ANALOG/RF CIRCUIT DESIGN.

ECM offers confidential and professional guidance: we will **listen to your requirements** and identify opportunities to suit your plans. Phone now for your FREE CASSETTE "Jobsearch Technology" and hear how ECM can help you to develop your career.

Call ECM on **0638 742244** - until 8.00 p.m. most evenings - or send your cv (no stamp needed) to:

ELECTRONIC COMPUTER AND MANAGEMENT APPOINTMENTS LIMITED
FREEPOST, BURWELL, CAMBRIDGE, CB5 8BR.

CAPITAL APPOINTMENTS LTD

THE UK's No. 1 ELECTRONICS AGENCY

If you have HNC/TEC or higher qualifications and are looking for a job in design, test, customer service, technical sales or similar fields:

Telephone now for our free jobs list
We have vacancies in all areas of the UK
Salaries to £15,000 pa

01 808 3050
(24hours)!

CAPITAL APPOINTMENTS LTD
76 WILLOUGHBY LANE, LONDON N17 0SF

(291)

ELECTRONICS INSTRUCTOR

required by S.E. London Charity for multi-racial project with young people at risk.
Experience of working with young people essential, qualifications desirable. £9.5 – £12.6K.
Application forms returnable by Monday 9 March.

Promoting Equality of Opportunity. For businesses and people who want a say in how their technology is used.
EfP Ltd., 28 Milsom St., BATH BA1 1DP (0225) 69671

EXCHANGE RESOURCES

RECRUITMENT AGENCY & BUSINESS CONSULTANCY

INNER LONDON EDUCATION AUTHORITY
Learning Resources Branch
Television and Publishing Centre, London SW8

TELEVISION ENGINEERS (MAINTENANCE)

(I) £9,690-£10,416 + £1,494 LWA
(II) £8,238-£9,327 + £1,494 LWA (+ £216 shift allownace)

To maintain a high level of performance of a wide range of sound and vision equipment relevant to the production of colour television programmes.

HEAD OF VIDEORECORDING SECTION

£10,416-£12,231 + £1,494 LWA

To lead and manage a section comprising of five television engineers. The work of the section includes videotape editing of colour television programmes and the production of tape submasters and videocassettes.

Applicants must demonstrate a thorough understanding of and commitment to the Authority's equal opportunities policy.

Suitable for job share.

Application form and full job description from EO/PER/PS4a, Room 362a, The County Hall, London SE1 7PB. Please enclose a SAE.

Closing date for completed application forms is 13 March, 1987.

ILEA IS AN EQUAL OPPORTUNITIES EMPLOYER.

389

ITN

SOUND MAINTENANCE ENGINEER

Independent Television News has a vacancy for a Broadcast Sound Engineer in its Sound Maintenance Section.

We are seeking an experienced maintenance engineer to join a small specialist team responsible for the maintenance of a variety of audio equipment, including sound mixing desks and associated studio sound equipment. It is expected that the applicant will also be fully conversant with talkback and external communication systems and will have kept abreast of recent developments in the audio field.

The starting salary will be commensurate with experience in the range of £17,509 to £22,647 per annum.

Applicants should be qualified to HND or equivalent level and have had at least eight years' experience in an appropriate broadcast environment.

Benefits include generous pension scheme, and free life assurance.

Applications should be made in writing including full curriculum vitae to:
The Personnel Manager, Independent Television News Ltd, ITN House, 48 Wells Street, London W1P 4DE.

Closing date for applications 7th March 1987.

ITN IS AN EQUAL OPPORTUNITIES EMPLOYER

401

NEW COMMUNICATION CHANNELS FOR A FAST-MOVING BUSINESS

Telecommunications Specialists to £19,200 Reading

Today's water business has to move fast to keep up with growing demand: not only for water supplies, but for the total management of the water resource, from conservation to recreation, from fishery development to pollution control.

Thames Water is using computing and telecommunications technology to help it meet these demands on its business. Within the next five years, it will establish a geographical and operational database on-line throughout the 9,000-strong organisation; adopt digital transmission techniques on a major scale; and consolidate a network capable of speech, data and image transmission.

Thames Water need talented specialists to work on these projects.

Co-ordinators and Team Leaders

Teams of technicians are being established in office communications (including voice and data links); wide area data networking; and maintenance. Communications specialists, preferably Chartered Engineers – although this is not essential – are required to co-ordinate, manage and lead them.

You will be experienced in at least one area – such as radio communications, digital PABX technology, computer WANs and LANs or network planning – and have successfully led teams of technicians in at least one implementation project. At least 10 years' broadly-based experience covering a number of areas is required for the more senior position. **Ref: 1251/ROB/EWW.**

Technicians and Engineers

A number of technicians and engineers are also needed to assist in these new and exciting implementation projects. These opportunities offer the chance to work with the very latest technology and gain a greater breadth of knowledge in new areas.

