Nanocomp/tty interface

Forth language

Digital rate meter

Precision preamplifier

Electronic weighing scale
The over and outperformer

For the address of your nearest dealer together with full details of the Shure Microphone range, write to: HW international Dept WW, 3-5 Eden Grove, London N7 8EQ or telephone: 01-607 2717.

WW – 027 FOR FURTHER DETAILS
THE PERSUADERS

COMMUNICATIONS COMMENTARY

STRAIN-GAUGE WEIGHING SCALE
by J. L. Linsley Hood

PRECISION PREAMPLIFIER
by D. Self

CURRENT DUMPING REVIEW
by M. McLoughlin

RAPID-UPDATE DIGITAL RATEMETER
by P. D. Coleridge-Smith

MICROCOMPUTER ANALYSIS OF LADDER NETWORKS
by L. E. Weaver

NEWS OF THE MONTH
Occam programming  Satellite news  Light-fibre multiplexer

WORLD TIMING ASSESSMENT USING H.F. BROADCASTS
by R. C. Macario and G. R. Munro

CIRCUIT IDEAS
Dot matrix display  6-digit counter  Current sensor

IMPROVING STEREO AT L.F.
by Y. Hirata

PROBLEMS IN SPECIAL RELATIVITY
by I. McCausland

USING A MICRO TO PROCESS 30-LINE BAIRD TV RECORDINGS
by D. F. McLean

ASSEMBLY-LANGUAGE PROGRAMMING
by R. F. Coates

FORTH COMPUTER
by B. Woodroffe

NANOCOMP TO TTY INTERFACE
by P. C. Barton

LETTERS TO THE EDITOR

NEW PRODUCTS
Out of this world for value!

**ET** Not our extra-terrestrial friend, but a versatile bench power supply —

—the ET30/2

For a modest price it will provide you with:
- 2 outputs at 0 to 30 volts d.c. at 1 amp or
- 2 outputs at 0 to 15 volts d.c. at 2 amps or
- 0 to 30 volts d.c. at 2 amps or 0 to 60 volts d.c. at 1 amp or 0 to 15 volts d.c. at 4 amps.

Send for details now from: FARNELL INSTRUMENTS LIMITED WETHERBY - WEST YORKSHIRE LS22 4DH TELEPHONE (0937) 61961 · TELEX 557294 FARIST G · REGIONAL OFFICE TELEPHONE (05827) 66123/4 · TELEX 826307
The WW ENTHUSIAST'S A-Z

BUYING GUIDE

It's amazing what you'll find in the pages of our current price list, be you
beginner, expert, or professional. The list below gives some indication of the
enormous stocks we carry and our service is just
as good as or

more. Careful reading can make it
WRITE, PHONE OR CALL
US FOR OUR LATEST
PRICE LIST NOW!


The basis and reduce the voltage capability.

In electronics, slew, size, thermal efficiency became particularly aggravated

in recent years.

Features:

- HIGH POWER, 1.2kW (single ended)
- LOW VOLUME, 3.6 cubic foot inc. Heat Sink
- VERSATILE, Delivers more than 1.5kW into 1/8 by 8 ohms
- OR 2 x 600W into 2 to 811
- OR 4 x 300W into 2 to 411 (200W into 811)
- OR \{ x 600W into 2 to 811
- OR \{ x 300W into 2 to 411
- OR \{ x 150W into 4 to 811
- Etc., etc.

Having been closely involved in a wide variety of OEM applications of their amp;
boards, Panetech became aware of numerous implementation problems often
left untackled by other amp board manufacturers. These problems specifically of
size and thermal efficiency became particularly acute at high powers and
considerably lengthened OEM product development time.

The basis for this considerable advance is the PANTECH 74 Heat Exchanger, newly
developed and manufactured by us. By eliminating the laminar airflow found in
conventional, extruded heat sinks, heat transfer to the cold plate is greatly
enhanced.

The flexibility of the 1.2kW amp stems from its division into 4 potentially
separable amplifiers of 300W each (downwivable with cost savings to 150W). These can be
paralleled, increasing current capability or output headroom (bridge in pairs) doubling
voltage capability. In consequence a large variety of amplifier/load strategies can be
implemented.

As panetech offer a full range of customising options including DC coupling,
ultra-high slew, etc. Contact Phil Rimmer on 01-800 8687 with your particular
application problem.

P/S Spec. as ever, are exemplary.

A wide range of other amplifiers and other modules available.

---

THE SOURCE OF ALL GOOD USED TEST EQUIPMENT

ANALYSERS

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7500</td>
<td>Spectrum Analyser</td>
<td>£1000.00</td>
</tr>
<tr>
<td>1500</td>
<td>Vector Analyser</td>
<td>£1500.00</td>
</tr>
<tr>
<td>2000</td>
<td>Tracking Generator</td>
<td>£2000.00</td>
</tr>
<tr>
<td>3000</td>
<td>RF Generator</td>
<td>£3000.00</td>
</tr>
<tr>
<td>4000</td>
<td>LCR Meter</td>
<td>£4000.00</td>
</tr>
<tr>
<td>5000</td>
<td>Power Meter</td>
<td>£5000.00</td>
</tr>
</tbody>
</table>

---

TEKTRONIX PLUG INS

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>Universal Power Supply</td>
<td>£7000.00</td>
</tr>
<tr>
<td>5000</td>
<td>Oscilloscope</td>
<td>£5000.00</td>
</tr>
<tr>
<td>3000</td>
<td>Tracking Generator</td>
<td>£3000.00</td>
</tr>
<tr>
<td>2000</td>
<td>Function Generator</td>
<td>£2000.00</td>
</tr>
</tbody>
</table>

---

TEKTRONIX TV TEST EQUIPMENT

<table>
<thead>
<tr>
<th>Model</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1414</td>
<td>Scope/Gen./Mon.</td>
<td>£1414.00</td>
</tr>
<tr>
<td>1482</td>
<td>Waveform Generator</td>
<td>£1482.00</td>
</tr>
<tr>
<td>6514</td>
<td>RF Generator</td>
<td>£6514.00</td>
</tr>
<tr>
<td>6584</td>
<td>RF Spectrum Analyzer</td>
<td>£6584.00</td>
</tr>
<tr>
<td>6711</td>
<td>RF Spectrum Analyzer</td>
<td>£6711.00</td>
</tr>
</tbody>
</table>

---

MISCELLANEOUS

<table>
<thead>
<tr>
<th>Availability</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>15V 25W 5%</td>
<td>Constant Ampitude Generator</td>
<td>£150.00</td>
</tr>
<tr>
<td>15V 25W 5%</td>
<td>RF Generator</td>
<td>£150.00</td>
</tr>
<tr>
<td>15V 25W 5%</td>
<td>RF Spectrum Analyzer</td>
<td>£150.00</td>
</tr>
</tbody>
</table>

---

Electronic Brokers Ltd., 61/65 Kings Cross Road, London WC1X 9LN. Tel:01-278 3461. Telex 289694

Electronic Brokers

www.americanradiohistory.com
TEONEX ELECTRONIC VALVES
AND SEMICONDUCTORS

SERVING THE WORLD FOR 30 YEARS

We specialise in the supply of
Industrial Valves of British, European and USA manufacture,
and semiconductors from the Philips Group.
Many types, including obsolete and obsolescent types,
always available from stock.

For further details, contact Mrs. Janet Lowy.
T.O. SUPPLIES (EXPORT) LTD., 2A Westbourne Grove Mews, London W11 2RY.
Telephone: (01) 727 3421 Telex: 262256 Answerback TOSPLY G

Get started in Fibre Optics

... with our new fibre optic experimental kit.

Features include:
- 0-10Mbit/s (NRZ) guaranteed to 15m with Polymer Cable. (Can be extended by using a glass fibre).
- TTL Compatible.
- No tools required to terminate cable.
- Fully tested modules.
- Complete with transmitter, receiver connectors and 5m of Polymer Cable.
- Also a full range of components for glass systems available.

Electroustic Ltd.
Hayward House, Northchapel, West Sussex, GU28 9HL
Tel: (042 878) 611/2. Telex: 858966

RADFORD

Audio Measuring Instruments,
Audio Amplifiers, Loudspeakers and
Loudspeaker Components for the
professional and enthusiast

RADFORD AUDIO LTD.
10 BEACH ROAD
WESTON-S-MARE, AVON BS23 2AU
TEL. 0934 416033

P & R COMPUTER SHOP

SALE:

IBM GOLFBALL PRINTERS from £70 EACH + V.A.T.
INTERFACE FOR IBM GOLFBALL £40 + V.A.T.
*BRAND-NEW LA36 DEC WRITERS – SALE £200 EACH + V.A.T.
CENTRONIC 779 PRINTERS – £325 + V.A.T.
CENTRONIC 781 PRINTER – £350 + V.A.T.
POWER UNITS, 5-VOLT 6-AMP – £20 EACH
FANS, PCBs, KEYBOARDS AND LOTS MORE
8-INCH IBM FLOPPY DISC DRIVES.
COME AND LOOK AROUND
SALCOTT MILL, GOLDHANGER ROAD
HEYBRIDGE, MALDON, ESSEX
PHONE MALDON (0621) 57440

4
a selection from our huge stocks. All items reconditioned unless otherwise stated.

SPECIAL PURCHASE OF PDP11/34A PROCESSORS
11/34A CPU
M511JP 64KB MOS Memory
DL11W Console Interface
KYL11B Programmers Panel
M9312 Bootstrap
BA11L5 1/4 Chassis
ONLY £2,500

DEC LSI PROCESSORS
11/03LK D111A CPU
KEV1 EIS/FIS, BDV11A
Terminator/Bootstrap
BA11N 5 1/4 Chassis with Backplane and Power Supply.
No memory included.
NEW £1,200
11/03N KD111G CPU
KEV1 EIS/FIS, BDV11A
Terminator/Bootstrap. BA11R
516 1/4 Chassis with Backplane
and Power Supply, MSV11DD
32KW MOS
NEW £1,495

DEC MAG TAPE
TE16 Slave
£4,500
TE16 Master with TM02
£5,750
TE16 Master with TM03
£6,250
TS11 Inc. Unibus Ctrl
NEW
£6,250
TU77 Master with TM03
NEW
£14,500
All above include DEC Cabinet

DECSCOPE TERMINALS
VT50B 20mA £199
VT50-AF EIA £225
VT52-AF 20mA £350
VT52-AF EIA £350
VT55-EB 20mA £450
VT55-EF EIA £495
VT55-FB + Copier, 20mA £710
VT55-FF + Copier, EIA £750

TEKTRONIX GRAPHICS EQUIPMENT

HIGH RESOLUTION BIG SCREEN GRAPHICS DISPLAY TERMINALS
4014-1, 4015-1 and 4016-1
19in. Screen providing 4096X by 3120Y displayable points or 8512
alphanumerics (models 4014 and
4015). 25in. Screen providing 4096X by 3120Y displayable points or
15,000 alphanumerics (model 4016).
APL Character Set (model 4015).
Plots-10 compatible. Prices include
Enhanced Graphics Option. Extra
Memory Option and Programmable
Keyboard Option.
4014-1 £6,850, 4015-1 £7,250,
4016-1 £8,850.
Other Tektronix graphics equipment,
currently available includes 4006-1,
4010-1, 4027, 4051, 4952,
606/606A/606B and 611.

TEKTRONIX
GRAPHICS EQUIPMENT

SCOOP PURCHASE OF GRAPHICS EQUIPMENT

EX-Demonstrator Stock in Original Manufacturer’s Packaging, Huge Savings on New Prices, Only Slightly Used — Covered by Full Warranty

DEC DISK DRIVES
RK07ED 28MB
£2,500
RK07PD 28MB
£2,500
RLO1 5MB
£995
RM02AD 67MB NEW
£6,250
RM03AD 67MB NEW
£6,250
RM05AD 256MB NEW
£14,750
RM08 124MB
£9,500
RX11 BD Dual Floppy
£995
RX21 BD Dral Floppy
£2,725

DEC SALES
NEW AUTUMN’83 CATALOGUE
NOW OUT
SEND FOR YOUR FREE COPY

VT100—PLUS
SPECIAL PURCHASE BRAND NEW DUPS
DEC PLOT11/220 PROGRAMMABLE DATA TERMINAL COMPRISING:
VT100 with Advanced
Supermarket Usability
Pro 80 column printer
RAM + 128K disk
Storage
2MB hard disk
2MB floppy
Welcome, et al.
£959 including comprehensive manual

6FT. PARABOLIC DISHES FROM ONLY £85 PLUS VAT.

6ft. dia. dishes, feed horns and electronics for use in 4GHz satellite reception. GaAs Fet transistors, SMA connectors, P.T.F.E., etc. available.
Please send s.a.e. for full details and data sheets.

HARRISON BROS.
Electronic Distributors
22 Milton Road, Westcliff-on-Sea, Essex SS0 7JX
Tel. Southend (0702) 332338
WWW - 007 FOR FURTHER DETAILS
<table>
<thead>
<tr>
<th>Component</th>
<th>Type</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SEMICONDUCTORS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MULLARD</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SEMI-COMponents</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BASES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CRTs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>INTEGRATED CIRCUITS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Terms of business: Cash. 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.

Accepts cash and top cheques subject to maximum orders of £50 on credit orders. Over 10,000 types of valves, tubes and semiconductors in stock. Quotations for any types not listed. S.A.E.

Phone: 01-677 2424 Telex: 946708

WWW 042 FOR FURTHER DETAILS

www.americanradiohistory.com
ANNOUNCEMENT

THE FOLLOWING ITEMS ARE AVAILABLE FOR HIRE FROM STOCK AT REALISTIC PRICES, WHERE HOME OFFICE RADIO LICENCES ARE REQUIRED SMC MAKE ALL THE ARRANGEMENTS.

1. 2-WAY HAND PORTABLE RADIOS
2. BASE STATIONS FOR USE WITH ABOVE
3. 60-FOOT TRAILER-MOUNTED TOWER
4. 1.6KW PETROL GENERATOR

Apply for details to:

SOUTH MIDLANDS COMMUNICATIONS LTD.
SN HOUSE, OSBORNE ROAD, TOTTENHAM
SOUTHAMPTON SO4 4QN, ENGLAND
TEL: 0703 863135
TELEX: 477501 SMCCS 6

WWW - 053 FOR FURTHER DETAILS

STEWARD OF READING
110 WYKEHAM ROAD, READING, BERKS RG6 1PL

Telephone: 0734 66941

Callers welcome 8 a.m. to 5:30 p.m. Monday to Saturday inclusive

WWW - 052 FOR FURTHER DETAILS

WIRELESS WORLD OCTOBER 1983

Electronic Brokers

Test Equipment DISTRIBUTORS

- Philips PM 2517X Handheld DMM £172

Multi-function, 4 digit, autoranging with manual override. True RMS to 10amp. Battery operation.
Optional accessories extend measurement capabilities

- Philips PM 3207 15MHz Oscilloscope £385

Tough light-weight, portable for field service work with big screen. Dual trace, TV triggering, X-Y option, add-in power.

- Philips PM 5501 Pattern Generator £296

Compact unit for TV and radio. Five different test patterns for colour and monochrome.
Dive, audio and RF switchable.

- Philips PM 6667/01 Frequency Counter £290

7 digit computing counter from 10Hz to 120MHz. Auto ranging on all waveforms PM 6668/01 (£425) performs to 1GHz

Fluke 8022B Handheld DMM £99

Rugged 3 1/2 digit, general purpose meter. Six functions include: diode test. Extensive overload protection and two year warranty period.

- 8010A Bench-top Portable DMM £210

Exceptional performance. 3 1/2 digit, true RMS meter. Seven functions with 10amp range capability. Comprehensive accessories and NiCd battery option available.

Fluke 8026B Handheld DMM £180

Versatile 3 1/2 digit, with true RMS capability. Eight functions include: conductance, and high speed audio continuity. Two year warranty applies.

- Hamag HM 103 10MHz Oscilloscope £158

Single trace, suitable for field service or home constructor. Two year warranty applies to this and all Hamag instruments.

Hamag HM £160 50MHz Oscilloscope £264

Dual trace for general purpose applications in industry and education. X-Y operation. TV trigger, add-in, and component tester.

- Hamag HM 264 20MHz Oscilloscope £365

High performance instrument, with sweep delay. Versatile triggering to 50MHz. Variable hold off control. 2 modulation and internal illuminated gate.

I.C.E. Microtest 80 Multimeter £19

Compact, meter in robust case. 43 ranges of measurements, with high sensitivity and accuracy. Large range of inexpensive accessories.

ADD 15% VAT TO ALL PRICES - Carriage and Packing extra

Electronic Brokers Ltd., 61/65 Kings Cross Road, London WC1X 9LN. Tel: 01-833 1166. Telex 298694

www.americanradiohistory.com
New low price
£795 + V.A.T.

At last a low-cost Colour Matrix Printer for Text, Graphics, Histograms, Colour VDU Dumps, etc.

Colour printout is quickly assimilated, makes graphics more understandable and is an ideal medium for the presentation of complex data or concepts.

Compatible with most microprocessors, prints in 7 colours – sophisticated internal programme makes the CX80 easy to use.


The CX80 is a product of our own design and development laboratories. It represents a British breakthrough in colour printer technology. Colour brochure on request. OEM pricing available.

INTEGREX LIMITED
Portwood Industrial Estate, Church Gresley
Burton-on-Trent, Staffs DE11 9PT
Burton-on-Trent (0283) 215432. Telex: 377106

HM 605 - The new 60 MHz-Performer
High quality scope at low cost

- 60 MHz Bandwidth
- 5mV-20V Sensitivity at 60MHz
- 1mV Sensitivity at 30MHz
- Timebase Range 5ns-2.5s/cm
- Reliable Triggering to 80MHz
- Normal and Peak Value Triggering
- Alternate Triggering
- Variable Sweep Delay
- 14kV Rectangular CRT
- Y-Output
- 1kHz/1MHz Calibrator
- HM8000-Compatibility
- 2 Years Warranty

£487 EXCLUDING VAT

write or call:
HAMEG LTD
74-78 Collingdon St. · LUTON, Beds. LU1 1RX · (0582) 41.31.74 · Telex 825 484

WW - 066 FOR FURTHER DETAILS

WIRELESS WORLD OCTOBER 1983
The professional communications receiver for point to point, ship to shore, and general coverage radio work:

**Range** 100kHz-30MHz ★ **Modes AM, SSB, CW, RTTY and optional FM** ★ **CPU based 10kHz step digital PLL synthesizer with DUAL VFO's** ★ **Frequency display 6 digit to 100Hz ★ Stability less than 50Hz after one hour ★ Power Supply 117 or 230V AC and optional 12V DC ★ IF - 1st 70.4515MHz, 2nd 9.0115MHz, 3rd 455kHz, 4th 9.0115MHz ★ Optional transceive units and filters available.