Because Thames Water offers extensive training and a structured career path, opportunities exist for even the most junior staff who have worked in such areas as telephony, digital switching, computer data communications of all types, mobile radio and microwave communications. **Ref: 1252/ROB/EWW.**

Negotiable salaries are supported by large-company benefits and relocation expenses where appropriate; but the greatest benefit will come from participating in a major implementation of a comprehensive state-of-the-art communications network.

To apply, please send brief cv, in confidence, quoting the appropriate reference, to Rory O'Brien, Technology Group, **PA Personnel Services,** Hyde Park House, 60a Knightsbridge, London SW1X 7LE. Tel: 01-235 6060.

Thames Water

RUNNING WATER FOR YOU

PA

PA Personnel Services

Executive Search · Selection · Psychometrics
Remuneration & Personnel Consultancy

Professional Career Opportunities

The Easy Way to look for your new job from the comfort of your own armchair. Our well qualified consultants will carefully match your requirements against appropriate vacancies.

We have many clients seeking Engineers and Technicians at all levels and we are particularly interested in hearing from you if you have experience in the following:

- **Real Time Software**
- **Technical Sales**
- **ATE Programming**
- **Radar Systems**
- **RF Development**
- **Technical Authorship**

Your next step is to complete and return the attached coupon or telephone **John Prodger** on 0442 47311 or one of our duty consultants on 0442 212650 during evenings or weekends.

Executive Recruitment Services

THE INTERNATIONAL SPECIALISTS IN RECRUITMENT FOR THE ELECTRONICS, COMPUTING AND DEFENCE INDUSTRIES

Freepost, Hemel Hempstead, Herts., HP1 4BR.

NAME .... (Mr/Miss/Mrs)

ADDRESS ....

....

POST CODE ....

TEL NO ....

QUALIFICATIONS AGE ....

☐ NONE ☐ CG/HNC ☐ DEGREE ☐ OTHER

SALARY ....

JOB .... WW

Communications Officers
Botswana Police Force

The Botswana Police Force presently has opportunities for two Communications Officers - one for Planning and one for Radio/Microwave installation and maintenance.

For the **Planning** post duties include assisting in planning, engineering and installation of the police telecommunications system; purchasing and evaluation of equipment; advising and consulting on set-up of control and radio rooms and liaising with other government departments on sharing facilities.

The **Radio/Microwave** role carries responsibility for the installation, maintenance and repair of microwave, multiplex, Teleprinter, UHF and VHF equipment; all tower and antenna installations; ordering and stock control of test equipment, spares and parts.

Applicants for both posts should be British Citizens aged 22-45 with a degree in telecommunications and 5 years experience, or an HNC, HND or C&G Full Technology Certificate and around 8 years experience. An in-depth knowledge of systems planning and engineering is essential as is a background in the military, police communications or Home Office telecommunications. Training of local staff will also be an important duty.

The appointments are on contract to the Government of Botswana for a period of 2½ to 3 years. Local salary is in the range 9,852 to 13,404 Pula pa, plus a tax free supplement, payable by ODA, in the range £12,780 to £14,436 pa. A terminal gratuity of 25% of local salary is also payable. Other benefits normally include free passages, children's education allowances and subsidised accommodation. Exchange rate as at January 1987 - £1 stg.=2.575 Pula.

For an application form, please write, quoting ref. AH364/ES/EWW, **stating post concerned,** to: Appointments Officer, Overseas Development Administration, Room 351, Abercrombie House, Eaglesham Road, EAST KILBRIDE, Glasgow G75 8EA.
Or telephone 03552 41199, extension 3528.

ODA OVERSEAS DEVELOPMENT
Britain helping nations to help themselves

Lecturer in electronics, electronic technicians and hospital technicians

An alternative to the rat race.

Skills taken for granted in this country are vital to members of poorer Third World communities.

In a world which by and large does nothing about poverty and injustice (let alone hunger). VSO volunteers work directly with those seeking to become more self-reliant.

No one can change the world. But as a VSO volunteer, you could make a world of difference:

We have 6 jobs for September 1987 departure. They require people who can maintain and repair a wide variety of equipment, as well as being able to train local technicians. The Lecturer will be training future technicians. This work is critical for the modernisation of many Third World countries. If you have the relevant qualifications and want to work with people, please apply now.

You should be without dependants and willing to work for the local rate of pay. Postings are for two years – although many choose to stay longer – and most U.K. employers should be prepared to grant leave of absence.

For more information please complete and return.

I'm interested. I have the following training/experience

VSO Join the human race.
Charity no 313757

Name

Address

Post to **Enquiries Unit, Voluntary Service Overseas, 9 Belgrave Square, London SW1X 8PW.** (24p S A E appreciated)

FIELD SERVICE ENGINEER CLINICAL CHEMISTRY ANALYSERS
NORTH WEST LONDON AREA

Due to a rapid increase in the number of instruments installed, our Diagnostics Division requires an additional Service Engineer to maintain and service instruments in Clincial Chemistry Laboratories in London, South East England and the South Midlands.

Ideally positioned to the North West of London, candidates should have a clean driving licence and be experienced in the maintenance and repair of microprocessor controlled precision electro-mechanical or electro-optical equipment.

Previous experience in commercial organisations providing rapid response field service would be an advantage.

This appointment will provide an attractive salary and benefits package together with good all round conditions of employment in an international organisation.

Please apply with full CV to:

BDH **G. A. Weston, Personnel Officer, BDH Limited, Broom Road, Poole, Dorset BH12 4N.**

PART-TIME TUTORS, ENGINEERING. Part-time tutors required in the following subject areas: Basic electronic skills; Digital and analogue electronic engineering. Posts available throughout the UK. Attractive rates of pay and ideall suited for College Lecturers interested in enhancing their pay, or recently retired professional persons anxious to retain contact with their subject areas. Please write to Academic Consultants, c/o Group Four Marketing Services, 138 High Street, Eton, Near Windsor, Berkshire SL4 6AR. 386

ELECTRONICS DESIGN ENGINEERS

Small electronics company with worldwide sales outlets looking for new products to manufacture and market.

All replies treated in confidence: BOX 402

402

ELECTRONIC SYSTEMS ASSISTANT MANAGER

£13,625-£14,999

To assist the Electronic Systems Manager in the organisation and management of the Electronic Systems Section. Duties will include the organisation, maintenance, repair, design and testing of electronic systems fitted or prosed for Luton Airport.

An alternating shift system is worked, Monday-Friday, for which an allowance of 14% is payable. The allowance is included in the above salary.

Possession of either HNC or H.Tech in Electronics, with previous supervisory experience in a related field is essential. Applicants with experience of ILS, Plessey Surveillance, Radar, Plot Extracted SSR and Modern Digital Techniques would be particularly suitable for this post. A working knowledge of micro-processor based systems, together with some programming experience is desirable.

Casual User Car Allowance. Generous relocation expenses are payable in appropriate cases and temporary housing may be available.

Luton International Airport

Please write or telephone for further details and an application form to the **Personnel and Management Services Department, Town Hall, Luton LU1 2BQ. Tel: Luton 31291 ext 2621. Closing Date 20 March, 1987. Luton Borough Council is an Equal Opportunities Employer. Luton is a Nuclear Free Zone.**

390

Hardware/Software/Systems

£9,000 – £25,000

As a leading recruitment consultancy we have a wide selection of opportunities for high calibre Design, Development, Systems and supporting staff throughout the UK.

If you have experience in any of the following then you should be talking to us for your next career move.

ARTIFICIAL INTELLIGENCE • IMAGE PROCESSING • ANALOGUE DESIGN MICRO HARDWARE & SOFTWARE • GUIDED WEAPONS • C • PASCAL ADA • RF & MICROWAVE • ELECTRO-OPTICS • SIMULATION • C³I REAL TIME PROGRAMMING • SYSTEMS ENGINEERING • ACOUSTICS SONAR • RADAR • SATELLITES • AVIONICS • CONTROL • ANTENNA VLSI DESIGN

Opportunities exist with National, International and consultancy companies offering excellent salaries and career advancement.

To be considered for these and other requirements contact John Spencer or Stephen Morley or forward a detailed CV in complete confidence quoting **Ref. WW/66.**

STS Recruitment

STS Recruitment, 85 High Street, Winchester, Hants SO23 9AP. Tel: (0962) 69478 (24 hrs).

OXFORDSHIRE HEALTH AUTHORITY
THE CHURCHILL HOSPITAL
Renal Unit Workshop

TECHNICIAN

We are looking for a technician with training/experience in Electronics and a working knowledge of mechanical or electrical engineering to join our team.

Minimum requirements O TEC or equivalent – Salary £5,992-£7,877.

Application form and job description from the **Personnel Officer, The Churchill Hospital, Headington, Oxford.**

391

COMMUNICATIONS CONSULTANT/ ENGINEER

HF/VHF/UHF/RTTY
BASE AND MOBILE PABX/ PAGERS

Widely experienced Afria and Middle East.

If you need communications you need reliability whether its installation, maintenance or advice, get an expert.

Contact:
FREMAR
CONSULTANTS ON
TEL (0722) 742284 or
TLX 477019 ASR-G
ATTN FREMAR CONSUL

382

WE

WAVERLEY ELECTRONICS
(A Dowty Group Co.)