**THIS SUPERB RECEIVER IS PRICED AT £433.91 + VAT**

Contact us for more details on this and other ICOM professional communications equipment.

**PMR - MARINE - AMATEUR**

Dealer enquiries welcome

**Thatch Electronics**

143 Reculver Road, Herne Bay, Kent
Tel: 0227 63855
Tel: 961579

---

**ICOM ICR70**

The professional communications receiver for point to point, ship to shore, and general coverage radio work:

**Range** 100kHz-30MHz ★ **Modes AM, SSB, CW, RTTY and optional FM** ★ **CPU based 10kHz step digital PLL synthesizer with DUAL VFO's** ★ **Frequency display 6 digit to 100Hz ★ Stability less than 50Hz after one hour ★ Power Supply 117 or 230V AC and optional 12V DC ★ IF - 1st 70.4515MHz, 2nd 9.0115MHz, 3rd 455kHz, 4th 9.0115MHz ★ Optional transceive units and filters available.

**THIS SUPERB RECEIVER IS PRICED AT £433.91 + VAT**

Contact us for more details on this and other ICOM professional communications equipment.

**PMR - MARINE - AMATEUR**

Dealer enquiries welcome

**Thatch Electronics**

143 Reculver Road, Herne Bay, Kent
Tel: 0227 63855
Tel: 961579

---

**DIACROM SPATULA**

Manufactured in France

British Patents applied for

No other cleaner has all these advantages:

1. **100% pure, natural diamond grits are used.**
2. Blades are treated with hard chrome to reinforce the setting of the diamond grits to eliminate loosening or breakaway during use. This process also prevents clogging of the diamond surface by residue required to prevent clogging of the diamond surface by residue required to preven...
THE COMPLETE PACKAGE!
MICROPROFESSOR PLUS THE STUDENT WORK BOOK

A low cost tool for learning, teaching and prototyping.

Micro-professor is a low-cost Z80 based micro computer which provides you with an interesting and inexpensive way to understand the world of microprocessors.

Micro-Professor is a complete hardware and software system and is a superb learning tool for students, hobbyists and microprocessor enthusiasts, as well as an excellent teaching aid for instructors of electrical engineering and computer science courses.

Micro-Professor £99.50 (+£ 4.00 p&p)

Now with the Student Work Book available Flight offer you the complete package. An easy to follow manual that will help further your understanding of microprocessors.

Student Work Book £16.00

SSB-MPF Speech Synthesizer Board
A vocabulary of up to 400 words based on the TMS 520C chip.

PRT-MPF Printer Board
Memory dump utility. BASIC program listing. Z80 disassembler.

EPB-MPF EPROM Programming Board
For all +5V 1KB/2KB/4KB EPROMS Read/Copy/List/Verify Capability.

Please send me
Micro-Professor £99.50 (+£4.00 p&p)
Student Work Book £16.00
SSB-MPF board £99.50
EPB-MPF board £99.50
PRT-MPF board £86.25

I enclose cheque/P.O. for £.............

Name

Address

Mail Order only
Prices include VAT. Please allow 28 days for delivery.

By phone or post

FLIGHT ELECTRONICS LTD.
Quayside Rd. Southampton.
Hants SO24 4AD. Telex 477793.
Tel. (0703) 340 003/277 21.
TELESCOPIC MASTS
Pneumatically operated telescopic masts. 25 Standard models, ranging from 5 metres to 30 metres.

Hilomast Ltd
THE STREET  HEYBRIDGE — MALDON
ESSEX CM9 7N3 ENGLAND
Tel. MALDON (0621) 56480
Telex No. 995855

WW - 010 FOR FURTHER DETAILS
LOOK AHEAD!

WITH MONOLITH MAGNETIC TAPE HEADS – VIDEO HEAD REPLACEMENT KIT

DOES YOUR VCR GIVE WASHED OUT NOISY PICTURES – ITS PROBABLY IN NEED OF A NEW HEAD – FAST FROM OUR EX-STOCK DELIVERIES.

SAVE £££'s ON REPAIR CHARGES.

OUR UNIVERSAL REPLACEMENT VIDEO HEADS FIT ALL MODELS OF VHS OR BETAMAX VCR.

FOLLOWING OUR REPLACEMENT GUIDE AND WITH A PRACTICAL ABILITY, YOU CAN DO THE WHOLE JOB IN YOUR OWN HOME WITH OUR HEAD REPLACEMENT KIT.

KIT CONTAINS – NEW VIDEO HEAD, 5 CLEANING TOOLS, HEAD CLEANING FLUID, CAN OF AIR BLAST, INSPECTION MIRROR, ANTISTATIC CLOTH, VHS/BETAMAX MAINTENANCE MAHLAL, CROSS HEAD SCREWDRIVER, HANDLING GLOVES, MOTOR SPEED DISC, SERVICE LABEL, HEAD REPLACEMENT GUIDE.

HOW TO ORDER,

PLEASE STATE CLEARLY THE MAKE AND MODEL OF YOUR RECORDER. THERE ARE TWO VERSIONS OF THE VHS HEAD AND YOUR ORDER CAN BE PROCESSED FASTER IF YOU CHECK THE SIZE OF THE CENTRE HOLE OF THE HEAD WHICH WILL BE EITHER 5mm OR 15mm DIAMETER.

VHS KITS £53.25 BETAMAX KIT £65.25 Prices include P. & P. and V.A.T.

GSC THE SPECIALISTS SUPPLIER TO MOST OF THE U.K.'s LEADING DISTRIBUTORS AND SERVICE ORGANISATIONS

MONOLITH ELECTRONICS CO. LTD
57 Church Street, Crewkerne, Somerset TA18 7HR, England
Telephone: Crewkerne (0430) 74827
Telex: 46308 MONOLITH G

EVERYTHING THERE IS TO MAKE IT EASY TO DO IT YOURSELF

THE GSC ELECTRONICS SPECIALISTS

announces two NEW handheld instruments

COMBINES THE PERFORMANCE OF BENCHTOP MODELS WITH THE CONVENIENCE OF PORTABLE UNITS

3002 AUTO-RANGING CAPACITANCE METER

In the palm of your hand - a capacitance meter that behaves like a benchtop model. Just look at the features that GSC have built into the Model 3002:

- 3½-digit liquid-crystal display
- Eight ranges from 1μF to 19,999μF
- Dual-threshold technique for high accuracy
- Accuracy down to 0.2%
- Measures only 193 x 95 x 44mm
- Battery or mains operation

And that's not all - because the 3002's d.c. charging characteristics allow it to determine the true capacitance of cables, switches and other components as well as capacitors. All this - plus the option of rechargeable battery or mains operation - for only £144.

GLOBAL SPECIALTIES CORPORATION

GSC (UK) Limited
Freepost-Saffron Walden, Essex CB11 3AQ Tel: Saffron Walden (0799) 21682 Telex: 817477
The new microprocessor controlled EP8000 Emulator Programmer will program and emulate all EPROMs up to 8k x 8 sizes, and can be extended to program other devices such as 16k x 8 EPROMs, Bipolar PROMs, single chip microprocessors with external modules. Personality cards and hardware changes are not required as the machine configures itself for the different devices. The EP4000 with 4k x 8 static RAM is still available with EPROM programming and emulation capacity up to 4k x 8 sizes.

**FEATURES**
- Software personality programming/emulation of all EPROMs up to 8k x 8 bytes including 2704, 2708, 2716(3), 2508, 2758A, 2758B, 2516, 2532, 2732, 2732A, 68732-0, 68732-1, 68766, 68764, 2564, 2764. Programs 25128, 27128 with adaptors.
- No personality cards/characterisers required.
- Use as stand alone programmer, slave programmer, or EPROM development system.
- Checks for misplaced and reversed insertion, and shorts on data lines.
- Memory mapped video output allows full use of powerful editing facilities.
- Built-in LED display for field use.
- Powerful editing facilities include: Block/Byte move, insert, delete, match, highlight, etc.
- Comprehensive input/output - RS232C serial port, parallel port, cassette, printer O/P, DMA.
- Extra 1k x 8 scratchpad RAM for block moving.

**DISTRIBUTORS REQUIRED**

GP Industrial Electronics Ltd.
Unit E, Huxley Close, Newnham Industrial Estate, Plymouth PL7 4JN

Tel: Plymouth (0752) 332961
Telex: 42513

FOR FURTHER DETAILS

VAT should be added to all prices

**EXPORT ENQUIRIES WELCOME**

**EP8000 EPROM EMULATOR PROGRAMMER**

- EP8000 8k x 8 Emulator Programmer - £695 + £12 delivery
- BSC8 Buffered emulation cable - £49
- SA27128 Programming adaptor - £69
- SA25128 Programming adaptor - £69
- EP4000 4k x 8 Emulator Programmer - £545 + £12 delivery
- BSC4 Buffered emulation cable - £39
- BP4 (TEXAS) Bipolar PROM Module - £190
- Prinz video monitor - £99
- UV141 EPROM Eraser with timer - £78
- GP100A 80 column printer - £225
- GR1 Centronics interface - £65

**VAT should be added to all prices**

---

www.americanradiohistory.com
P8000 — THE PRODUCTION PROGRAMMER THAT HANDLES ALL NMOS EPROMS

- Checks, Programs, Compares up to 8 devices simultaneously
- Handles all NMOS EPROMS up to projected 128K designs with no personality modules or characterisers – See list
- Easy to use, menu driven operation for blankcheck, program, verify, illegal bit check, checksum, self-test
- Constant display of device type, mode and fault codings
- Individual socket LED indicators for EPROM status
- Comprehensive EPROM integrity checks – Illegal bit check, data and address shorts, constant power line monitoring
- Full safeguard protection on all sockets
- Automatic machine self-test routine
- RS232C interface supplied as standard
- Powered down sockets
- Cost effective price – £695 + VAT
- Available from stock

Write or phone for more details

DISTRIBUTORS REQUIRED  •  EXPORT ENQUIRIES WELCOME

GP Industrial Electronics Ltd.  
Unit E, Huxley Close, Newnham Industrial Estate, Plymouth PL7 4JN

Tel: Plymouth (0752) 332961  
Telex: 42513H

WIRELESS WORLD OCTOBER 1983
CRICKLEWOOD ELECTRONICS LTD.
40 Cricklewood Broadway, London NW2 3ET Tel: 01 452 0161. Tel: 914937.

Here you will find a wide range of radio parts. Full price list free on request. Orders by credit card if you order by mail and all products are grade A. No VAT on orders over £100. All US orders dispatched same day. VAT on all goods. Orders over £100. In stock items dispatched on receipt. All orders over £100. VAT on all goods. Orders over £100. VAT on all goods.

Stocking parts other stores cannot reach!

### Resistors

<table>
<thead>
<tr>
<th>Value (Ω)</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100k</td>
<td>0.05</td>
</tr>
<tr>
<td>10k</td>
<td>0.10</td>
</tr>
<tr>
<td>1k</td>
<td>0.20</td>
</tr>
<tr>
<td>100Ω</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Capacitors

<table>
<thead>
<tr>
<th>Value (µF)</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1µF</td>
<td>0.05</td>
</tr>
<tr>
<td>1µF</td>
<td>0.10</td>
</tr>
<tr>
<td>10µF</td>
<td>0.20</td>
</tr>
<tr>
<td>100µF</td>
<td>0.25</td>
</tr>
</tbody>
</table>

### Diodes

<table>
<thead>
<tr>
<th>Value</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1N4148</td>
<td>0.50</td>
</tr>
<tr>
<td>1N4149</td>
<td>0.50</td>
</tr>
<tr>
<td>1N4147</td>
<td>0.50</td>
</tr>
<tr>
<td>1N4146</td>
<td>0.50</td>
</tr>
</tbody>
</table>

### Logic

<table>
<thead>
<tr>
<th>Type</th>
<th>Price (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CMOS</td>
<td>0.10</td>
</tr>
<tr>
<td>TTL</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### Just Released

NEW ILLUSTRATED CATALOGUE
£1.00 inc. VAT, p&p

WWW.058 FOR FURTHER DETAILS

Wireless World October 1983
The lightweight mast with 101 applications

The smoothly operated QTM Mast comes fitted with handpump or can be vehicle mounted with 'Power Pack' for extension and retraction. Available in a range of heights up to 15 metres, the QTM mast can provide the ideal answer for:

- Mobile Radio Telephone
- Police Mobile HQ (UHF)
- Field Telecommunications
- Floodlighting
- Anemometer and Wind Measurement
- Environmental - gas sampling collector
- High level photography
- Meteorology
- And a host of other uses

CLARK MASTS

Find out more about the QTM series by writing or phoning:

U K
CLARK MASTS LTD. (IV W )
Evergreen House, Ringwood Road.
Binstead, Isle of Wight.
England PO33 3PA
Tel: Isle of Wight (0983) 63631
Telex 866668

EUROPE
GENK TECHNICAL PRODUCTS N.V.
Woudstraat 21, 3600 Genk.
Belgium
Telephone 011-380831
Telex 39354 Genant B.

“Instruments for Industry”

Multimeters EX-STOCK from ANDERS

This superb range of hand-held and bench multimeters offers a unique choice of 3½ or 4½ digit specifications and features. Engineering excellence at competitive prices with numerous supporting accessories to suit design, production and service needs. Now available ex-stock from one of the U.K.'s most experienced electrical measurement specialists. The complete range of Anders instruments and panel meters is described in the "Instruments for Industry" catalogue.

For your personal copy contact:

ANDERS ELECTRONICS LIMITED
48-56 Bayham Place
London NW1 0EU
Tel: 01-387 9092. Telex: 27364

Audio Jackfields?

Over 100 listed in our Catalogue.

Write or call for your free copy.

FUTURE FILM DEVELOPMENTS
114 Wardour Street, London W1V 3LP Telephone: 01-434 3344.
Telex: 21624 ALOFFD G.

WW - 024 FOR FURTHER DETAILS

WW - 011 FOR FURTHER DETAILS

WW - 065 FOR FURTHER DETAILS
KEYBOARDS FROM £95.00
12" P31 MONITORS FROM £95.00
CP/M 2-2 FOR IBS 750 £95.00
DOCS £15.00

5½" TEAC DISK DRIVES
250K FD55A = £159.00
500K FD55E = £189.00
1MB FD55F = £249.00
Subject to Yen fluctuation

SWITCH MODE POWER SUPPLY
+ 5V @ 7 amps
+ 12V @ 3 amps
+ 12V @ 1 amp
5V @ 1 amp
80W £79.95

NEW BUDGET ACCOUNT
£1,000 INSTANT CREDIT ON ANY PRODUCTS
10% Deposit + 24 x Monthly Payment Credit Limit. A.P.R. 30.6%

MADE IN IRVINE SCOTLAND BY IRVINE BUSINESS SYSTEMS LTD.

A SINGLE CARD COMPUTER FOR ONLY
THE IBS 750 S.B.C.

£423.35 + VAT
Deposit £48 Per Month £19

★ 4 MEG Z80 CPU
★ 64K RAM
★ 16K PROM
★ 5" & 8" DISK CONTROLLER
★ 80x24 VIDEO GEN
★ 2x SERIAL I/O
★ 4x PARALLEL I/O
★ IEEE 488 INTERFACE
★ KEYBOARD PORT
★ HARDWARE RTC
★ MONITOR IN PROM
★ BARE BOARD AVAILABLE @ £99.95

SWITCH MODE POWER SUPPLY
+ 5V @ 7 amps
+ 12V @ 3 amps
+ 12V @ 1 amp
5V @ 1 amp
80W £79.95

NEW BUDGET ACCOUNT
£1,000 INSTANT CREDIT ON ANY PRODUCTS
10% Deposit + 24 x Monthly Payment Credit Limit. A.P.R. 30.6%

MADE IN IRVINE SCOTLAND BY IRVINE BUSINESS SYSTEMS LTD.

THE RADIO MAGAZINE
OCTOBER 1983 90p
Five projects for the radio enthusiast

TEST GEAR SPECIAL

- Sensitive Capacitance Meter
- QRP RF Wattmeter
- Digital Calibrator
- Simple wavemeter for 144MHz
- QRP SWR Bridge

Special designs to test small capacitors, measure low power transmitter output and antenna SWR, check 144MHz transmitters and produce frequency markers to VHF and beyond.