Waverley Electronics is a highly successful electronics design and manufacturing company possessing particular expertise in the sonar and signal processing fields used for both commercial and defence applications.

Several vacancies now exist within our test and inspection department for:

TEST TECHNICIANS

Being responsible for functional testing and inspection of various electronic assemblies and sub assemblies. You will require a sound working knowledge of electronic circuits and the use of proprietary test and measuring equipments. In addition, the preparation of written records of measurements and results is necessary: experience, or an ability, in fault finding will be considered a distinct advantage.

A completed apprenticeship in electronics engineering with at least ONC or TEC qualification and previous experience in similar work is expected. (Some relocation assistance will be paid where appropriate).

If you consider your experience and qualifications match with our requirements, please submit C.V. or telephone for an application form to:

**Mrs Terri Houghton, Personnel Officer,
Waverley Electronics Limited,
10 Cambridge Road,
Granby Industrial Estate,
Weymouth DT4 9TJ.
Tel No: (0305) 784738 Ext. 167**

We're Videcom

The well established British manufacturers of a unique range of Visual Display Terminals, Computers and communications equipment.

We need, at our premises in Reading, (Sutton Industrial Park):

SKILLED TEST/REPAIR ENGINEERS

With at least 5 years experience repairing to component level on digital and analogue computer equipment.

Must be familiar with Micro Processors, preferably Z80, DMA and Memory Mapping Techniques, and Multi Layer, PCB Technology.

For further details or application form please contact

**Sylvia Quedley on (0491) 578427
Videcom Ltd
Newtown Road
Henley-on-Thames, Oxon**

VIDECOM

APPOINTMENTS

CLIVEDEN

SATELLITE TV SYSTEMS
Repair of complex digital and microprocessor control equipment
£9,500 **Wilts**

NAVIGATION SYSTEMS
Installation and maintenance of lighthouse electronic equipment.
to £12,500 **Middlesex**

TEXT-PROCESSING
Maintain and installation of multi-processor micros used within the printing industry.
£9,000 + car **EC1**

COMPUTERISED MAPPING SYSTEMS
Service and support of VAX/PDP11 based graphics.
£11,000 + car **Berks**

BROADCAST TV
Chief of test with experience of analogue, digital and microprocessor systems.
£14,000 **Middx**

DATACOMMS/NETWORKS
Install and maintenance of digital networks. Experience of RS232 serial interfaces.
£9,500 + car
Maidenhead & C. London

Hundreds of other Electronic and Computer vacancies to £15,000.

Phone or write:
Roger Howard C.Eng. M.I.E.E. M.I.E.R.E.
CLIVEDEN RECRUITMENT
92 Broadway, Bracknell, Berkshire RG12 1AR
Tel: 0344 489489

ELECTRONICS DESIGN ENGINEERING

required by a worker co-operative

DELTA-T DEVICES LTD is a well-established 19 member co-op, which designs, makes and sells scientific instruments for environmental science.

We need another experienced electronics/microprocessor hardware designer, who could work well in a co-op.

We welcome applications from women, ethnic minorities and disabled persons.

We have equal pay of £6.10 per hour, with other benefits.

For details and application form (for return by March 2) contact:
Richard Spencer, Delta-T Devices Ltd, 128 Low Road, Burwell, Cambridge CB5 0EJ.
Tel: 0638 742922 398

ELECTRONIC DESIGN

Specialising in:
Lasers for industrial & commercial applications
Power supplies including linear H.V.
Electronic flash, also measurement and industrial control

PULSE PHOTONICS
3 Alnwick Drive, Bury BL9 8BZ
Tel: 061 796 6410

Marconi Signal Generators £35-£175 Record chart recorder £65 Elliott Semiconductor curve tracer £85 Philips Transistor Analyser £75 Wave Energy Systems Wattmeter £65 STC Distortion Meter £75 Rank G-K Wow & Flutter Meter £55 Strain Gauge Meter £65 Oscilloscope. Laboratory Scales £45 Component Bridges, source & detectors Densitometer Vacuum pump £98 Diffusion, high vacuum pump £35 Stereoscopic, binocular, prismatic microscope £195 Monocular microscope £79. Ignition Analyser £39 Dawe Phasemeter £69 Megohhmeter Precision decade capacitance box Marconi Voltmeter DC-UHF Lohmeter 100 2SD Data Logger Variphase Strobe Unit Simulator Alternator Control Centrifuge £49. High DC Ammeter. VHF Frequency Standard 1" Recording Tape on NAB reel £5. Pulse Generator Peak Accelerometer Ultrasonic Receiver Detector Ultrasonic transmitter low power generator Kango hammer & ten chisels £79 1KW 240/115 isolation transformer £35 Stainless Steel Film Processor £75 Chromalog Chart Recorder BICC Cable Test Set Tektronix Fast Rise-Time Plug-in Type 1 £39 Foster AC Impedance Meter Creed Facsimile T R £29 Copper still & accessories £69 Aircraft Radio Test Set £35 Marconi Variable Frequency Audio Attenuator £29 etc etc 040-376236.

THE MIDDLESEX HOSPITAL MEDICAL SCHOOL
(University of London)

Electronic Technician (Senior MLSO)

required for the Interdepartmental Workshop to modify and/or construct a wide range of electronic equipment used in the various departments of the school.

Salary scale £9,479-£12,159.

For further details contact:
Dr J. W. Tappin, Department of Medical Physics, Windeyer Building, Cleveland Street, London W1P 6DB.
Telephone: 01-380 9323. 392

VHF-FM BROADCAST EQUIPMENT

A special range of high quality transmitters, power amplifiers, stereo encoders, UHF repeater links, compressors, antennas. Powers 10w to 1kw. Built to high specifications at an economic price. Meets IBA & Full Broadcast specifications.

Phone now for prices and delivery:
Cyberscan International,
3 Eastcote View, Pinner,
Middx HA5 1AT. Tel: 01-866 3300 396

SILLY PRICED T.T.L.

OWING TO DISCONTINUED PRODUCTION WE HAVE ON OFFER

300	74LS123	60	74LS138
4,000	74LS165	80	74LS00
100	74LS163	1,500	5 Volt Reg+
50	74LS74	3,500	74LS05
15	NT28	3,100	74LS365
100	74LS04		

PRICE GUIDE! HALF OF YOUR LOWEST NEW PRICE
WILL SELL SEPARATELY
PHONE: 0276 29219 (SHOP)
Comp Shop Hi-Tech,
311 London Road, Camberley, Surrey GU15 3HE 403

ARTICLES FOR SALE

BRIDGES waveform/transistor analysers. Calibrators, Standards. Millivoltmeters. Dynamometers. KW meters. Oscilloscopes. Recorders. Signal generators – sweep, low distortion, true RMS, audio, RM, deviation. Tel: 040 376236. (2616)

BUYING OR SELLING TEST EQUIPMENT OR COMPUTERS

For our free monthly catalogue containing an up-to-date list of equipment write to or phone:
David Maxfield on 048 641 3000
TEM Albury House, Albury Guildford GU5 9BP 395

SEMI CUSTOM IC DESIGN. Very low cost/power, fast delivery, eraseable. Special i.c.s, standard logic, PAL replacement, protoyping, microprocessor/peripheral application. Design changes easily carried out. All designs copy protected. Price starts at as little as £50. Glenavon Electronics at 0733-733385. 388

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, N.12
(5 minutes from Tally Ho Corner) (1613)

FOR SALE. 2 Boards and 18MB Hard Disk Drive for Olivetti M40 ring Graham Ledger 01-647 4747. 385

HONEYWELL VIP7700R TERMINALS, used, reconditioned with manual £125 each. Tel: Gary 0268 419523 or Phil 04024 45676. 399

SERVICES

CIRCOLEC
THE COMPLETE ELECTRONIC SERVICE

Artwork, Circuit Design, PCB Assembly, Test & Repair Service, Q.A. Consultancy, Prototypes, Final Assembly. Full PCB Flow Soldering Service.
Quality workmanship by professionals at economic prices.
Please telephone 01-646 5686 for advice or further details.
TAMWORTH MANOR
302-310 COMMONSIDE EAST, MITCHAM
(1391)

Radiotelephones, Terminal Units, Test Equipment, Ex-RAF Radar and Instruments.

Forward £1 00 P O (Refundable on first purchase for list)
Address to
Brent Electronics & Comms,
49 Seaview Street, Cleethorpes,
South Humberside DN35 8EU.
Tel: 0472 690383.

G.W.M. RADIO LTD

40/42 Portland Road, Worthing, Sussex.
Tel: 0903 34897

Constantly changing stock of interesting items for callers Receivers, test equipment, components etc Pye pocketfone PFITX units with battery and circuits £12 inc p&p Pye PFI TX and RX with batteries and circuits £18 inc p&p for the pair Pye PF70 (PF2UB) with battery and speaker/mic £35 inc p&p Racal MA1963 HF VSWR meters 2 to 30MHz 10 to 150W power handling £27 inc p&p Ex-navy quartz chronometers clear 7cm dial, large second hand, wood case £27 inc p&p Tele F £12 inc p&p 400

TURN YOUR SURPLUS i.cs transistors etc. into cash, immediate settlement. We also welcome the opportunity to quote for complete factory clearance. Contact COLES-HARDING & CO, 103 South Brink, Wisbech, Cambs. 0945 584188. (92)