AND RIG REVIEWS
ICOM IC-505 50MHz
PLUS the STANDARD matching
VHF & UHF mobile rigs
OCTOBER ISSUE 90p
ON SALE NOW

www.americanradiohistory.com
**DIGITAL MULTIMETERS**

- All models: Dual digits unless stated.
- [Model Details](#)

**FREQUENCY COUNTERS**

- PFM201A: 20 MHz hand held pocket digital LCD
- MET100: 10 digit LED bench range 1 MHz
- MET600: 6 digit LED bench range 3 MHz
- MET1000: 10 digit LED bench range 1 GHz
- 1200 MHz: 6 digit LED bench range 12 GHz
- M7 Optional: 5 MHz, 9 MHz, 15 MHz, 20 MHz, 30 MHz, 50 MHz, 75 MHz
- Frequency/Period: 57.90 inc VAT (£63.89)

**ELECTRONIC INSULATION TESTER**

- All models: 1000 V. with carry case
- [Details](#)

**OSCILLOSCOPES**

- Full specification/any model:
- [RM SERIES NAMES: SC](#)
- THORAC, LS (Ultra-wide range)
- HI-TACHIC, SINGLE TRACE (UK)$374.00
- $431.45 (0.60 MHz), $457.50 (1.0 MHz), $480.00 (2.0 MHz), $500.00 (4.0 MHz), $520.00 (8.0 MHz), $540.00 (16.0 MHz), $560.00 (32.0 MHz), $580.00 (64.0 MHz), $600.00 (128.0 MHz)
- $620.00 (256.0 MHz), $640.00 (512.0 MHz), $660.00 (1024.0 MHz)
- $680.00 (2048.0 MHz), $700.00 (4096.0 MHz), $720.00 (8192.0 MHz)
- [Specifications](#)

**VARIABLE POWER SUPPLIES**

- PP442: 12V 2A$112.00
- DP500: 50A 240V £500.00
- [Order Now](#)

**HIGH VOLTAGE Meters**

- [Details](#)

**DIGITAL CAPACITANCE METER**

- [Model Available](#)

**SPECIAL ORDER**

- DM500: 20 range 30kV £15,000
- [Model Details](#)

**MULTIMETERS**

- [Model Details](#)

**COMPONENTS**

- [List of Components](#)

**FREE CATALOGUES**

- [Free Catalogue](#)
Over the last few years we have received feedback via the general public and industry that our products are from Taiwan, Singapore, Japan, etc... ILP are one of the few 'All British' electronics companies manufacturing their own products in the United Kingdom. We have proved that we can compete in the world market during the past 12 years and currently export in excess of 60% of our production to over twenty different countries – including USA, Australia and Hong Kong. At the same time we are able to invest in research and development for the future, assuring security for the personnel, directly and indirectly, employed within the UK. We feel very proud of all this and hope you can reap some of our success.

I.L. Potts – Chairman

WE'RE INSTRUMENTAL IN MAKING A LOT OF POWER

In keeping with ILP's tradition of entirely self-contained modules featuring, integrated heatsinks, no external components and only 5 connections required, the range has been optimized for efficiency, flexibility, reliability, easy usage, outstanding performance, value for money. With over 10 years experience in audio amplifier technology, ILP are recognised as world leaders.

BIPOLAR MODULES

<table>
<thead>
<tr>
<th>Module Number</th>
<th>Output Power Watts</th>
<th>Load Impedance</th>
<th>DISTORTION @ 1KHz Type</th>
<th>I.M.D. (%)</th>
<th>M.O.S Module</th>
<th>Size (mm)</th>
<th>WT</th>
<th>Price inc. VAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>H5248</td>
<td>1-15</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(8.40)</td>
<td></td>
</tr>
<tr>
<td>H5124</td>
<td>1-15</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(9.55)</td>
<td></td>
</tr>
</tbody>
</table>


PRE-AMPLIFIERS

<table>
<thead>
<tr>
<th>Module Number</th>
<th>Output Power Watts</th>
<th>Load Impedance</th>
<th>DISTORTION @ 1KHz Type</th>
<th>I.M.D. (%)</th>
<th>M.O.S Module</th>
<th>Size (mm)</th>
<th>WT</th>
<th>Price inc. VAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HY5124</td>
<td>1-15</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(10.75)</td>
<td></td>
</tr>
<tr>
<td>HY5124</td>
<td>1-25</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>HY5124</td>
<td>1-35</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>HY5124</td>
<td>1-45</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>HY5124</td>
<td>1-55</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
</tbody>
</table>

Most preamp modules can be driven by the PSU driving the main power amp. A separate PSU 230, a casetogether plenty for these modules if required for £5.47. Preamp and mixing modules in 18 different varieties.

MOSFET MODULES

<table>
<thead>
<tr>
<th>Module Number</th>
<th>Output Power Watts</th>
<th>Load Impedance</th>
<th>DISTORTION @ 1KHz Type</th>
<th>I.M.D. (%)</th>
<th>M.O.S Module</th>
<th>Size (mm)</th>
<th>WT</th>
<th>Price inc. VAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOS125</td>
<td>1-25</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(10.75)</td>
<td></td>
</tr>
<tr>
<td>MOS240</td>
<td>1-35</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>MOS360</td>
<td>1-45</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>MOS480</td>
<td>1-55</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
<tr>
<td>MOS600</td>
<td>1-75</td>
<td>4-8</td>
<td>0.00% &lt;0.005%</td>
<td>1.15</td>
<td>76 x 68 x 40</td>
<td>240</td>
<td>(12.75)</td>
<td></td>
</tr>
</tbody>
</table>

Protection: Able to cope with complex loads without the need for any specific protection circuitry (fuses will suffice).


'NEW to ILP' Car Entertainmen

C15 Mono Power Booster Amplifier to increase the output of your existing car radio or cassette player to a nominal 15 watts rms.

Very easy to use.

Robust construction.

Mounts anywhere in car.

Automatic switch on.

Output power maximum 22w peak into 43.

Frequency response: 5-30kHz. Input sensitivity: 500mV rms.

Input impedance: 100K. Damping factor: 10KHz>400.

Size 95 x 48 x 50mm. Weight: 250g.

C15S stereo version of C15.

Size 95 x 40 x 80. Weight: 40g.
TOROIDALS

The toroidal transformer is now accepted as the standard in industry, overtaking the obsolete laminated type. Industry has been quick to recognise the advantages to offer in size, weight, lower radiated field and, thanks to I.L.P., PRICE.

Our large standard range is complemented by our SPECIAL DESIGN section which can offer a prototype service in within 7 DAYS together with a short lead time on quantity orders which can be programmed to your requirements with no price penalty.

**Gold service available. 21 days manufacture for urgent deliveries.**

**Orders despatched within 7 days of receipt for single or small quantity orders.**

**5 year no quibble guarantee.**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>SERIES</th>
<th>VA</th>
<th>Primary</th>
<th>Secondary</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 VA</td>
<td>0x101</td>
<td>6-6</td>
<td>1-2</td>
<td>1-2</td>
<td>£5.12</td>
</tr>
<tr>
<td>30 VA</td>
<td>1x101</td>
<td>6-6</td>
<td>1-2</td>
<td>1-2</td>
<td>£5.49</td>
</tr>
<tr>
<td>60 VA</td>
<td>2x101</td>
<td>6-6</td>
<td>1-2</td>
<td>1-2</td>
<td>£6.13</td>
</tr>
<tr>
<td>120 VA</td>
<td>4x101</td>
<td>6-6</td>
<td>1-2</td>
<td>1-2</td>
<td>£8.43</td>
</tr>
<tr>
<td>300 VA</td>
<td>7x101</td>
<td>6-6</td>
<td>1-2</td>
<td>1-2</td>
<td>£14.38</td>
</tr>
</tbody>
</table>

**NEW PRODUCTS**

**HYBRID REGULATOR MODULES**

The HR314 and HR614 regulators provide a constant 13.8 V d.c. output at up to 3 A or 6 A respectively. The modules are encapsulated into an integral heatsink and are fully short circuit protected making them suitable for home or bench running of C.B., car stereos or any 12 V d.c. equipment required for many hobby or professional applications.

HR314 £10.23 inc. VAT
HR614 £18.51 inc. VAT

**TECHNICAL SPECIFICATIONS**

- **Output Voltage:** 13.8 ±1%
- **Output Current:** 3 A approx.
- **Current Limit (max):** 12 A approx.
- **Maximum Input Voltage:** 250 V
- **Minimum Input Voltage:** 110 V
- **Maximum Input Voltage for nominal output current:** 110 V
- **Maximum output current at 30% input:** 12 A approx.
- **Output ripple (100 kHz):** See Note 1
- **Size:** 1 in. x 1/2 in. x 1/4 in.

**POWER SUPPLY UNITS**

Suitable for running one HR314 at full rated current: £13.17 inc. VAT
Suitable for running one HR614 at full rated current: £19.13 inc. VAT

For 110 V primary insert 0 in place of X in type number.
For 220 V primary insert 1 or 2 in place of X in type number.


Telephone (0207) 4178 Telex 009208

WIRELESS WORLD OCTOBER 1983

WVW - 019 FOR FURTHER DETAILS
OPUS AUTUMN OFFERS

JVC 14" COLOUR MONITOR OFFER

This month's offer is another winner - a consignment of 14" R.G.B. colour monitors manufactured by J.V.C. - at prices never seen before in the U.K.

Suitable for use with BBC Micro.

RGB MEDIUM RES £199


RGB HIGH RES £299


*** Case has PSU. Complete P.

 Hundred S.D. 200K D.D.

TEAC 55A

RGB prices never

* Fast ex-stock delivery.
* 1 year warranty.
* Quantity and Educational discounts available.

DISC DRIVE DISCOUNTS

* Japanese manufacture.
* Slimline * Low Power Consumption.
* Ideal for use with BBC, Dragon, etc.

Canon MDD 6106 S/S 40 Track
100K S.D. 200K D.D. £129.95
National Panasonic D/S 40 Track
200K S.D. 400L D.D. £159.95

TEAC DISC DRIVES

* Latest technology
* 1/2 height * Fast access time.
* Direct drive mechanism.
* Hardware 40/80 switchable.

TEAC 55A - S/S 40 Track
100K S.D. 200K D.D. £139.95
TEAC 50F - D/S 80 Track
400K S.D. 800K D.D. £229
Case to hold 1 drive £9.95
Dual case with PSU £39.95
P. Lead £5 Ribbon Lead £12
Dual Ribbon Lead £15

CASED DRIVES

Complete with all Leads and ready to run - Case has PSU.
* Dual 200K Drive £319.95
* Dual 400K Drive £349.95
* Dual 600K Drive as illustrated. 40/80 Switchable. 800K £499.95

ACORN D.F.S. NOW IN STOCK

OPUS 3" MICRODRIVE

NEW OPUS LOCK

The first nationally available dual sided 3" Drive offering 500K Capacity.

* 200K. Formatted S.D.
* 400K. Formatted D.D.
* Japanese Manufacture
* Fully compatible with 5¼" Drives
* One touch cartridge loading

Dual Drive * 400K/800K. Only £199

FREE on first 100 orders received

We will supply case and leads free of charge.

VIEW DATA TERMINALS PRESTEL

Built-in modern Slimline design

ONE YEAR WARRANTY 22 MHZ
Ex-stock delivery. Limited quantity
Phono Connector. Only
£69.95
Lead to connect to BBC £3.95

12" GREEN SCREEN MONITOR

ONLY £199 LIMITED QUANTITY
Green characters/black background 24 lines x 40 characters

NASHUA FLOPPY DISCS

Minis

S/S D/D £16.95 for 10
S/S D/0 £19.95 for 10
D/D D/D £22.95 for 10
D/D S/D £24.95 for 10
S/S 80 Track £14.95 for 10
D/S 80 Track £16.95 for 10

With full 5 year warranty. All mini discs have hub rings and a FREE plastic library case.

To Order: Add carriage at the following rates:
Discs B/S. Others goods (£) Add V.A.T at 15% to total and send your order to:
Opening Hours Mon.-Fri. 9-6
Sat. 9.30-1.30

OPUS SUPPLIES

158 Camberwell Road. London SE5 0EE
Tel: 01-701 8688 (3 lines) 01-703 6156/7

Government and Educational orders welcome

NOW TRADING 6 DAYS A WEEK.
VISIT OUR SHOWROOM.

Lynx, Oric, Apple II, Apple III and IBM etc.
It's safe to put a cheque in the post today. Because if you find someone who's cheaper, we'll refund the difference.

WWW.americanradiohistory.com
The persuaders

In the long term, it will probably be of benefit to the population as a whole to be aware of and familiar with "new technology". In a matter of a few years, people will, perhaps, come to accept the use of computers, interactive services, automatic manufacture and all the other aspects of life in the 'eighties. Maybe it will make for a happier life, given that jobs can be found or that the use of enforced leisure can be made productive. But whether a post-Orwell society is to be acceptable or not, it is disturbing to hear that the Government is to spend many thousands of pounds on persuading us that technology is good for us. And it is even more worrying that the money is to go towards the support of university research into the best ways of convincing the population that next year is only coincidentally 1984 — "...to secure greater acceptance of new technologies by developing their positive aspects and minimizing their negative aspects..." in the words of a DTI report.

Their new role of advisors on the techniques of public relations may possibly cause some of the researchers furiously to think. While it is generally conceded that the practical application of research is nowadays a praiseworthy object — in addition, of course, to pure research in the accumulation of knowledge with no immediate application — it is a legitimate view that scientists ought to be concerned rather more with defining the truth than with assisting the Government to manipulate it.

The acceptance or otherwise of technology by the public is a matter for the public itself to decide. Teach them the benefits, by all means, but do not try to conceal — "minimize" — the drawbacks. A home computer may well fill the leisure time of a lathe operator with transports of delight, gaining a whole-hearted convert to the concept of information technology. But when he discovers that just such a computer is going to operate his lathe and make him an ex lathe operator, he will not find it easy to listen to anyone wanting to minimize the negative aspect of his experience. He might even express the opinion that someone could, perhaps, have mentioned the possibility of redundancy to him before the event, instead of accentuating the positive and eliminating the negative.

What these social science researchers are being asked to do is suspect and should be examined very carefully before research contracts for the Government are taken on. The very most a scientist should do in these circumstances is to investigate the possible consequences of a comprehensive embrace of technology in all human activities and to lay the options before the public. Once the facts and all the prognoses are present, we need no accentuation or minimization of the truth to help us decide what kind of society we wish to live in. To suggest otherwise is to credit politicians with the possession of greater wisdom than 60 million of the rest of us — a proposition which some may be disposed to question.
Pure and applied

Recently the Royal Society organized a valuable one-day colloquium on research that brought together some 70 engineers, scientists and academics whose work contributes to either the commissions of the International Union of Radio Science (URSI) of the more down-to-earth study groups of the Consultative Committee (CCIR). This could be the forerunner of annual meetings to bring these pure and applied groups into closer touch with each other's work and objectives.

Whether such laudable aims will ever be met fully remains to be seen. The meeting made evident how wide a gap currently exists between research scientists and those concerned with the practical operation of systems for telecommunications, maritime and aeronautical radio, military systems and broadcasting. Neither side seems happy with the way the spectrum is parcelled out and the pecking order of research projects.

It is also clear that the impact of digital techniques is tending to distort the pattern of university and industrial training. Several speakers spoke of a growing shortage of radio-frequency and radio-propagation specialists, resulting from students and teachers preferring the mathematical certainties of digital electronics to the more vague, but often more challenging, analogue systems. Then again, r.f. propagation studies and research projects tend to involve time-scales appreciably more than three years and cannot be easily fitted into university courses.

The academics are also frustrated because the decisions of CCIR, spectrum regulation, etc., are seldom determined by the solutions of pure science, even when available, but more often by political and commercial considerations on the principle of 'the least objectionable to the greatest number'. Several speakers referred to the great gulf that exists between radio physics and practical applications. The academics stressed the difficulty of providing input to CCIR and other international groups. Those who cannot afford to attend the long CCIR meetings find their thoughts are overshadowed by "strong characters with their own pet ideas." Input from non-attenders is often wasted.

Using millimetres

Several of the speakers at the Royal Society meeting concentrated on the renewed interest in utilizing frequencies between 30 and 300 GHz, though paying tribute to the early pioneers such as Bose in India who carried out some surprisingly sophisticated work in the era of spark transmission. There was also renewed interest during the period 1947 to 1978 for the proposed tele-

communications trunk waveguide system, involving frequencies between 30 and 110 GHz, finally abandoned in 1978 in favour of optical fibres.

Free propagation is much affected by the absorption bands though, perhaps surprisingly, communications interest is often concentrated on the frequencies with especially high absorption. Such frequencies are ideal for short-range covert communications links that effectively are immune to detection, interception or jamming.

In a review of British and European firms working on millimetric components and systems, Patrick Sargeant (Marconi Research Centre) mentioned EMI at Wells, GEC Hurst Laboratories at Wembley, Philips at Redhill, Plessey at Caswell, EEE (scanning, noting that their work includes 25 GHz satellite systems (GEC-Stanmore), 35 and 95 GHz radar (EMI, Decca, Marconi, British Aerospace), 30 GHz British Telecom links, 40 GHz AEG-Telefunken railway communications, 30-900 GHz modelling techniques (EMI-Wells), 300-500 GHz receivers (ESA) and measurement techniques up to 1 THz at NPL.

Aerial puzzles

Almost every m.f. broadcasting station uses some variation of the vertical monopole aerial, with either a single omnidirectional element or a directional phased array, based on the classic work of Dr George Brown and his RCA colleagues in the 1920s. For h.f./v.h.f. communications, the quarter-wave element is often raised and the ground system of up to about 120 buried earth radials replaced by a few elevated and insulated radials.

One would have imagined that by now both theory and practice of such aerial systems would have been fully and unambiguously developed. Yet recently a surprising number of controversies have arisen.

For example, Archibald Doty, together with two other retired engineers in the USA, has shown the advantages of the once-popular 'counterpoise' or elevated ground screen, noting that currents flowing in buried radials are not, as conventionally postulated, uniform but depend upon ground conductivity in the immediate vicinity of the individual wires. Les Moxon has similarly shown the value of counterpoise systems and has also drawn attention to the common misconception that the input impedance of a groundplane antenna with horizontal radials is 36 ohms, the same as for grounded monopoles with an extensive earth system; he notes that Brown's original papers showed clearly that the correct figure was nearer 18 ohms, though this was subsequently overlooked in many later standard textbooks.

Helically-wound loops

For many years there have been determined efforts to improve the radiation efficiency of miniature h.f. transmitting aerial elements. Loading coils, top-hat capacitances, folded elements, ferrite-loaded elements, single-turn and multi-turn small loops, the normal-mode helix: all these and other techniques have been used with some degree of success, but all imposing compromises.

In theory any element, no matter how small in terms of wavelength, can radiate all the power fed to it; in practice severe difficulties are experienced in feeding energy into a short element without losing most of the energy in the coupling networks, incurring significant power losses due to the very low radiation resistance relative to ohmic losses, and the narrow bandwidth of high-Q elements.

Alec Clelland, DJOFL/G3UQ, has drawn my attention to a recently published European Patent Application (EP 0 043 591 A1) by James F. Corum of West Virginia. This covers a large family of aerials based on the reduction in size of a full-wave loop element by winding it helically in the form of a torus. The conductor is configured to establish a closed standing wave path to inhibit the velocity of propagation and support a standing electromagnetc wave. The inventor claims that although such elements can have a much smaller physical size than existing aerials they possess greater radiation resistance and hence greater efficiency than conventional loop aerials of similar size, and can radiate controllable mixtures of vertically, horizontally and elliptically polarized waves. He describes practical examples of such aerials for use from l.f. to v.h.f., using circular and square loops for broadcast, communications, amateur radio and c.b. frequencies. Bandwidth, however, would appear to remain restricted.