PCB'S MANUFACTURED. Prototype, small/large production runs, single, double-sided, P.T.H. screen printing, panels, labels, solder masking & photography. Orbitechnic Circuits, The Rear of 127 Woodlands Road, Ilford, Essex. Tel: 01-553 5211. (154)

DISH AE Radar dishes 32" dia 5" deep new, £26 50. RX AD94 24v DC I/P 2×L.W and 4×SW 2/18 5Mc/s with circ £85. VEHICLE NAV TS by Sperry see list £95. RAPID DISCHARGE CAPS 215Uf 2.5Kv Pk ex photo flash £14.50 lamps etc. available. MONOC SIGHTS 5×27 5 £7 50. VARIACS 240v at 8 amps £38 REC PAPER press ink fric feed 8" wide Gould £6.50 BIRD METERS spares for thro linex 30Ua new £12.50 AUDIO TAPE 1" 14" dia new £14 50 BLOWERS med size single ended 115v new £14 50 CAPS 2700Uf 250v £4 50. 33 000Uf 60v 2 for £6.50 ROT INV 18v DC I/P 230v 180w 50c/s O/P £45. CT471 ELEC multimeters with RF probes £75. RX AE PRE AMPS 162/174 Mc/s 4 O/Ps 12/24v DC £16.50 PHILLIPS PM5508 TV Patt Gen. £85. COAX TEST & CONNEC LEADS see list. MULTI TRACK FM RECORDER WITH H/Bks £165. Prices are inclusive. List 39 available on request.

A. H. Supplies, 122 Handsworth Road, Sheffield S9 4AE. Tel: (0742) 444278. 381

GOLLEDGE ELECTRONICS

QUARTZ CRYSTALS OSCILLATORS AND FILTERS of all types. Large stocks of standard items. Specials supplied to order. Personal and export orders welcomed – SAE for lists please. OEM support thru: design advice, prototype quantities, production schedules. Golledge Electronics, Merriott, Somerset YA16 5NS. Tel: 0460 73718. (2472)

P.C.B. ASSEMBLY WORK CARRIED OUT BY EXPERIENCED COMPANY

Fast, efficient and reasonable. Prototypes, sub-assemblies, cable loom and test facilities available.

R.C.C. ELECTRONICS,
Woodman Works, 204 Durnsford Road, London SW19 8DR. Tel: (01) 879 1242

IMPORTS/EXPORTS of all kinds of Electronics and Computers. Please send your enquiry or product details to DEDICATED MICROPROCESSORS LTD, 299A Edgware Road, London W2 1BB, England, or Telex 945922 GLADEX-G for the attention of Mr. C.Paps. (300)

FOR SALE TEKTRONIX 7L5 low frequency Spectrum Analyser for less than half current price of package which includes 7603 mainframe, L3 input module and tracking generator. WPA Ltd. Linton, Cambridge. Tel (0223) 892688. 373

ARTICLES WANTED

When replying to classified advertisements, readers are recommended to take steps to protect their interest before sending money

BOX Nos

Box number replies should be addressed to:

**Box No............
c/o Electronics & Wireless World
Quadrant House,
The Quadrant,
Sutton,
Surrey SM2 5AS**

FOR CLASSIFIED ADVERTISEMENTS RING SUSAN PLATTS

661 3033

WANTED

Test equipment, receivers, valves, transmitters, components, cable and electronic scrap and quantity. Prompt service and cash. Member of A.R.R.A.

M & B RADIO
86 Bishopsgate Street
Leeds LS1 4BB
0532 435649

ELECTRONIC SERVICES

CIRCUIT DESIGN, ARTWORK, PCB ASSEMBLY, PROTOTYPES

For quality workmanship at economic prices please telephone:

LOGICOMP
at 01-281 0633 328

WANTED. Televerters (VHF to UHF). Portable VHF or VHF/UHF signal level meters and spectrum analyser. TV relay system repeaters, EMI, Jerold etc. Sadelco or other spectrum calibrator. Selling valves:– 90cv. T41. E180F. EL81. CV4004. PC:– 86, 88, 900, 97, etc. PCC:– 89. 189. 86. PCF:– 86, 800, 801. Others all new and cheap. 05055-2118 8am–10pm. 344

WANTED

E C COMPONENTS
We buy large and small parcels of surplus I/C, transistors, capacitors and related electronic stock. Immediate settlement.
Tel: 01-208 0766
Telex: 8814998
(2491)

TEST EQUIPMENT
FOR SALE & WANTED
Buyers and Disposal Officers contact:
COOKE INTERNATIONAL
Unit 4, Fordingbridge Site
Main Road, Barnham
Bognor Regis
West Sussex PO22 0EB
Tel: 0243 68 2111/2
Stock list available. Send 50p to cover p&p. 179

WANTED GOLD PLATED SCRAP. Best prices edge connectors boards etc. Send smaple with no obligation to P & F Turner & Sons, 9 Farndon Road, Oxford OX2 6RS. Tel: Oxford (0865) 510293. (329)

PLATINUM, GOLD, SILVER SCRAP, melted assayed and paid for within 24 hours. Relay contacts, p.c.b.s, thermocoupoles, crucibles, plugus, connectors, etc. Totally free sampling service. Send samples or parcels (registered post) or contact Eric Henderson, 0703 760661. Steinbeck Refineries (UK) Ltd, Anchor House, Anchor Road, Eastwood, Notts. 406

WANTED: Who has experience and can develop a radar receiver with the frequencies 9,41 and 34,36 GHz for radar car speed control detection? WALLFASS, P.O. Box 1244, D-405 Moenchengladbach, W-Germany. Tlx 852582, tel 2161-88555. 380

STEWART OF READING
110 WYKEHAM ROAD
READING RG6 1PL
TEL NO: 0734 68041
TOP PRICES PAID FOR ALL TYPES OF SURPLUS TEST EQUIPMENT, COMPUTER EQUIPMENT, COMPONENTS etc. ANY QUANTITY 103

WANTED FOR CASH,
SURPLUS AND REDUNDANT BROADCAST EQUIPMENT
Particularly medium-wave transmitters, FM transmitters, studio links (STL), studio furniture, affects, cart machines, AA3 carts.
COMP SHOP HI-TECH
311 LONDON ROAD
CAMBERLEY, SURREY
Tel: 0276 29219 404

O.E.M. OVERSTOCK!
We buy your overstock; and slow moving components.
I.C's: TRANS: CAPS: OPTO: POWER SUPPLY: SCREWS: ETC.
Tel: 01-904 1979
Fax: 01-904 9508
INTEGRATED TRADING

CLASSIFIED ADVERTISEMENTS

Use this Form for your Sales and Wants

PLEASE INSERT THE ADVERTISEMENT INDICATED ON FORM BELOW

To "Electronics & Wireless World" Classified Advertisement Dept., Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

- Rate £5 PER LINE. Average six words per line. Minimum £40 (prepayable).
- Name and address to be included in charge if used in advertisement.
- Box No. Allow two words plus £11.
- Cheques, etc., payable to "Reed Business Publishing" and cross "& Co." 15% VAT to be added.

NAME..

ADDRESS...

....

....

			REMITTANCE VALUE .... ENCLOSED		

PLEASE WRITE IN BLOCK LETTERS. CLASSIFICATION.................. NUMBER OF INSERTIONS.................. (1)

INDEX TO ADVERTISERS

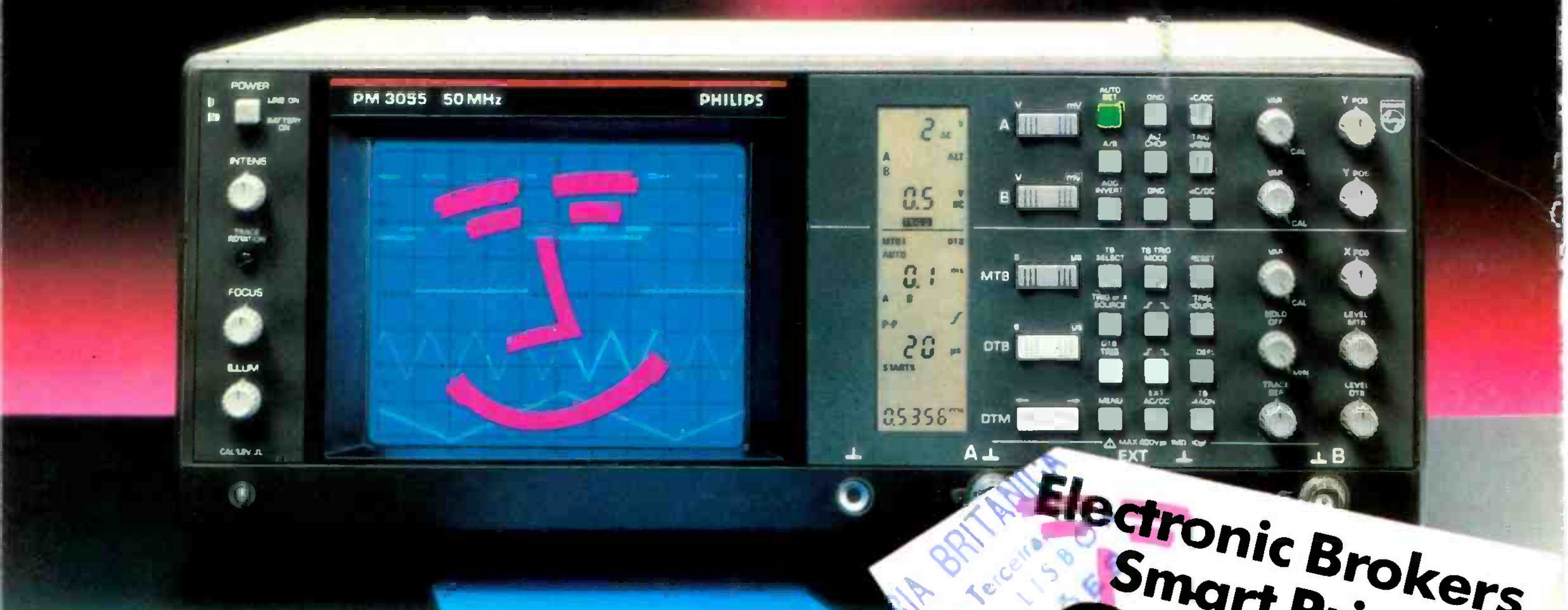
Appointments Vacant Advertisements appear on pages 346-351