Hazards

The American Center for Disease Control, Atlanta, has recently warned that many r.f. dummy loads manufactured as recently as the late 1970s used cooling oil containing polychlorinated biphenyls (PCBs), a man-made chemical that has been linked with liver cancer. Even fumes from a hot-running load are stated to be dangerous in poorly ventilated situations.
PCBs were used in the UK for about 40 years until 1977 in oil-cooled transformers, high-voltage and fluorescent-lamp capacitors, dummy loads, etc.

A legal battle in New Jersey is centred on the question of possible health hazards from hand-held transceivers. General Electric (US) is being sued by the father of a 14-year-old boy, who alleges negligence in not providing the warning recommended by the US federal government in 1973. If the claim succeeds, American amateurs fear the case could be used as a basis for local authority legislation that might severely restrict the use of hand-held amateur radio. It is generally believed that hand-portables with an output of less than about 5 watts can be used without risk, even with short-normal-mode helix aerials not far from the eyes.

Aerial tower restrictions in Burbank, LA, remain the best legal restraint on radio amateurs on the grounds that they represent a violation of constitutional rights of free speech and civil rights.

**Here and there**

An American study by International Research Development foresees the development of combined power and fibre optics cables which would carry into homes not only TV programmes and all interactive telecommunications but also electric power. The power cable would provide the necessary supportive package for the fragile glass fibres.

An investigation by NHK of Japan into the feasibility of introducing a s.s.b. into h.f. broadcasting suggests that in a transition period the carrier could be reduced by 6dB to permit continued use of envelope detection. Later 12dB suppression would be used with synchronous detection. Tests on television paths have underlined the advantages of s.s.b. including lower susceptibility to selective fading distortion. Carrier suppression of more than 12dB, however, would lead to degradation of quality due to the difficulty of achieving carrier reconstruction for synchronous demodulation.

Recently I reported the use by 50 American stations of the Harris linear a.m.-stereo system: by early summer the number had risen to 67, but the more interesting development is that this includes 10 m.f. stations in Australia and New Zealand, and also Radio Mundo Brazil.

RCA chairman, Thornton F. Bradshaw, has established a $100,000 grant for the electrical engineering department of Purdue University in memory of television pioneer Dr Vladimir Zworykin who died last year at the age of 92. Zworykin received more than 120 U.S. patents ranging from television to medical electronics.

**Return to Post Office**

On the day following the publication of the Merriman Report, the Department of Trade and Industry announced the transfer, from September 19, of amateur radio licensing to the Post Office from the Radio Regulatory Division, now part of DoTT. This is expected to lead quickly to computerization of the records and to reduce the time in dealing with applications to a maximum of ten days at peak times and five days normally. Applications will be processed by post when sent to: Radio Amateur Licensing Unit, Chetwynd House, Chesterfield, Derbyshire S49 1PF (telephone Chesterfield (0246) 207555) who will also issue the application forms. Amateur radio was administered by the Post Office for many years until the setting up of the short-lived Ministry of Posts and Telecommunications.

While most amateurs, particularly those who have recently passed their RAE, will welcome the promised speed up in licensing process, there is some fear that this change is a further step towards making amateur radio ‘up-market c.b.’ as a form of revenue-collecting, leisure-time hobby rather than at least to some degree a self-training and experimental service of technical investigations in support of radio science and technology. The vast increase in licences over the past decade to 48,000 reflects the introduction of the Class B v.h.f.-only licence and the multi-choice form of RAE, combined with the complete absence in the UK of any form of incentive licensing.

With the majority of its licensed members now holding the Class B licence, RSGB policy appears to be changing. The 1983 president Don Baptiste, CBE, is on record as stating “the Class B permit is in no way to be regarded as inferior to the Class A version but simply reflects an interest in v.h.f./u.h.f. technique rather than in h.f.-bands communications”. The Society claims there is “little or no demand” for a novice licence intended to encourage training in Morse. A number of Class B members are lobbying for the society to support code-free licences for h.f. operation.

85% of “optimum”

In the August “Letters to the Editor”, Paul Thompson suggested that I was mistaken in believing that the Woodpecker roughly follows the m.u.f., and thought it more likely that the troublesome over-the-horizon radar follows the “optimum traffic frequency” (f.o.t.). While I am not privy to the Russian procedures, I believe this suggestion arises from a common misconception of the definition of f.o.t. Far from being a true “optimum frequency” it is a purely notional frequency, usually taken as 85 per cent of the m.u.f., in order that h.f. communications links are not disrupted by the considerable daily and hourly variations and errors in the predicted values of the m.u.f. A frequency-agile system such as the Woodpecker, that disregards IFRB frequency assignments and Radio Regulations, would clearly be made more effective by keeping as near to the m.u.f. as possible. It is indeed a typical piece of misplaced engineering jargon that defines f.o.t. as the optimum frequency!

There is, however, an important exception to the idea that one should always use the highest possible frequency for a specified path. This is for around-the-world “long-path” transmissions where using the daylight m.u.f may result in much less favourable propagation than using a “darkness” or grey-line chordal-hop path at much lower frequencies. A good example is to be found in using 10 or 14-MHz bands to contact Australia in the European mornings even when the daylight m.u.f. may well be above 21MHz.

**In brief**

Headquarters station of the RSGB at Potters Bar, normally GB3RS, is additionally using the call GB3WCY (World Communication Year) on Friday afternoons until the end of 1983, mostly on the 7MHz band... American amateurs are no longer legally required to keep a detailed station log, one result of F.C.C. “deregulations”... Ray Crabtree GB2J, GB3J and GB3WCY, the n.b. operator and transequatorial propagation pioneer, whose efforts to renew his British amateur licence were noted in the July issue is, after all, being granted his old G2AUX licence without having to take the RAE and Morse test... The next Radio Amateurs Examinations will be on December 5, 1983; March 19 and May 14, 1984... RAE courses and/or Morse classes are starting this September in a number of further education centres, etc. RAE classes at Basildon, Birmingham, Colwyn Bay, Crawley, Derby, Dudley, Durham, Heckmondwyke, London (Acton and Brixton), Manchester, Melton Mowbray, Newcastle-upon-Tyne, Newquay, Nottingham, Orpington, Morley, Portsmouth, St Austell, Stamford, Turingford, Walsall, Wakefield and Wittingey; Morse classes at Bromsgrove, Cheshunt, Grantham, Heckmondwyke, London (Acton, Beckenham) and Manchester... The Midlands VHF Club were guests at the British Telecom Training School, Stone, Staffs on Saturday, October 15...

PAT HAWKER, G3VA
Strain-gauge weighing scale

A range of 0.1g to 1kg, with a high degree of linearity and low drift, is obtained from a novel, simply made load cell and an improved d.c. amplifier. The instrument will also measure temperature, using a thermocouple.

The old familiar swinging arm balance has now almost entirely disappeared from our shops and laboratories, to be replaced by electronic weigh scales with fixed-position pans and digital displays, a change which will be regretted by very few of those who have to use them in the course of their work. Such a scale is a very convenient thing to have around the house - though at the moment, rather expensive.

Since one of my hobby interests is photographic chemistry, in which the weighing out of chemicals for various processing solutions is a frequent activity, my thoughts have turned from time to time towards the construction of such an instrument. In the consideration of this, my view has been coloured by the relatively limited facilities and skills which are at my disposal in the mechanical field, and the solution which I have adopted has therefore tended to favour electronic rather than mechanical complexity. Manufacturers would choose a different compromise - but then they are not contemplating a one-off exercise.

The basic elements of an electronic balance, to give it its more usual name, are a load cell, some form of electronic amplifier having zero and gain adjustment facilities, and a digital display system. Since digital display elements are now readily available commercially, at a sensible price, this part of the task presents no problem. The load cell is a different matter, alas, and my own searches through manufacturers lists did not disclose any suitable cell at less than several hundred pounds in cost, which would defeat the purpose in mind.

The methods available for determining the weight of a body placed on a weighing pan fall into three broad categories: a simple strain gauge load cell; a pan suspended on a spring mount with a linear displacement transducer attached to the suspension so that the displacement under load produces a suitable signal output; and a force balance of some kind, such as an electromagnetically energised solenoid in which a magnetic plunger is held against the applied load by electromagnetic force, its position being held substantially constant by some closed-loop servo-system based on a position sensing element, which increases the current through the solenoid, as the load increases, to maintain the status quo.

Other systems have been employed for this purpose, such as those based on a resonant element whose period of artificially sustained low-level oscillation changes as the mass on the weighing pan is altered, but the three listed above represent the main stream of electrical weighing systems.

Of the methods listed, undoubtedly the spring system with a displacement transducer would have the greatest ability to withstand overloads and misuse, but of the non-contacting displacement transducers, the linear differential transformer is the most suitable, and this is an element which would be difficult to construct for oneself while preserving adequate linearity. The idea of using a differential grating, with a photocell, and simply counting the alternating cycles of light and dark was a beguiling one, but the finest grating easily available (old Dufaycolor reseau) offered only 40 l/mm, and if a range of 10,000:1 or even 1000:1 was sought, the displacement would need to be substantial, with consequent problems of linearity.

Similarity, with a desired maximum load of 1kg, a suitable solenoid for a force balance would need to be a massive one. I therefore returned to the consideration of possible strain-gauge systems which might possibly meet the basic specification of a measuring system which would operate over the range 0-1kg, with a sensible resolution of 0.1g. To avoid the need for any sophisticated engineering in the suspension system, it was desired that there should be no moving or pivoted elements, and that the total suspension should be of the taut wire form.

These considerations led to the evolution of the structure shown in Fig. 1. In this a pair of fixed members A-A served as anchor points for resistance wire elements MM, NN, SS, TT, connected to the central moveable bush B and C urged outwards to tauten the wire elements by the tensioning screw Z. Under a

by John L. Linsley Hood

Fig. 1. Wire load-cell principle. Anchor ring A is fixed, B and C move and vary tension on wires.

Fig. 2. Connection of wire elements to form Wheatstone bridge.

Fig. 3. One side of load cell. Where wires MM and NN cross, plastic film used for insulation.

One of four mounting pillars

Mounting holes

Anchorage pins

Thin polythene under & between wires

Wires MM and NN intersect at N-N cross, plastic film used for insulation.

Fig. 4. Completed cell.

WIRELESS WORLD OCTOBER 1983
downward load \( W \), the elements MM and NN become less taut, and the elements SS and TT become tighter. If then, the four elements are connected in the Wheatstone bridge form shown in Fig. 2, there is a resultant electrical unbalance, and a measurable output voltage if a load is applied to B-C.

In a practical form, the member A-A is an annular ring and B and C are smaller discs mounted in the centre of this, as shown in the plan view of Fig. 3. In the prototype, the strain gauge element was made from a 4\times 4\text{in} square of \( \frac{3}{8}\text{in} \) 'Perspex' sheet, from which the outer ring, 4\text{in} o.d., and 3in i.d., and the two inner bushes each \( \frac{3}{4}\text{in} \) o.d. were cut. A series of 14 1.3\text{mm} holes was then drilled, uniformly around the periphery of the inner bushes, and a corresponding series of 12 similar holes, plus two pairs of tapped holes to hold solder tags, was then made in the outer ring, so that the whole could be strung with resistance wire, as also shown in Fig. 3. The wire starts and finishes at the soldering points, and is looped around standard Vero type solder pins inserted into the holes, and anchored there by applying a hot soldering iron to the head of the pins so that they move inwards under the influence of the applied heat and pressure, and cause the softened Perspex to grip them firmly, when it cools.

The mechanical structure of this load cell is shown in Fig. 4, and the central bushes, in 'exploded view', in Fig. 5. The tensioning screw \( T \) was made from an M8 steel, and its head was covered by a polythene diaphragm, secured in place by a set screw, to the head of which a piece of \( \frac{3}{4}\text{in} \) brass spindle was soldered, with a screw slot on the lower end to allow it to be rotated to tension the wire elements.

After some inward debate, supported by experiments, it was decided to make the wire elements from 44s.w.g. Nichrome, obtainable (if one is patient) from the Scientific Wire Co., of London E4. Strain gauges are usually made from one of the zero temperature-coefficient Cu-Ni alloys, such as 'Eureka' or 'Constantan.' However, Nichrome has a higher specific resistance, which is helpful, and is very much stronger, which avoids the aggravation of the wire breaking during the threading up.

A relatively crude test suggested that the breaking strain of the 44s.w.g. Nichrome is in excess of 1kg, so that if the angle of the wire elements to the horizontal is 20\(^\circ\), and there are 28 of these bearing the downward load, the cell should carry 28\times \text{sin} 20^\circ \text{kg} (less the pretensioning force, say 1.2kg) before rupture. Since this is some 8.3kg, it would appear that the structure would be adequately strong for its purpose. As even finer wire, such as 46s.w.g., would undoubtedly be usable, with a higher gauge output, if the awkwardness of handling such a fine wire could be tolerated. Some form of jig such as shown in Fig. 7, to hold the central bushes in position is essential during threading. The load cell must be exercised both to ensure that the loops of wire sit against the Perspex at the base of the pins, and that the threading tension is the same on both sides of the annulus. Otherwise, when the tensioning screw is tightened up, the screw will tilt over at an angle to the vertical, which will impair the performance of the bridge. It is well to be reconciled to the probability that one will have to go through this exercise several times before achieving a reasonably satisfactory result, and it is prudent to refrain from cutting off the stray ends of the wire until the result has been passed as satisfactory.

As constructed, the bridge elements each have a resistance of about 100 ohms, and with a bridge supply of approx. \( \pm 3.4 \text{volts d.c.} \), the d.c. output is of the order of 2mV/100g. With a display having a sensitivity of 199mV, so that 100mV would be equivalent to 100g on the 0-150kg range, an amplifier gain of about \( 50 \times \) is required. Although something a bit better than the standard '741' is needed as the amplifier element, there are some very good i.e. op-amps available which have negligible noise or drift under these conditions. The extra complexity of an a.c. energized bridge and synchronous demodulator was not therefore thought to be worthwhile. In fact, the major source of long- and short-term drift is in the thermal sensitivity of the strain-gauge element due to the physical separation of the four component arms of the bridge. To combat the adverse effects of random movements of air within the strain gauge, two thin polythene diaphragms are placed under the position of the wires before the strain gauge is threaded up, and in the final model, the whole gauge was enveloped in a single layer of cling film on top of the wire elements. This was helpful.

The choice of 46s.w.g. for the elements would increase the bridge sensitivity by some \( 1.76 \times \), and would give an element resistance of about 175 ohms, which would reduce the gauge dissipation from 460mW to 240mW and help lessen thermal effects. To lessen the extent of the sensitivity of the strain gauge to lateral components of the downward force, due to unsymmetrical loading of the pan, the top of the gauge is coupled to the pan support by a steel pin, sharpened to a point at both ends, held between a conical hole in the centre of the top plate and the bottom of the hole drilled in the tensioning screw, as shown in Fig. 6. The top plate itself is then held against lateral movement by a 'spider' made from three webs cut from 0.002in brass shim, anchored at the edge of the plate in which a suitable aperture has been cut to allow the upper scale plate to be accessible.

In my own instrument, the circular strain gauge, the electronics, power supply and display unit were mounted in a 8.5\times 5.5\times 2in diecast box, with the top balance plate and coupling linkage housed on top of it, as shown in Fig. 8. Although I feel that the choice of the positions within the box in which the separate components are to be mounted can well be left to the judgment of the constructor, the layout which I adopted was to have the display element mounted at the front of the upper face, with the main zero-adjust knob below this. The other controls were grouped on the right-hand side of the box, for the convenience of a right-handed user, and some space was left at the rear for a small, internally screened, compartment to house the power supply transformer, rectifiers and reservoir capacitors. This then left an unoccupied left-hand wall on which the small electronic amplifier panel, assembled, on a piece of 0.1in perforated 'Vero' strip board, could be mounted on short, threaded stand-off pillars.

The unit was then finished, mechanically, by four stick-on rubber feet on the detachable lid which forms the base of the lower box, and a disc of cork was then stuck on to the upper pan plate to provide a small degree of mechanical shock isolation to the strain gauge element from items dropped upon the pan.

**Electronics**

As mentioned above, my deliberate choice in this design was to use the simplest practicable mechanical load measuring element and to accept the extra complexity which this would impose upon the electronic circuitry used with this. Inevitably, the problems in d.c. amplification, from such low-output signal levels as those from a strain gauge bridge,
centre around the presence of zero drift. With modern i.c.s, this need not be due to inadequacies in the d.c. amplifier itself, but will arise in respect of the input signal.

The inevitable difficulty due to differential thermal effects upon the resistance wires of the load cell has already been mentioned. This can only be minimized by restricting air movement within the weigh scale housing, by using a well-sealed container box, and within the strain-gauge element by the use of thin polyethylene diaphragms interleaving the windings to diminish internal air cooling effects. Fortunately, in my experience using the prototype, this only affects the long-term zero setting, which is adequately stable during any one weighing for the

beginning and end zero readings to be the same within the ±0.1g basic uncertainty of the reading.

However, there is a more insidious difficulty, due to random excursions of the voltage of the + and −5V supply lines. With a 2mV/100g bridge sensitivity, the required 0.1g zero stability represents 2µV. Using the standard ±5V i.c. regulators as the basic bridge supply brought home to me that random fluctuations of a few mV in their output potential, could represent common-mode voltage swings of a few mV at the output terminals of the bridge. To achieve the required input voltage stability of better than 2µV demanded a common-mode rejection capability from the d.c. amplifier of some 70-80dB. This was much greater than attainable from a low-drift op-amp used in the conventional differential amplifier mode. The first improvement in the performance of the system was therefore made by the use of a separate d.c. supply system for the negative line, shown in Fig. 9, in which the operation of the circuit is such that a negative supply is generated which closely matches, in opposite polarity, any random excursions of the positive supply line, as seen at the strain gauge bridge pick-off point at the junction of R13 and C10.

The second circuit improvement relates to the design of the d.c. differential amplifier itself, shown in Fig. 10. The
normal 'instrumentation amplifier' layout employs two i.c.s. (as IC1 and IC2) arranged to have a high gain to signals applied differentially to their inputs, but unity gain in respect of signals applied equally to both. A third i.c. op-amp is then used as a differential amplifier to reject the residual common mode output.

Unfortunately, it is impracticable to employ negative feed-back around such an op-amp differential amplifier without making the two inputs unsymmetrical, in that there is a higher gain from the non-inverting input than from the inverting one. Conventionally, this shortcoming is remedied by inserting an attenuator network in the non-inverting input limb, but this would only work for a fixed-gain stage as the differential amplifier, and would prejudice the use of this stage as an active integrator to slug the response of the circuit to unwanted i.f. noise.

In the improved arrangement shown, an additional inverting stage IC3(b) (±LVF353) is inserted in one of the output limbs from the input differential amplifier pair, so that IC1(b) can be used as a summing amplifier, in which common-mode signals, now presented in opposition, will cancel at the 'virtual earth' input point, while differential signals will be added at this point. There is then no difficulty in making the gain of IC1(b) adjustable for providing the necessary full scale calibration adjustment on the 0-100g scale, and in putting a suitable value integration capacitor (C2) across this i.c. to give a suitably 'dead-beat' response to the weight scale reading. This is advantageous when weighing up chemicals by pouring them into the pan, since they are likely to be lumpy, which would give an apparently jerky character to the meter reading.

The 0-100g and 0-1kg scales are switched by an output attenuator on the output of IC1(b), rather than by switching VR4, to avoid shifts in the d.c. zero from one range to the other. If suitable facilities are available for determining resistor values, R3 and VR5 could be replaced by a fixed 10k resistive attenuator. With the 0-0.19999V digital panel meter unit employed, it was possible to switch the decimal point so that the 100g range read 100.0g and the 1kg range read 1000g, as the scale was switched.

A small 6VA 6-0-6V mains transformer powers the unit, feeding a pair of 5V i.c. voltage regulators to provide a stable voltage line for the i.c.s and the bridge, unaffected by mains voltage fluctuations, and a i.e.d. is fed from the positive 5V line to warn that the unit is on.

Any convenient and suitable transistors can be used for Tr1 and Tr2, IC1 and IC2 should be a low-drift, low-noise i.c. type. In the prototype I have used the excellent OP-27 types, available from Precision Monolithics Inc., (Bourns in UK) because I had a pair of these to hand, though there is little doubt that other, less expensive, instrumentation type low-drift operational amplifiers, such as the LM725, would serve equally well. With these i.c.s, the zero stability, with both inputs taken to 0V, is well within the 0.1mV output requirement over a period of 24hr, which vindicates the original decision to use a d.c. energized bridge, in that the residual problems due to differential thermal effects in the strain gauge would be presented equally in an a.c. energized system. The d.c. systems avoids difficulties due to inadvertent signal coupling through wiring stray capacitances. The circuit of the complete weigh-scale amplifier is shown in Fig. 11.

Temperature compensation

Although the bridge system is very nearly fully symmetrical, inadvertent asymmetries in the mechanical construction, coupled with the physical changes, due to thermal effects, of the structure of the load cell, lead to a negative temperature coefficient in the prototype of some 5°C. A first-order compensation for these is provided by the thermistor/resistor network across the limb of the bridge feeding the non-inverting input.

Use and setting up

As indicated earlier, it is probable that one's first attempt(s) at wiring up the strain gauge element will be less good than those made when one has gained a little more familiarity with the problems involved in getting the wires to sit in the required positions and with uniform tension when the tensioning screw is tightened. Fortunately, with a suitable jig to hold the separate parts of the strain gauge while the wire is applied, it doesn't take too long to pull it apart and try again. So, it is sensible to build the electronic amplifier and power supply unit before one makes the load cell so that this can be tested after it has been assembled.

A slightly discomforting effect, initially, is the way in which the output signal will vary up and down, in a random manner, after the tensioning screw is adjusted, or readjusted, as the tensions in the individual wires in the strain gauge rosette accommodate to one another by slipping round the anchoring pins. This process can be speeded up a bit by gently tapping the tensioning screw, but ultimately one must just be patient and wait a few hours for the load cell to settle down again. This accommodation of the individual wires to a state of uniform tension is also responsible for the hysteresis (failure of the gauge to return to zero after a load has been applied and removed) which is an annoying feature commonly found in freshly constructed load cells. Normally this effect will progressively lessen as weights are applied and removed during the calibration process of setting VR4 and VR5, for appropriate f.s.d. readings.

If hysteresis persists, one must conclude, with regret, that the strain gauge cell has not been built adequately well, and have another go. In the prototype, the hysteresis is now, after some time in use, of the order of 0.2g following an applied load of 200g. I have, I think, in the course of developing the prototype, rebuilt the load cell five times, though some of these were in the pursuit of hoped-for design improvements. I still have the feeling that I could make it a bit better, to equal the performance given by one of the earlier versions, where I had got the wire tension particularly uniform.

The static tension applied to the wires by the tensioning screw should be adequate to make the gauge linear over the range of loads which it is desired to apply: further tightening is of no benefit.

In use, the zero adjust pot. VR5 and the fine zero adjust pot. VR6, both of which are 10-turn type, should be set to a position near to their mid point. The 10R coarse zero-adjust pot. (VR2) should be adjusted, slowly, until the reading is somewhere within ±100gms on the 1kg scale range. The zero set pot. VR1, in parallel with VR2 can then be adjusted to set the meter reading within the ±2gms range covered by the fine zero control,

![Fig. 12: Stability is such that temperature measurement can be carried out. Circuit shows offset voltage source and input switching.](www.americanradiohistory.com)
which is the normal operating zero control of the instrument.

The linearity of the prototype, when checked against a set of good-quality chemical balance weights, was within 0.2% over the range 0-250gms, with the major contribution to this being the small remaining hysteresis. It is probable, therefore, that the scales could be set up adequately by pouring a measured quantity of water into a suitable vessel mounted on the weighing pan, in the absence of appropriate calibrated weights, without incurring unacceptable errors in intermediate readings.

Adjusting temperature compensation
As mentioned above, because the final strain-gauge load cell, in the prototype, was not completely symmetrical, there is a residual long-term sensitivity to changes in ambient temperature, which require the zero to be reset more often, in day to day use, than is desirable. A simple thermistor compensation circuit is therefore connected across the +3.4V supply and an input to the amplifier. (Which input is required will depend on the final strain-gauge temperature characteristics, which will depend on its construction.) The easiest way to adjust the trimmer resistor VR3, is to put the whole instrument in a refrigerator, and then, after removal, as it warms up to room temperature, adjust VR3 so that the scale reading drifts neither up nor down.

The total power consumption of the instrument is less than 2 watts, and there is no detectable change in the temperature of the housing, compared with the ambient, over a 12 hour period. To prevent errors due to air currents entering the instrument holding up to 500 longer words which can be adapted to the requirements of the individual: words which would normally call for 14 or more pushes can thus be produced with four or five.

For more elderly patients there is another mode of operation, simpler to use but slower; and for children who have not yet learned to read there is even a sort of video game designed to familiarise them with the box and its method of operation.

The output of the box is available in RS232 serial code for connection to a printer. Power comes from a built-in rechargeable battery giving 11 hours of continuous operation and the unit has an energy-conserving standby mode to which it reverts when not in use.

Wheelchair word-processor
This communications aid for the disabled is not an entry for our competition, but it does show the sort of results that can be achieved by volunteers working to a restricted budget. Designed for those whose faculty of speech is impaired or perhaps lacking altogether, the writing box can be produced in a variety of configurations to match the needs of the individual user. The device is the work of a non-profit-making group in Belgium and costs around £300.

The liquid-crystal display shows four lines of 40 characters, while for longer texts there is memory capacity for up to 6500 characters. Writing and editing is possible using a keyboard, although users with a lesser degree of dexterity can choose from a range of unusual input devices including foot switches, eye-movement detectors, blow pipes and sound-operated switches.

The fourth line of the display can act as a menu to help in obtaining the right characters; and a subtle feature of the unit is the capability for storing and displaying messages defined by the user. For example, three switch-pushes might produce "lift me up a bit, please". In addition to this, there is a word memory
Many designers have not, until recently, considered op-amps a suitable choice for preamplifier designs of the very highest quality. Newer types now obtainable have changed this and Doug Self's new design exploits the 5534 op-amp.

Until relatively recently, any audio preamplifier with pretensions to above-average quality had to be built from discrete transistors rather than integrated circuits. The 741 series of op-amps was out of the question for serious audio design, due to slew-rate and other problems, and the TL071/72 types, though in many ways excellent, were still significantly noisier than discrete circuitry. In an article some years ago I attempted to show that it was still feasible to better the performance of such devices by using simple two or three-transistor configurations.

The appearance of the 5534 low-noise op-amp at a reasonable price, has changed this. It is now difficult or impossible to design a discrete stage that has the performance of the 5534 without quite unacceptable complexity. The major exception to this statement is the design of low-impedance low-noise stages such as electronically-balanced microphone inputs or moving-coil head amplifiers, where special devices are used at the input end.

5534 op-amps are now available from several sources, in a conventional 8-pin d.i.l. format. This version is internally compensated for gains of three or more, but requires a small external capacitor (5-15pF) for unity-gain stability. The 5532 is a very convenient package of two 5534s in one 8-pin device with internal unity-gain compensation, as there are no spare pins.

The 5534/2 is a low-distortion, low-noise device, and a typical audio stage could be expected to generate less than 0.005% t.d.b. over the range 1kHz-20kHz, leaving the residual distortion lost in the noise of all but the most expensive analysers. Noise performance obviously depends partly on external factors, such as source resistance and measurement bandwidth, but as an example consider the moving-magnet disc input stage shown in Fig. 3. When prototyped with a TL071, the noise (with a 1k resistor input load) was -69dB with reference to a 5mV r.m.s. 1kHz input. Substituting a 5534 improved this to -84dB, a clear superiority of 15dB.

Another advantage of this device to the audio designer is its ability to drive low-impedance loads (down to 500 ohms in practice) to a full voltage swing, while maintaining low distortion. This property is much appreciated by studio mixer designers, whose output amplifiers are still expected to drive largely fictitious 600 ohm loads. As a comparison, the TL071 is only good for loads down to about 2kΩ.

Architecture
As explained in a previous article, the most difficult compromise in preamp design is the distribution of the required gain (usually at least 40dB) before and after the volume control. The more gain before the volume control, the lower the headroom available to handle unexpectedly large signals. The more gain after, the more the noise performance deteriorates at low volume settings. Another constraint is that it is desirable to get the signal level up to about 100mV r.m.s. before reaching the volume control, as tape inputs and outputs must be placed before this. The only really practical way to get the best of both worlds is to use an active gain-control stage—an amplifier that can be smoothly varied in gain from effectively zero up to the required maximum.

If the input to the disc stage is a nominal 5mV r.m.s. (assumed to be at 1kHz throughout the avoid confusion due to RIAA equalization) from either moving-magnet cartridge or moving-coil head amp, then 26dB of gain will be needed to give the 100mV which is the minimum it is desirable to offer as a tape output. This can easily be got from a single 5534 stage, and taken together with the supply rails (±15V) this immediately fixes the disc input overload at about 320mV r.m.s. A figure such as this is quite adequate, and surpasses most commercial equipment.

One must next decide how large an output is needed at maximum volume for the 5mV nominal input. 1V r.m.s. is usually ample, but to be certain of being able to drive exotic units to their limits, 4V r.m.s. is safer. This decision is made easier because using an active gain-control frees us from the fear of having excessive gain permanently amplifying its own noise after the volume control. Raising the 100mV to this level requires the active gain stage to have another 26dB of gain available; see the block diagram in Fig. 1.

The final step in fixing the preamp architecture is to place the tone-control in the optimum position in the chain. Like the most Baxandall stages, this requires a low-impedance drive if the response curves are to be predictable, and so placing it after the active gain-control block (which has the usual very low output impedance) looks superficially attractive. However, further examination shows that (a) the active-gain stage also requires a low-impedance drive, so we are not saving a buffer stage after all, and (b) since it uses shunt feedback the tone-control stage is rather noisier than the others, and should therefore be placed before the gain control so that its noise can be attenuated along with the signal at normal volume settings. The tone-control is preceded by a unity-gain buffer stage with low output impedance and a very high input impedance, so that the load placed on line input devices does not vary significantly when the tape-monitor switch is operated. This brings us to the block diagram in Fig. 1. Figure 3 shows the circuit diagram of the complete preamplifier. The components by D. Self

---

Fig. 1. Block diagram. Tone-control placed before gain-control block to reduce noise from tone-control.
around A₁ and A₂ make up the moving-magnet disc stage and its associated subsonic filter. Disc preamp. stage A₁ uses a quite conventional series feedback arrangement to define the gain and provide RIAA equalisation. This provides a clear noise-performance advantage of 13dB over the shunt feedback equivalent, which is sometimes advocated on the rather dubious grounds of “improved transient response”. The reality behind this rather woolly phrase is that the series configuration cannot give the continuously descending frequency response in the ultrasonic region that the RIAA specification seems to imply, because its minimum gain is unity. Hence sooner or later, as the frequency increases, the gain levels out at unity instead of dropping down towards zero at 6dB per octave. As described in refs. 1 and 2, when a low-gain input stage is used to obtain a high overload margin, “sooner” means within the audio band, Fig. 2. Fig. 3. Complete circuit diagram. Decoupling capacitors for i.c.s must be close to packages.
and so an additional low-pass time-constant is required to cancel out the unwanted h.f. breakpoint; once more it is necessary to point out that if the low-pass time-constant is correctly chosen, no extra phase or amplitude errors are introduced. This function is performed in Fig. 3 by R₆ and C₁₂, which also filter out unwanted ultrasonic rubbish from the cartridge.

It was intended from the outset to make the RIAA network as accurate as possible, but since the measuring system used (Sound Technology 170 A) has a nominal accuracy of 0.1dB, 0.2dB is probably the best that could be hoped for. Designing RIAA networks to this order of accuracy is not a trivial task with this configuration, due to interaction between the time-constants, and attempting it empirically proved most unrewarding. However, Lipshitz, in an exhaustive analysis of the problem, using heroic algebra in quantities not often seen, gives exact but complicated design equations. These should not be confused with the rule-of-thumb time-constants often quoted. The Lipshitz equations were manipulated on an Acorn Atom microcomputer until the desired values emerged. These proved on measurement to be within the 0.2dB criterion, with such errors as existed being ascribable to component tolerances.

Design aims were that the gain at 1kHz should be 26dB, and that the value of R₁ should be as small as feasible to minimize its noise contribution. These two factors mean that the RIAA network has a lower impedance than usual, and here the load-driving ability of the 5534 is helpful in allowing a full output voltage swing, and hence a good overload margin.

There is a good reason why the RIAA capacitors are made up of several in parallel, when it appears that two larger ones would allow a close approach to the correct value. It is pointless to design an accurate RIAA network if the close-tolerance capacitors cannot be easily obtained, and in general they cannot. The design is one of the well-known Suflex range, usually sold at 2.5% tolerance. These are cheap and easy to get, the only snag being that 10nF seems to be the largest value widely available, and so some paralleling is required. This is however a good deal cheaper and easier than any other way of obtaining the desired close-tolerance capacitance.

Metal-oxide resistors are used in the RIAA network and in some other critical places. This is purely to make use of their tight tolerance (1% or 2%), as tests proved, rather unexpectedly, that there was no detectable noise advantage in using them.

The recently updated RIAA specification includes what is known as the "IEC amendment". This adds a further 6dB/octave low-cut time-constant that is -3dB at 20.02Hz. It is intended to provide some discrimination against subsonic rumbles originating from record warps, etc., and in a design such as this, with a proper subsonic filter, it is rather redundant. Nonetheless the time-constant has been included, in order to keep the bottom octave of the RIAA accurate. The time-constant is not provided by R₅, C₈ which is no doubt what the IEC intended, but by the subsonic filter, a rather over-damped third-order Butterworth type designed so that its slow initial roll-off simulates the 20.02Hz time-constant, while below 16Hz the response drops very rapidly. Implementing the IEC roll-off by reducing C₃ is not good enough for an accurate design due to the large tolerances of electrolytic capacitors. However, the R₃, C₅ combination is arranged to roll-off lower down (-3dB at about 5Hz) to give additional subsonic attenuation.

Capacitor C₆ defines the input capacitance and provides some r.f. rejection. A compromise value was chosen, and this may be freely modified to suit particular cartridges.

The noise produced by the disc input stage alone, with its input terminated with a 1k resistor to simulate roughly a moving-magnet cartridge, is -85.4dB with reference to a 3mV r.m.s. 1kHz input (i.e. 100mV r.m.s. out) for a typical 5534A sample. The suffix A denotes selection for low noise by the manufacturer. When the 1k termination is replaced by a short circuit, the level drops to -86dB, indicating that in real life the Johnson noise generated by the cartridge resistance is significant, and so the stage is really as quiet as it is sensible to make it.

Subsonic filter

As described above, this stage not only rejects the subsonic garbage that is produced in copious amounts by even the flattest disc, but also implements the IEC roll-off. Below 16Hz the slope increases rapidly, the attenuation typically increasing by 10dB before 10Hz is reached. The filter therefore gives good protection against subsonic rumbles, that tend to peak in the 4-5Hz region.

This filter obviously affects the RIAA accuracy of the lowest octave, and so C₁₂, C₁₃, C₁₄ should be good-quality components. A 10% tolerance should in practice give a deviation at 20Hz that does not exceed 0.7dB, rapidly reducing to an insignificant level at higher frequencies. The tape output is taken from the subsonic filter, with R₁₂ ensuring that long capacitive cables do not cause h.f. instability. If it really is desirable to drive a 600 ohm load, then C₁₃ must be increased to 220 μF to maintain the base response.