OVERSEAS ADVERTISEMENT AGENTS
France and Belgium: Pierre Mussard, 18-20 Place de la Madelaine, Paris 75008.
United States of America: Jay Feinman, Business Press International Ltd, 205 East 42nd Street, *New York*, NY 10017 – Telephone (212) 867 2080 – Telex 23827.

Printed in Great Britain by E.T. Heron (Print) Ltd, Crittall Factory, Braintree Road, Witham, Essex CM8 3QO, and typeset by Graphac Typesetting, Imperial House, 108 The Broadway, Wimbledon SW19, for the proprietors, Reed Business Publishing Ltd, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. © Reed Business Publishing Ltd 1987. *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: Eastern News Distribution Inc., 14th Floor, 111 Eighth Avenue, New York, N.Y. 10011.

ELECTRONIC BROKERS

THE SMART CHOICE FOR THE SMART SCOPE



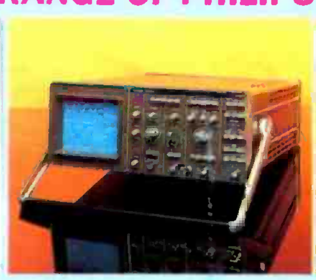
Electronic Brokers Smart Price £945

Philips' all-new PM 3055 is the smart scope – in more ways than you'd think! First, it's smart in *performance*. With an advanced-technology 16 kV CRT, versatile triggering functions up to 100 MHz, and fast computer hook-up via an IEEE option.

And it's smart in *simplicity*, with Autoset, right-every-time micro-computer control and full modular design for fast, easy service.

All these features come for a smart price of £945. Call us now for more details – make the smart choice.

ELECTRONIC BROKERS THE FIRST CHOICE FOR A FULL RANGE OF PHILIPS T&M EQUIPMENT



PM 2535 3½ TO 6½ DIGIT SYSTEM MULTIMETER £1267

- 0.005% true RMS accuracy
- 0.002% stability
- Resolution to 100nV
- 10 memory locations
- Up to 100 Measurements/Second
- Built-in calculation

PM 5786 125 MHz PULSE GENERATOR £2793

- 2ns to 0.1s variable rise/fall times
- Dual outputs
- Burst option of up to 9999 pulses
- 0.2V to 5V into 50Ω
- Simultaneous Normal Inverted pulses

PM 3256 75 MHz RUGGEDISED OSCILLOSCOPE £1808

- Dual Trace
- 2mV sensitivity
- Delayed timebase
- Trigger view
- TTL triggering
- Designed for harsh field environments

PM 3305 35MHz 4-CHANNEL DIGITAL STORAGE OSCILLOSCOPE £2857

- 4096 x 8 bit memory
- Pre-trigger 4096 bits max
- Min/Max mode catches 10ns glitches
- Direct display
- IEEE Option £3726
- Sequential sampling mode

PM 6673/4/5/6 UNIVERSAL COUNTERS FROM £641

- Versions to 120 MHz, 550 MHz, 600 MHz, 1.5 GHz
- 9-digit LED display
- 10mV sensitivity control
- CW, burst, multiple burst, frequency average and arming capabilities
- Error-free triggering with noise suppression

Electronic Brokers, 140-146 Camden Street, London NW1 9PB.
Tel: 01-267 7070 Telex: 298694 Fax No: 01-267 7363

Electronic Brokers

For further information contact our Sales Office. All prices exclusive of carriage and VAT.
Prices correct at time of going to press. A copy of our trading conditions is available on request.