High-impedance buffer

This buffer stage is required because the following tone-control stage demands a low-impedance drive, to ensure that operating the tape monitor switch S₂ does not affect the tape-output level. If the input selector switch S₁ was set to accept an input from a medium impedance source (say 5k), and the buffer had a relatively low input impedance (say 15k), then every time the tape-monitor switch was operated there would be a step change in level due to the change of loading on the source. This is avoided in this design by making the buffer input impedance very high by conventional bootstrapping of R₁₅, R₁₆ via C₁₇. This is so effective that the input impedance is defined only by R₁₄. Unlike discrete-transistor equivalents, this stage retains its good distortion performance even when fed from a high source resistance, e.g. 100k.

Tone-control stage

Purists may throw up their hands in horror at the inclusion of this, but it remains a very useful facility to have. The range of action is restricted to ±8dB at 10kHz and ±9dB at 50Hz, anything greater being out of the realm of hi-fi. The stage is based on the conventional Baxandall network with two slight differences. Firstly the network operates at a lower impedance level than is usual, to keep the noise as low as possible. The common values of 100k for the bass control and 22k for the treble control give a noise figure about 2.5dB worse. Even with the values shown, the tone stage is
about 6dB noisier than the buffer that precedes it. Both potentiometers are 10k linear, which allows all the preamp. controls to be the same value, making getting them a little easier. The low network impedance also reduces the likelihood of capacitive interchannel crosstalk. Once again, implementing it is only possible because of the 5534's ability to drive low-value loads.

Secondly, the tone-control stage incorporates a vernier balance facility. This is also designed as an active gain-control, with the same benefit of avoiding even small compromises on noise and headroom. The balance control works by varying the amount of negative feedback to the Baxandall network, and therefore some careful design is needed to ensure that the source resistance of the balance section remains substantially constant as the control is altered, or the frequency response may become uneven. Resistors $R_{22}$, $R_{23}$, $R_{24}$ define this source resistance as 1k, which is cancelled out by $R_3$ on the input side. The balance control has a range of +4.5 to -1.0dB on each channel, which is more than enough for moving the stereo image completely from side to side. If you need a greater range than this, perhaps you should consider siting your speakers properly.

**Active gain-control stage**

An active gain-control stage must fulfill several requirements. Firstly, the gain must be smoothly variable from maximum down to effectively zero. Secondly, the law relating control rotation and gain should be a reasonable approximation to logarithmic, for ease of use. Finally, the use of an active stage allows various methods to be used to obtain a better stereo channel balance than the usual log. pot. offers.

All the configurations shown in Fig. 2 meet the first condition, and to a large extent, the second. Figures 2(a) and 2(b) use linear controls and generate a quasi-logarithmic law for both the input and feedback arms of a shunt-feedback stage. The arrangement of Fig. 2(c), as used in the previous article, offers simplicity but relies entirely on the accuracy of a log. pot. While 2(a) and 2(b) avoid the tolerances inherent in the fabrication of a log. track, they also have imperfect tracking of gain, as the maximum gain in each case is fixed by the ratio of a fixed resistor $R_3$ to the control track resistance, which is not usually tightly controlled. This leads to imbalance at high gain settings.

Peter Baxandall solved the problem very elegantly, by the configuration in 2(d). Here the maximum gain of the stage is set not by a fixed resistor/track ratio, but by the ratio of the two fixed resistors $R_3$, $R_0$. A buffer is required to drive $R_3$ from the pot. wiper, because in a practical circuit this tends to have a low value. It can be readily shown by simple algebra that the control track resistance now has no effect on the gain law, and hence the channel balance of such a system depends only on the mechanical alignment of the two halves of a dual linear pot. The resulting gain law is shown in Fig. 4, where it can be seen that a good approximation to the ideal log (i.e. linear in dB) law exists over the central and most used part of the control range.

A practical version of this is shown in Fig. 3. As is a unity-gain buffer biased via $R_{25}$ and $R_{26}$, $R_{27}$ set the maximum gain to the desired +26dB. Capacitor $C_{25}$ ensures h.f. stability, and the output capacitor $C_{26}$ is chosen to allow 600 ohm loads to be driven. A number of outwardly identical Radionu 20mm dual-gang linear pots were tested in the volume control position, and it was found that channel balance was almost always within ±0.3dB over the gain range -20 to +26dB, with occasional excursions to 0.6dB. In short, this is a good way of writing the maximum performance from inexpensive controls, and all credit must go to Mr Baxandall for the concept.

At the time of writing there is no consensus as to whether the absolute polarity of the audio signal is subjectively important. In case it is, all the preamp. inputs and outputs are in phase, as the inversion in the tone stage is reversed again by the active-gain stage.

**Power supply**

The power supply is completely conventional, using complementary i.e. regulators to provide ±15V. Since the total current drain (both channels) is less than 50mA, they only require small heatsinks. A toroidal mains transformer is recommended for its low external field, but it should still be placed as far as possible from the disc input end of the preamplifier. Distance is cheaper (and usually more effective) than Mu-Metal. Since the 5534 is rated up to ±20V supplies, it would be feasible to use ±18V to get the last drop of extra headroom. In my view, however, the headroom already available is ample.

**Construction**

The preamplifier may be built using either 5534 op-amps or the 5532 dual type. The latter are more convenient (requiring no external compensation) and usually cheaper per op-amp, but can be difficult to obtain. To compensate each 5534 for unit gain, necessary for each one, connect 15pF between pins 5 and 8. Note that the rail decoupling capacitors should be placed as close as possible to the op-amp packages — this is one case in which it really does matter, as otherwise this i.c. type is prone to h.f. oscillation that is not visible on a scope, but which results in a very poor distortion performance. It must also be borne in mind that both the 5534 and 5532 have their inputs tied together with back-to-back parallel diodes, presumably for voltage protection, and this can make fault-finding with a voltmeter very confusing.

Only 2.5% capacitors should be used in the RIAA networks if the specified accuracy is to be obtained. Remember that Fig. 3 marked * should be metal oxide 1% or 2%, for reasons of tolerance only. Each of these resistors sets a critical parameter, such as RIAA equalization or channel balance, and no improvement, audible or otherwise, will result from using metal oxide in other positions.

Several preamp. prototypes were built on Veroboard, the two channels in separate but parallel sections. The ground was run through in a straight line from input to output. Initially the controls were connected with unscreened wire, and even this gave acceptable crosstalk figures of about -80dB at 10kHz, due to the low circuit impedances. Screening the balance and volume connections improved this to -90dB at 10kHz, which was considered adequate. It must be appreciated that the crosstalk performance depends almost entirely on keeping the two channels physically separated.

Some enthusiasts will be anxious to (a) use gold-plated connectors; (b) by-pass all electrolytics with non-polarized types; or (c) remove all coupling capacitors altogether, in the pursuit of an indefinable musicality. Options (a) and (b) are pointless and expensive, and (c) while cheap, may be dangerous to the health of your loudspeakers. Anyone wishing to dispute these points should arm themselves with objective evidence and a stamped, addressed envelope.

**Specification**

(Based on measurements made on three prototypes, with Sound Technology 1710A).

**Moving-magnet**

<table>
<thead>
<tr>
<th>Noise</th>
<th>Reference 1</th>
<th>RIAA accuracy</th>
<th>Input overload point (1kHz)</th>
<th>Line inputs</th>
<th>Reference 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>ref. 5mV r.m.s., 1kHz input</td>
<td>±81dB</td>
<td>±0.2dB</td>
<td>300 mV r.m.s.</td>
<td>Noise ref. 100mV r.m.s. i/p</td>
</tr>
</tbody>
</table>

**References**

Current dumping
review – 2

Current dumping is a circuit technique which claims to abolish all crossover and other distortion caused by a class B output stage. This analysis shows that in precisely this respect the performance of current dumping is notably inferior to that of a traditional amplifier of similar design.

Discussion so far can be summarized by reference to Fig. 8, where V represents the distorting dumper \( V_{be} \) and its quasi-rectangular behaviour. Signal input has been ignored as it is the influence of \( V \) on \( E \) which is to be studied.

The aim is to ensure that variation of \( V \) does not affect \( E \). If \( A \) is taken as finite this cannot be done by balancing the bridge in the usual fashion. For no change at \( E \) then implies no change at \( C \) or at \( B \), implying change at \( E \) contrary to hypothesis. What is required is for the bridge to be a little off balance, so that when \( E \) remains constant a small amount of \( V \) is fed back to the amplifier: enough to shift \( B \) appropriately. Clearly then the small bridge unbalance required is inversely proportional to the gain \( A \). Algebra will handle the details, and dumper distortion will totally cancel, however \( V \) behaves.

As mentioned, taking \( A \) as infinite leads to destruction of the system. The bridge would require to be balanced as normal, because \( A \) now requires no input voltage. Whence if \( E \) is not varying with \( V \) the negative input of \( A \) might as well be connected to \( E \) instead of to \( C \). Then \( Z_1 \) and \( Z_2 \) can be removed, and \( Z_4 \) replaced by a wire.

Previous discussion was based on a floating signal source, which is not attractive. Further, the floating "zero volts" rail required frequent corrections to the algebra. Divan and Ghate (WW April 1977) remove these irritations, and bring the theory to a new level with the circuit of Fig. 9. They include \( Z_{im} \) together with the gain-setting element \( Z_1 \) hinted at by Walker, and take \( A \) as finite. Their balance condition (6) is derived in two lines in Fig. 9, and contains all earlier results.

Invalidity

Murmurs have been heard that much of this debate is invalid. Suppose that the output current through \( Z_1 \) in Fig. 9 is sinusoidal. Then the current marked i through \( Z_2 \) supplies most of it, but it is switched off during crossover. Meanwhile I\(-i\) flowing through \( Z_3 \) supplies what is wanting. Then both of these currents depart dramatically from the sinusoidal form.

Now the interest of this analysis lies largely in the study of the very successful Quad 405 amplifier design that uses the technique. But in that amplifier \( Z_2 \) is a capacitor and \( Z_4 \) an inductor. When currents and voltages depart from the sinusoidal it is impossible to attach impedance values to these components, and the symbols used above for such quantities have no meaning. Take the case of Fig. 10, where a 'square' voltage wave is applied to a capacitor and series resistor. The ratio \( V/I \) wanders through most values from zero to infinity throughout the cycle, and there is no constancy about it at all. In these circumstances one may certainly not note the current through \( C \), and divide by \( joC \) to obtain the voltage across this component. Fig. 10 certainly presents an extreme case, but if \( Z_2 \) is a capacitor it is just the case of Fig. 9. A quasi-rectangular voltage is applied to this component, and the current is to be derived by multiplying by \( joC \).

If \( V \) in Fig. 10 is a sinusoid then the current I has that form also. If we agree to make comparisons with a certain time delay between these two variables, then a constant of proportionality which does not vary with time will again emerge. And the complex number analysis has been developed to mechanize the accounting. And it would be valid in this circuit to resolve \( V \) into sinusoids, use complex numbers on each separately to deduce the consequent I, and add the results. Of course the results would be at different frequencies. But this does depend on the circuit being composed of only linear components, where the output due to a sum of inputs is sure to be the sum of what each would produce separately.

This might be tried in Fig. 9, by

by Michael McLoughlin
resolving the currents i and I−i into sinusoids, and discussing each component separately. But Fig. 9 does not show a network composed of linear elements: base-emitter junctions are non-linear in the extreme. This route is barred.

One example of the many possible consequences of reckless resolution into sinusoids is provided by the ordinary a.m. detector. Suppose that sinusoids of different frequency and phase are input to the detector. With or without carrier modulation, the carrier component will be always present, and the higher frequencies may now be considered to be modulating it, and hence the sum and difference frequencies at a lower frequency will now be present, as well as the carrier signal.

Validity

Such criticisms do appear to apply to most of the previous discussion, including of course our own treatment in Fig. 9. However the bridge model of Fig. 8 escapes untouched. Here the troublesome non-linear elements are replaced by a voltage generator, and in determining whether a circuit is composed of linear elements the generator does not have to pass any tests. (Detailed information about the behaviour with time of this generator will be required later.)

If it cannot be tedious to turn our attention to another aspect of the problem: the role of diodes in a.c. detectors.

The terminal voltage of a diode is not a reproduction of the input voltage. It is the result of a complex network which takes place between the diode and its termination, and which has the essential properties of a voltage-controlled current source. The diode is not a linear circuit element.

Consider the case of a diode (D) and a.c. input (Vin) in series, and a load resistor R. Fig. 10 shows what happens.

Table 1. Discontinuity in sinusoidal output E at crossover. Theory predicts these figures, but when tolerances are taken into account, Case 1 offers two transitions per crossover, and the figure in the text has been doubled, as e=0.2 now. Using closer tolerance components would benefit the first two cases equally. Adding bias components would benefit three cases equally.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>V pk-pk</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. As supplied</td>
<td>7.0mV</td>
<td>( \propto E ) and ( \propto f )</td>
</tr>
<tr>
<td>2. Resistor bridge</td>
<td>0.6mV</td>
<td>at all E and f</td>
</tr>
<tr>
<td>3. Traditional amplifier</td>
<td>0.15mV</td>
<td>at all E and f</td>
</tr>
</tbody>
</table>

Transitions at crossover: Quad 405
e=0.2 f=13.2kHz E=1V r.m.s.
just given for the driver of Fig. 11 it is clear that above 1kHz it works as an operational amplifier, ensuring that most of the current supplied by Tr2 is drawn away through C, while leaving only a small amount to work the driver itself. Now as the current gain of Tr2 from emitter to collector is unity, C could indeed syphon off this current with similar effect at the emitter instead.

But this alteration does obscure an important factor. In Fig. 11 the element Z1 is marked as 500Ω, but in fact any current due to dumper V variation flowing into Tr2 emitter is also affected by the emitter input impedance found there. Owing to the presence of R12 this may be as high as 3.3kΩ + 25/6 = 76Ω, causing a 14% increase in the effective value of Z1. If now Z2 is connected instead to the emitter and there syphons off its current from that flowing into the driver, then scarcely any of the current supplied through the Z1 remains to flow into the emitter. Not much impeding voltage arises, and the 14% adjustment required in the value of Z1 disappears. If a bridge is to be balanced then a 14% adjustment in the value of one arm is serious, and Z2 may not be reconnected as proposed in any accurate model of Fig. 11.

It seems possible that Z1 and Z2 were initially connected to the same point of Tr2, but were later separated as part of the h.f. trimming programme evident in the full circuit.

Quad 405 model

Fig. 12 offers a model for Fig. 11. The driver has been reduced to linearity by its specification in terms of mutual conductance. The dumpers are so reduced by thinking of them as transistors of equal current gain but zero Vbe, in series with a generator to simulate the latter. The driver is equipped with input impedance Zd and output impedance Zo. Gain-setting element Z1 appears. Delivery of feedback to both ends of Tr2 is properly represented. Finally Z2 is in series with Tr2 emitter to stand for the input impedance found there.

The circuit may now be analysed in terms of the two input voltages A and V. Because the components are all linear these may be treated separately, and as sums of sines. Thus complex number analysis is valid. But the twin menaces of this sort of analysis are sufaces and denominators. It has been possible to avoid both by giving each impedance a second unbracketed symbol to represent its admittance.

The definitions section of Fig. 12 starts by defining k to account for dumper current gain, and there follow names for concatenations of symbols that will arise. About half the remainder may be omitted at first reading, and the new balance condition (8) can be attained quite quickly.

Constraints

Solving the circuit of Fig. 12 consists in obtaining the relationship between the three voltages A, V and E. To build relationships it has been necessary to introduce voltages B, C and D, so these are to be eliminated.

Observing that the current flowing away
from the driver is equal to what it provides, then line 1 collects the variables (capitals) in this constraint, using the shorthand defined. Line 2 starts by defining E, using Millman's theorem if S/5 is added to both sides.

From an a.c. viewpoint the upper end of u is at potential A, and so later in line 2 Millman's theorem is used to define B. If this equation is multiplied by the factor on its right it may be rewritten as (3) by using (2).

This captures D and B in terms of desired variables. It is just a little harder to do this for C. A constraint is given for it later in line 3. If the two terms in q on the right are transferred to the left hand side, the equation is justified as a statement that the current flowing away from C is just what is delivered there by Tr2. Multiply the equation in its present form by n(s + 1) as suggested on its right. It should be possible to arrive at line 4 without a pencil, using (2) and (3) to remove D and B. Collecting first the terms in A yields a coefficient uu(n(s + 1) - un(s + 1)), equal to what is written. Collecting the terms in E out of B and D is easier. And the coefficient for V is simpler than expected because two terms nqs have cancelled.

**Argument**

The peak of difficulty is already passed, and (8) is within reach. Focus on line 1 of constraints. If the equations at the start of the next three lines were used to remove D, B and C from line 1, a gigantic equation would result. But it would only contain the desired variables E, A and V. So it would have the form of (7). If y = 0 then certainly E and A are bound into proportionality, and the sinusoid V has no effect on E, leaving it free from distortion.

You are therefore dispensed from pursuing w and x in (7); it suffices to study y alone. Now (7) is to be considered as derived free from first multiplying that line by the factor noted on its right. This suffices to prevent the generation of any fractions. So multiply line 1 as stated, and collect on its right hand side the terms in V only, including those V found when D, B and C are substituted. Hopefully this will give y as stated.

**Balance equation**

First note that two terms bns(h + q) cancel out in y. Now write the result line. Then divide as stated, remembering u/n = λ. But write the result in terms of impedances rather than admittances, and (8) will appear. If this holds then y = 0 in (7), and the disturbing V does not influence the output.

**Relation to other balances**

Equation 8 now provides the balance condition for the Quad 405. It includes the driver output impedance Z0, and the double delivery of feedback is studied. The emitter input impedance of Tr2 is included, and the balance is altered by the new factor λ on that account. Suppose first that this emitter input impedance is zero (λ = 1 and Z0 = 0). Then if Z0 is also excluded by setting it infinite, (8) reduces to the balance condition of Vanderkooy and Lipshitz. But if Z0 tends to zero while g becomes large, so that gZ0 = λ, the driver has become a voltage amplifier. And then (8) takes the form of (6), though Zp is not the same because of the isolating effects of Tr2. Of course, setting g infinite reduces (8) to the basic Z4/Z1 = Z5/Z2.

But none of these things are true when λ is taken into account. If the input transistor has its minimum gain of 50, then as suggested earlier Zr = 700Ω, and so λ = 0.65. Inserting this into (6) or (8) removes all previous balance conditions. The gain of Tr2 may rise to 300, yielding Zr = 15.2Ω and λ = 0.90, which is still serious. It appears that the balance of the Bridge is critically dependent on the gain of the particular transistor inserted at Tr2.

Listed below (8) are approximate values, and it is clear that Z4/Z1 can be dismissed from the square bracket of (8). And the fractions that remain fall by about an order of magnitude a time: 1, Z4/Z0, k, Z4/Z1. This follows for all that attainable the balance condition simplifies to

$$\lambda \frac{Z_4}{Z_1} = \frac{Z_4}{Z_1} + \frac{1}{Z_1} + \frac{1}{Z_2} - k - \frac{Z_3}{Z_0}. \quad (9)$$

**Bridge balance**

Many balance conditions have been published, but no-one has yet inserted the four Z values of Fig. 11 into their result. This may be because the simple condition

$$Z_4/Z_1 = Z_4/Z_1$$

reduces to L = R=R, and it shows a 6% unbalance. To find figures for g and Zp in (9), consider the two 5601 resistors in Fig. 11. These provide a nominal 50mA current sink for the dumper bases, and around crossover this current is provided by the driver. Now the input most heavily on the 4087 base, causing the usual 4% alteration in its collector current. This change is 2mA, which shows that the driver mutual conductance g is around 2 amps/volt. Assume minimum transistor gains, and follow the electrode impedances associated with 50mA current output back to the input terminal; the impedance there is just over 50kΩ. This is a fair figure for Zp also, because even at 10kHz the reactance of Zp is still 133kΩ. So gZp in (9) is 10Ω, or more if the transistor gains exceed minimum.

Take λ = 1 for the moment, and suppose f is the standard frequency of 13.2kHz at which Vanderkooy and Lipshitz worked. The three terms of (9) work out in millennia as 498Ω, 468Ω, and 10 or less. The first two terms are imaginary and the third is real. Then the best that can be done is to balance off the first two terms by Z4/Z1 = Z4/Z1, and ensure that the third term is small. The designers appear to have done this. But there is still that unexplained 6% unbalance between the large terms.

But the two imaginary terms of (9) should really be balanced off by

$$\lambda \frac{Z_4}{Z_1} = \frac{Z_4}{Z_1} + \frac{1}{Z_1} + \frac{1}{Z_2} - k - \frac{Z_3}{Z_0}. \quad (10)$$

Now the median gain of Tr2 is 175, so its emitter input resistance may be 3300/175 + 25/6 = 231Ω, yielding λ = 0.852. The three terms in (9) now work out in millennia as 424Ω, 468Ω, and 10 or less. The first term is now significant, and the Quad 405 bridge appears to be out of balance by this amount in the opposite direction.

An easy way to correct this would be to reduce Z4 by the same factor 424/468, which could be done by connecting in parallel a 4.8kΩ resistor. Now Vanderkooy and Lipshitz did vary the resistance of Z1 to achieve minimum crossover distortion, and they demonstrate their results with oscillograms. Their finding: for best balance Z1 requires a resistor in parallel of "about 5Ω". This confirms that there is a systematic unbalance of some 10% in the Quad 405 bridge, though the precise figure varies sharply with the gain of Tr2.

**Conclusion on circuit design**

Clearly the dv/dt limiter R32 with C9 that can be unpredictable must be placed earlier in the circuit and not here. The low impedance source driving Tr2 must be allowed direct access to this transistor, and resistors must be kept out of this area. Another way of making the first point is to observe that extra input current flow during crossover, and the input impedance of a current dumping circuit varies wildly as a result.

There are only three terms in (9), and the third is by far the smallest at typical frequencies. If 5% components are used, as in the v/v, then each of the first two terms can vary 10% by tolerance errors. Then one side of 9 may exceed the other by 20% on that account. Then it is useless to seek circuit sophistication to eliminate the unbalancing effects of k (dumper base current) in (9): any such effects are orders of magnitude less than tolerance errors. Although T. Hevreng [1] pointed out this problem in a way that must command admiration (May 1979), such a solution is not of practical utility. The correct conclusion is the inverse: k affects the balance of (9) so little that it is not worth using Darlington type dumpers to reduce it. And the Quad 405 designers were right not to bother. Equally, H. S. Malvar is not really practical in going after any 10% variations in g during the signal cycle.

**Minor effects**

Vanderkooy and Lipshitz point to the upper 5601 resistor in Fig. 11 as an unbalancing element. It can be modelled as connected from V+D to D in Fig. 12. And a mesh-structure transformation with Z4 and Z5 shows that the effect is to reduce both these values by 8%, leaving unaltered the balance of the first two terms in (9). The lower 5601 is effectively connected from D to ground, and a similar transformation with the new value of Z4 and the load shows that this term is effectively reduced about 1%/Ω, but without other compensations in (9). Thus these resistors do not affect the possibility of bridge balance.

These two authors also point to the unbalancing effect of the compensation
components R₂₃ and C₁₁ in Fig. 11. These load the driver output a little, but they can be included in the symbol Z₀ of Fig. 12, so that the bridge can still be balanced. Their effect on the driver input can be seen as follows. Suppose the driver output rail in Fig. 11 is falling at 10V/s; then 0.33mA flows out from C₁₁, causing the top of R₂₃ to fall 0.4V. If the first transistor in the driver has a collector impedance of 100kΩ when its base current is held constant, then 4μA will be drawn through it. An identical disturbance to its current would be produced by increasing its base current by 0.1μA or less. Meanwhile, in response to the driver output ramp, Z₀ is delivering 0.12mA, which is being fed to it from T₂. Then 0.1% increase in the value of Z₂ would increase the current in it by 0.1μA, which would come from the driver input terminal. Conclusion: the disturbance to the input can be well modelled by imagining Z₂ is increased by up to 0.1%. Compared with the tolerance error of that component this is a trivial correction.

An equivalent amplifier

Because reactive components have been used the first two terms of (9) are imaginary, and so the best that can be done to balance it is to insist on (10). But this means p = q = 0. So no V appears in the equation for C in line 4 of Fig. 12. Voltage C represents the mix of both signal and feedback, and it controls the output completely. And the equation for it is now

\[ (h+q)C = -\lambda f(p+a) + m \lambda p + q + e \]

Provided that C is bound to A and E in this way any method of deriving it may be used, and will produce the same output voltage as before. For example, disconnect q in Fig. 12 and connect it in parallel with h. Then C will arise as just specified if a current equal to the expression on the right of this equation is injected into the emitter. So replace f and p in Fig. 12 by p' and q', but connect the right hand side of the latter directly to E. The upper end of u may be considered to have potential A. Then by studying only the components now connected to B it is easy to verify that the current entering T₂ emitter is correct if

\[ p' + f = p + f \]

\[ q' = (p + q')m/(s + t) \]

If these values are fitted the amplifier will have the same performance as the current dumping circuit. Further, Z₀ can now be shorted and its influence absorbed into V₀, about which we have never had to be specific. The amplifier is now shorn of its current dumping components Z₂ and Z₄, but with three others adjusted it will have identical performance.

These modifications alter the output load slightly, but that has never been a factor. Also a 50Ω load was removed from D in Fig. 12. A mesh-star transformation between this, Z₄ and Z₅ shows that this removal is equivalent to increasing Z₄ by 1½%. Reduce it again and operation is as before. And the new Z₄ can be absorbed into V as previously.

Infertility?

Current dumping then is doing nothing useful, because of the particular bridge balance chosen. Observation of this tenor, by Halliday, Olsson and Bennett were reported toward the end of Part 1, and this view is now supported by the model of Fig. 12.

Such algebra invites an explanation. The trouble seems to start with (9). Faced with that requirement a designer unsure of his g may make it large and forget it, relying on (10). And with the Quad 405 the imaginary character of the first two terms in (9) compels the designer to resort to (10).

Now redefine Z₁ in (9) as Z₁ = Z₃/i. This means that we propose to account for the 250Ω or so impedance found at the emitter of T₂ by thinking of Z₁ as altered slightly to include its resisting effects. The circuit now identifies well with that of Fig. 8 with Z₁' fitted there. Now multiply (9) by Z₁/Z₀ to yield the alternative form

\[ Z₄ \cdot Z₁ = Z₃ \cdot Z₂ \cdot Z₁' \cdot Z₁/Z₀ \cdot [1-k+Z₃] \]

(11)

Earlier we expected the bridge ratios in Fig. 8 to be slightly out of balance if the effect of V on B₂ was to cancel, and (11) establishes the required differences. And this difference was expected to be inversely proportional to driver gain, as it is here.

But the designers have decided to neglect the gain term, found on the right of (11), and instead have set these bridge ratios equal by (10). But the entire purpose of current dumping is to define correctly the small amount by which the two bridge ratios need to be out of balance if the effects of V are to cancel. The idea is destroyed by anything that proposes to ignore the gain term in (11) and set these fractions equal. Such a move discards the essence of the dumping technique. And as shown above it is then possible to alter the amplifier into a conventional structure of identical performance.

Tolerances

The above criticism was based on the designer's decision to rely on (10). But further difficulties now arise, because the components he specifies to do this will not have their nominal values, but (in the Quad 405) may each be 5% out. This issue has been treated by T. C. Stancliffe (November 1976.)

The analysis in Fig. 12 will yield an accurate assessment of the effect of tolerances. Equation 8 will not now balance exactly, but it may be made to do so with the actual components used if the left hand side is multiplied by (1 - e). We shall make no capital out of λ as a simple design improvement can remove this factor. Then e can reach 0.2 in magnitude. Prefacing the equation with (1 - e) is equivalent to approximating it with an extra leading term -eVZ₂Z₁ = - exp/t instead. Then the previous equation can be asserted, with an extra leading term -exp/gn = -eps' su. The previous line for y remains valid, but y is clearly now eps' su. Now multiply constraint line I by the factor on its right, do the elimination and verify that x in (7) is correctly stated. To verify the expression given for w note that the last term in its first square bracket will be needed to reconcile the first term there. Examine w and x in the light of the approximate admittances listed. Dismiss the entire square bracket in w by writing out just its last products

\[ h(t + kp + kl) \]

The last of these is the largest, but it is many times thousand times smaller than the last term of w, approximated by

\[ w = m gp su \]

Actually if all its products are multiplied out (7) contains initially 284 terms. But cancel g in the expressions just given, and that equation reduces with greater accuracy to

\[ mpe = (t + f + p) + epsV \]

The contribution to E from A may now be studied. As may be readily explained from Fig. 12 if V is held constant, there is a gain of 1/Z₁/Z₀, followed by an output impedance Zₒ/Z₁.

Tolerance unbalance

Of greater interest here is the contribution to E from V:
This strikingly simple expression can be explained from the elementary model of Fig. 8. Consider the error in equation 8 as concentrated in $Z_2$; the value fitted is too large by a fraction $e$, because balance is achieved when (8) is multiplied by (1-e). Thus in Fig. 8 instead of the correct $Z_2$ the value is a fraction $e$ larger. Once $V$ is fixed, potentials B and D are in the merciless grip of the amplifier there. And as $Z_2$ is small, moving the tap at $E$ off the balance point by $eZ_2$ yields (12).

Consider first the easy case where all components are resistive. Now $V$ passes in almost rectangular fashion between $-0.7$ and $0.7V$, the transition occurring during the length of each crossover. As the factors in (12) are real the distortion $E$ given there will have the same waveform. Take $e$ at its maximum value of 0.2 or so. Take $Z_2 = 47\Omega$ and $Z_4 = 0.1\Omega$: the amplitude of the rectangular distortion contributed to $E$ is given by (12) as 0.6 mV pk-pk.

Now suppose that $Z_4$ is inductive. As the square bracket term in (8) is small, errors in the others will dominate and will still be real. Then it is legitimate to regard $E$ in (12) as derived by forcing a current $eVZ_2$ through this inductor, where $V$ is a sinusoidal component of the distortion voltage. But the inductor is a linear component, so the various sinusoidal currents can be recombined into a current $eVZ_2$, where $V$ now represents the final quivalent of the rectangular distortion voltage waveform. If $L$ is an inductor and $v$ is the rate of change of $V$ this produces $E = Lev/Z_2$.

To obtain a figure for $v$ suppose that at $E$ the signal output is Asinot: then near upward crossover its slew rate is $\text{Ato}$. To maintain this during crossover $V + D$ has to slew an extra $Z_2Z_4$, times as fast (where $Z_4$ is the load and does not refer to the inductor.) So $V$ itself has to slew at $\text{Ato}Z_2Z_4$. This provides the figure for $v$ above, yielding distortion

$$E = e\text{Ato}LZ_4$$

constant during crossover but zero elsewhere.

Optional calculus

Calculus supports these manoeuvres. The argument is sketched in Fig. 13, and as investigation is concentrated on bridge unbalance the gain $A$ has been taken as infinite. Signal has been set at zero and only the effect of $V$ is studied. If the voltages at the upper bridge vertex are $x$ then the current through $C$ is as stated, whence the voltages at the lower vertex may be written. The two voltages must differ by $V$, yielding the constant given. With the forcing function shown for $V$ this is an easy specimen of its kind, and the full solution is sketched. As $V$ passes the point $A$ then $x$ follows the broken curve shown. This may be accurately specified by saying that at $A$ the voltage $x$ falls by $\text{Ato}$, but the exponential columns shown to the origin are added back to $x$. At $D$ the voltage may be said to make the same jump upward, and then to suffer the subtraction of the same columns to yield a curved transition. And $y$ is as shown: a rectangular pulse lasting for the crossover but modified briefly at each end by the same set of exponential columns.

Rewrite (8) with $Z_2 = Z_2' + Z_4$, to the exclusion of $Z_1$ and $V$ (the final terms, the square bracket are frivolous and may be ignored.) Now suppose the error is concentrated in $Z_1'$. Because for balance this equation had to be multiplied by $1 - e$ it follows that $Z_1'$ is just a fraction $e$ too small. In terms of Fig. 13 the resistor $R_1$ after being set at $Z_1/\lambda$ turns out to have a tolerance error making it a fraction $e$ too small.

Now suppose the change in output volts $E$ in Fig. 12 which results from a change in $V$ is zero. Then

$$\frac{d}{dt}(y+e)=\frac{dx}{dt} = \frac{1}{R_1L} \left[ C \right]$$

If $R_1 = L/R_1C$ as before then $i + j$ is constant, consistent with zero change in $E$, and the problem is solved. But now change $R_1$ to 1 - $e$ times this expression. Examine the way in which the voltages are originally established: an additional $-e$ volts now appears at the lower vertex of the bridge, transmitted to $Z_4/R_3$ with short time constant $L/R = 0.4\mu s$. Appeal to the sketch of $y$: the resultant output $E$ is a rectangular pulse of amplitude $\text{emn}$ for the duration of crossover. Insert for $m$ the slew rate $v$ derived earlier, and (13) follows. It is true that the new volts $y$ do alter slightly the constraint given, but this is a second order effect.

**Programmed model**

If $Z_2$ in Fig. 11 is to be recognised from the start as an inductor $L$, then a fourth model of current dumping naturally arises. Suppose the output volts at the load are coasting steadily upward to zero from below. Then a steady voltage exists across $L$, with the left hand side positive. When the lower dumper goes off, the current in $L$ has reached zero and it stays zero. There is no final spectacular rate of change to generate a transient, and all that happens is that the steady voltage just mentioned suddenly collapses. This provides the negative-going steady voltage pulse just discovered, which is applied to $Z_4$ to the resultant steady current integrated into a rising voltage ramp on the right of $Z_2$. The simplest algebra shows that if $L = R_1R_3C$ the resultant current ramp through $Z_2 = R_3$ maintains the rate of ramp of amplifier output voltage identical with its value before the lower dumper turned off.

We are left with a picture of current dumping where as crossover approaches L is programmed with a steady voltage measuring the output ramp rate. When the dumper stops conducting this programmed voltage collapses, duly executing the measures required to hold output ramp rate unaltered.

In more abstract terms L differentiates the dumper current and $C$ recovers it by integration, together with a negative sign. As a result $Z_2$ passes a current equal and opposite to any sudden change in dumper current. Vanderkooy and Lipshitz make some observations on $L$ in their article on feedforward error correction in which they produce oscillograms to show that while a good inductor causes no trouble, an inductor wound with thick wire on a narrow former causes sharp distortion spikes during crossover, Fig. 10. The proposed explanation is that eddy currents are at work in the inductor. You might doubt whether the gentle usage just explained is appropriate to produce such transients, and the oscillogram does resemble their Fig. 9(b), showing what happens when the bridge is unbalanced. But if this assertion is confirmed it would be a reason to expect still worse results in the first line of Table 1, reinforcing the conclusions below.

**Test case**

In their WW article Vanderkooy and Lipshitz provide oscillograms of crossover distortion for $A = 1.4V$ at $f = 13.2kHz$ with $Z_4 = 100\Omega$. When the bridge was unbalanced by reducing $Z_4$, by an unspecified amount, rectangular distortion pulses did indeed appear for the duration of crossover. They observed best balance when $Z_4$ was reduced 10%; implying an $e = -0.1$ for their amplifier when $Z_4$ is restored to its normal value. Then according to (13) there should be a rectangular pulse of just $3V/\text{mV}$ height lasting for the duration of crossover. The oscillograms

(their \( 4c = 5a = 6a \)) are not easy to read, but offer 4mV pk-pk amplitude. The pulse appears to be rectangular, but to include as well perhaps a 60% overshoot on return. The overshoot then decays with time constant about 5µs. All this is encouraging, and can be made more so.

Taking median gain figures for the transistors in the driven, its input impedance would be 460kΩ, combining with \( C = 120pF \) to yield 55µs time constant. This is not likely to be the decay involved. But \( C_6 \) with \( R_2 \) yields 3.3µs, or slightly more if the source driving \( V_{in} \) offers some impedance at \( r_f \).

With the output described, crossover lasts 2.2µs, as seen in Fig. 11 from the effect on output of 1.4V transition at the driver output. Then initially \( C_6 \) offers a short circuit to ground for the rectangular pulse offered to it via \( Z_1 \) and \( T_2 \). But as the pulse develops it begins to compare with 3.3µs. Then \( C_6 \) has largely charged, and the pulse faces almost \( R_2 \) instead of a short to ground. And when the pulse has finished \( C_6 \) has to charge. It follows reverse current into \( T_2 \) and causes the overshoot noticed, which then decays as it should with time constant 4 to 5µs. The oscillogram provided is now well explained.

If the experiment were repeated with larger \( A \), then crossover time would fall in proportion, and \( C_6 \) would not have time to develop significant charge. The circuit would tend to behave more as if \( R_2 \) were shorted. Thus as \( A \) rises in this way the crossover moves from something like 10% unbalance in one direction, passing zero to arrive at 6% unbalance in the other.

These figures were justified earlier. Then as \( A \) rises in (13) the quantity \( e \) first falls towards zero and then rises on the other side. So initially not much increase in output distortion is expected, as these factors are behaving in opposition. But after a while distortion should rise rapidly, perhaps after the style of a square law, when both factors are pulling in the same direction. This is just what is reported: as \( A \) was increased up to 14V there was little increase in distortion, but as \( A \) climbed by a further factor of 2.5 distortion rose by a factor of five (observe approximate square law behaviour!)

Further progress would require more and clearer oscillograms.

**Traditional amplifier**

How does crossover distortion in the circuit of Fig. 11 compare with that present in an equivalent traditional amplifier? Some comparisons have been based on shorting \( Z_4 \) while leaving \( Z_2 \) in place but these need not detain us. It is clear that the capacitor \( Z_2 \) will then seriously inhibit the driven transistor in producing rapid transition of its output voltage during crossover. Hence no traditional amplifier would contain such a component.

A comparison was made above with a traditional amplifier, and it was found that there was no difference. But this supposed a certain condition that had been perfectly balanced by (10). Now compare a dumping amplifier with unbalance leading to (13) with a traditional amplifier, and figures become essential.

The circuit of Fig. 11 may be converted into the equivalent traditional amplifier by shorting \( Z_4 \) and also removing \( Z_2 \). Further, \( R_{12} \) should be shorted and \( C_6 \) removed: impedance cannot be tolerated in this area, and dv/dt limiting must be done earlier. Copy the circuit of Fig. 12 with these simplifications.

Then \( D \) becomes equal to \( E \), and if study is confined to the effects of \( V \) on \( E \) then \( C \) becomes just a multiple of \( E \). As \( T_2 \) emitter input impedance is now low \( B \) can be taken as zero and all three unknown voltages that previously had to be eliminated have now vanished. The problem can be solved in two lines by applying the same current constraint as previously, and the contribution to \( E \) due to \( V \) becomes

\[
E = \frac{1}{Z_{in}} \frac{Z_1}{Z_2} V.
\]

As all components are resistive, \( E \) will just follow the waveform of \( V \) in this fashion. The worst figure of 500µ for \( Z_4 \) produces 0.15mV pk-pk to complete Table 1.

**Results**

Current dumping has aroused much interest, and there have now been some 20 contributions to the discussion in this periodical alone. It has been suggested here that when the analysis takes account of the delivery of feedback to both ends of \( T_2 \) a new factor \( \lambda \) appears in the bridge balance (9). The new factor is due to the presence of \( R_2 \) and may vary between 0.65 and 0.90 depending on the gain of \( T_2 \). Supposing that this gain has its median value it would appear that a 10% bridge unbalance is built into the design of the Quad 405. This result has been accurately verified by Vanderkooy and Lipschitz. Conclusion: \( R_{12} \) is causing unpredictable consequences and it must go. The bridge must be balanced. But suppose this is accepted (or indeed rejected). Then the best attempt at bridge balance is to ensure that (10) holds. But this drives the whole system, and an amplifier of traditional type and identical performance results if the dumping components \( Z_2 \) and \( Z_4 \) are removed, provided three other elements are adjusted.

Finally, tolerance errors prevent perfect balance of (10), and further distortion results, erasing the current dumping amplifier below its traditional equivalent. Final figures are in Table 1. It seems to be an improvement to use resistive rather than reactive dumping elements, and further improvement to abandon them altogether.

The gain term in (9) is about \( 10^5 \) in the Q405, and it will almost certainly be small in any implementation of current dumping. Given the tolerances of the other terms it will scarcely be possible to take it into account. Then objections would apply unaltered to any alternative dumping circuit.

Part 1. On page 43 of the September article, the lower \( Z_4 \) in equation 5 should read \( Z_1 \).

**The new Z80**

Coinciding with the introduction of the 32-bit Z80000 mid next year Zilog plan to introduce the Z8000 8/16-bit family of processors with Z80 software compatibility. With clock rates of up to 25MHz (preliminary information) and memory manipulation features, these devices will also make full use of current high-speed rams and, besides providing a stop-gap for the eight-to-sixteen bit transition, the family will act as input/output processors for the 16-bit Z8000. There are four devices: two with a 16-bit data bus, the Z8116 and 8216; and two with eight bits, the Z8108 and 8208. The 82 versions are physically larger than the other two i.c.s and have four direct-memory access channels and built-in uart: all of the i.c.s have four 16-bit counter timers.

The new processors have an integral memory-management unit that allows them to access either 512K-bytes or 16M-bytes, depending on the type, and they have 256 bytes of memory which, when configured as a 'cache', may be programmed to contain either instructions or data, or both. This speeds up program execution by reducing the number of external bus accesses. Operation and updating of the cache is automatic.

Although the instruction set will be expanded and augmented, all Z80 instructions are compatible with binary. Basic addressing modes of the Z80 will be augmented with the addition of a base-index mode and 16-bit displacements for indexed, program-counter-relative and stack-pointer-relative modes. These new addressing modes are incorporated into many of the old Z80 instructions. Additions to the instruction set include 8/16-bit signed and unsigned multiply and divide, 8/16-bit sign extension, and a test-and-set instruction for use in multi-processor applications. Sixteen-bit instructions include compare, memory increment/decrement, negate, add, and subtract.

Largest of the Z8000 family, the 16-bit 8216, with Z80 instruction compatibility. Of the four devices, the two eight-bit versions are compatible with the Z80 bus and the two 16-bit versions are designed for use with the 16-bit 2-Bus.
Rapid-update digital ratemeter

The normal method of digital frequency measurement is slow and inaccurate at very low frequencies, such as those encountered in medical research. This design enables pulse rate to be determined after only two heart beats.

by P. D. Coleridge Smith* MA FRCS

It is often necessary to measure the heart rate of subjects undergoing intermittent exercise. When equipment for such application is to be used outdoors, it is essential that it should be robust, consume little power, be accurate to within 1% and indicate heart-beat between 40-240 beats per minute.

The need for robustness ruled out the use of a moving-coil meter: low power requirements and the need for legibility in daylight dictated the choice of a liquid-crystal display.

Rate conversion itself necessitated careful consideration. Rapid settling following switch-on and frequency change was required, since the subjects of the study were connected to the equipment immediately following exercise. An 'instant' indication of heart rate was essential and the meter had to be capable of closely following the change in rate.

A variety of analogue solutions were considered, from diode-pump ratemeters to analogue inverse-function generators. The simpler solutions would have taken too long to respond, the more complex suffered drift and difficult setting-up procedures. All, of course, would have required digital conversion before display.

These problems led to the final, all-digital design, in which a 10 bit binary counter measures the period between input pulses. An eprom uses the count as its address input, and contains a look-up table of rates at each of the 1024 points of the 10 bit counter, the data derived from the eprom being latched into display decoder/drivers: the circuit includes under- and overflow indication as well as leading-zero suppression. The instrument gives an accurate

*Academic Department of Surgery, Royal Free Hospital, London NW3.
Hexadecimal dump of eprom contents. This table also includes values for addresses where n<100, for development purposes. These may be altered as suggested in the text to indicate meter 'overflow' if required.

| 000 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 010 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 020 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 030 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 040 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 050 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 060 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 070 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 080 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 090 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0A0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0B0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0C0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0D0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0E0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |
| 0F0 | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F | 0F |

indication of rate after the arrival of only two input pulses and correctly updates it after each subsequent pulse. It can be used in any application where the frequency of the input signal is 500Hz or less, and is well suited to use below 5Hz where other techniques involve excessive integration periods.

The low-level signal amplification and pulse extraction are achieved conventionally, using a high input-impedance differential amplifier to detect the electrocardiogram voltages — of the order of 1-2mV peak — peak, which is subsequently converted to c.m.o.s. levels for connection to the ratemeter.

**Circuit description**

IC1(e) forms a 1MHz crystal oscillator, which is divided by 2048 in IC2, resulting in an output of 488.28Hz to IC3. These counters are controlled by IC2 and IC4, a decoded decade counter.

When the ratemeter input (pins 8, 9 and 12 of IC2) is below 3V until the decoded '1' output goes high. IC3, then applies a high level to the clock-enable input of IC4 and further counting ceases, whereupon a high level at the input again enables counting, with outputs 2 to 9 being taken high in sequence. The low level at IC4 clock-enable also enables the 2716 eprom.

Output '2' from IC4 resets IC5, preventing any change in the count of IC4 during the look-up procedure. This ripple counter, IC5, provides the address for IC6, which holds the rate data in a look-up table.

Output '3' latches the high-order data from IC6 into display driver/latches IC7. The carry output of IC7 then goes low, selecting the lower half of the look-up table in IC8, the data from which is latched by the '5' output into IC10.

Output '7' then resets IC8 ready for the next measurement cycle, the count output of IC6 remaining at '0' until the input goes low again.

IC1b, IC1b', and half of IC1 provide a precise 1:1 duty cycle square-wave drive for the i.c.d. driver i.c.s and display. A 3½ digit device has been used for convenience, with unused segments tied to the back-plane.

The entire look-up cycle takes place at a 1MHz clock rate and is therefore complete in less than 9us.

Should the interval between successive positive input transitions exceed that taken to count through the first ten stages of IC4, output Q4 of IC5 will go high. This inhibits further clock pulses to the counter chain via IC1b and stops the eprom address from IC4 at zero. This location (0) in eprom contains a range underflow indi-
Fig. 2. Memory map of 2716 eprom.

cator - "000" in my original design.
The data in the eprom is derived from the simple formula:

\[
\text{rate} = 60f/n \times \text{pulses per minute}
\]

where \( f_i \) is the input frequency to IC\(_ 7 \), 488.28 Hz in the diagram shown, and \( n \) is the base address in the range 0-1023.
The rate for each of the memory locations was calculated and rounded to an integral number before being programmed using a microprocessor-based system. For locations with \( n=100 \), the entry was replaced with \( 999 \) to indicate meter overflow, since the accuracy in this address range does not fulfill design criteria.
The high-order digits are stored in the upper half of the eprom memory range in b.c.d. form, that is from 1024-2047 (decimal), while low-order digit data is located in the upper half of each byte from address 0-1023. The remaining half byte in each of these locations is not used in this application. Leading-zero blanking is accomplished by substituting a non-b.c.d. value (0-F hexadecimal) in place of the relevant zero. The CD 4543 responds to this code by blanking the digit concerned. Figure 2 is the complete memory map for the eprom.

Power is derived from a 9 volt battery via a 78L05 supply regulator to ensure that the rail requirements of the 2716 are not exceeded. The entire circuit consumes about 30mA, of which the eprom accounts for the greatest part.

**Construction**

The layout is non-critical and the prototype was constructed on Veroboard.

### BOOKS

- **Mastering Electronics** by John Watson, 382 pages. Macmillan, £10.00 hard cover. Electronics for the beginner - from basic physics to radio, tv and computing.
- **Learning IBM Basic** by David A. Lien, 421 pages. Commodore Publishing, $19.95, soft cover. For the IBM personal computer.
- **The World Connecta** by Timothy Orr Knight, 142 pages. Prentice/Hall International, £8.45, soft covers. The romance of the micro, by a 16-year-old enthusiast.

### Computer Communication Techniques

- **iAPX 88 Book** by staff of the Intel Corporation, 80 pages. Prentice/Hall International, £11.00, paper cover. All about the Intel 8088 8-bit microprocessor.

### Microprocessors and Digital Systems


### Security Electronics


### Basic Electrical Installations


### Electrical Installations and Regulations

- **Electrical Installations and Regulations** by Michael Neidle, third edition, 99 pages, Macmillan, £4.95, soft cover.

### Electrical Installation


### IC Timer Cookbook

- **IC Timer Cookbook** by Walter G. Jung, second edition, 384 pages. Prentice/Hall International, £15.25, soft cover. Everything there is to know about the 555 and its cousins.

### A 280 Workshop Manual

- **A 280 Workshop Manual** by E. A. P arr, 184 pages. Bernard Babani, £2.75, soft cover. Assembly language and machine code for the ZX81, Spectrum, Nascom, TRS80 etc.

### Easy Add-on Projects

- **Easy Add-on Projects for Spectrum**, ZX81 & Ace by Owen Bishop, 182 pages. Babani, £2.75, soft cover. 17 projects including a light-pen, a model railway controller and an anemometer, with software suggestions in Basic and Forth.

### Video User's Handbook


### Computer Communication Techniques


### Radio and Television Servicing


### Microelectronics:

- **Microelectronics: practical approaches for schools & colleges** edited by Graham Bevis and Mike Trotter, 94 A4-size pages plus two small wall-charts doubling as overhead projection transparencies. BP Educational Service, with the Microelectronics Education Programme and BBC Schools Radio, £2.75, soft cover. Lots of things to do, and how to do them; great fun for beginners young or old.

### Microcomputer companies:

- **UK (euroc) 58** edited by John Beaven, 370 pages, soft cover. £32 plus £2 post and packing. From euroc, 6 Woodbury Lane, Clifton, Bristol BS8 2SD. Guide to more than 1700 micro hardware and software suppliers.

### A user guide to the UNIX system:

- **A user guide to the UNIX system** by Rebecca Thomas and Jean Yates, 510 pages. McGraw-Hill, £12.95, soft cover. At-the-keyboard tutorial course for users of this computer operating system, widely used on machines from mainframes to micros.

### IBM Personal Computer Technical Reference Manual:

Microcomputer analysis of a ladder network

Flow diagrams enable a program for ladder network insertion loss and its delay equalization written for a ZX81 to be modified for other computers

by L. E. Weaver

Since the publication of my article "Network analysis with a ZX81" in Wireless World (August and September 1982 issues) I have received appeals for help in adapting the program for micros other than the ZX81. Such a procedure is always full of well-concealed traps even when the dialect of Basic is nominally the same, and after many tedious hours at the v.d.u. I am convinced that in nearly every instance it pays handsomely to start by understanding how the program work, and then to rewrite it for one's own machine and in one's own way. This is all the more valid when the program was originally written for the ZX81, which has certain idiosyncrasies.

What I have done, therefore, is to rewrite the program slightly in a form which is likely to be more generally acceptable to other micro-computers, while keeping the overall format the same to facilitate cross-referencing. The result is given in the form of a series of flow diagrams which point to the relevant lines in the original. As a further aid, these lines or sequences of lines are reproduced in an appendix.

First, a brief review of the method of analysis of the network and the development of the fundamental algorithm. Figs 1(a) and 1(b) show the two possible configurations, the first with shunt input and the last with series. We need to determine the ratio of the voltage across the output termination RI to that of the generator feeding the output termination RO, that is e0/eI, complex quantity, say a+jb. Then the insertion loss is 10log10 ((a+jb)/4, and the insertion phase shift

β=arctan(b/a).

The starting point is the A-matrix for the input termination which, as it must always be considered to be in series, is

\[
\begin{bmatrix}
1 & RI \\
0 & 1 \\
\end{bmatrix}
\]

The A-matrix of the first reactance arm is then added by matrix multiplication, followed by all of the other arms in sequence. Finally, the output termination is added in shunt. The process can be generalized as follows.

Stage 1: data input

The program can be conveniently divided into distinct stages, each with its own flow diagram. The first step is the input of the basic data, i.e.

- FO is starting frequency for the computation (MHz)

Flow diagram for data input

FM is finishing frequency (MHz)
DF is frequency step (MHz)
D is dissipation constant
FD is the frequency associated with D. Remember that D is a function both of the resistive component of a reactor and its reactance. Usually, FD is made the frequency of maximum D over the range of interest, also in MHz.
RI is the value of the input termination (ohms)
RO is the value of the output termination (ohms)
the number of branches NM. These must be alternately series and shunt, or vice versa.

The next step is to input the reactance values into the arrays L(N) and C(N), where N is the number of the branch starting from the input. Each reactance arm is allowed one inductor and one capacitor, where either may be allocated the value zero. This is not a restriction on the applicability of the program. It was demonstrated back in the original article.
(August 1982) that arms with three or more components can be dealt with by means of a simple device.

The method used should be clear from the flow diagram of Fig. 2. Each arm in succession is flagged by means of the arrays T(N) and G(N) to indicate unambiguously whether it contains a series resonant circuit, a parallel resonant circuit, an inductor only, or a capacitor only. Although it is not shown in Fig. 2, it is very desirable to STOP the program when all entries have been made and GOTO a subroutine listing all inputs with the corresponding branch numbers. Without a check of this kind, errors are all too likely. If at some point in this process the matrix has become

\[ Z_1 \times Z_2 + Z_2 + Z_1 \]

then after the addition of a series arm \( Z_s \), this becomes

\[ Z_1 + Z_2 + Z_1 + Z_2 \]

and after the addition of a shunt arm \( Z_p \)

\[ Z_1 + Z_2 + Z_1 + Z_2 \]

At the end, after the addition of the output termination, the matrix element \( Z_{11} = 0/0 \) gives the insertion loss and phase. The element \( Z_{11} \) is not unimportant as it is the input impedance of the network as seen through the input termination RI. However, in the original program this was not required, so that the second row of the matrix does not enter into the computation and may therefore be ignored.

The final result is a pair of what must more correctly be called algorithms, although for the sake of convenience they will still be referred to as matrices:

\[ Z_{11} + Z_{12} + Z_{11} \]

addition of series arm \( Z \),

\[ Z_{11} + Z_{12} + Z_{11} + Z_{12} \]

addition of shunt arm \( Z_p \)

Each term can be a complex number so that an array of the form \( A(1,4) \) is required for the representation of the working matrix, where \( A(1,1) + A(1,2) \) is used for \( Z_{11} \), and \( A(1,3) + A(1,4) \) for \( Z_{12} \).

**Stage 2: computation of loss and delay**

This part of the program has been modified slightly from the original to make it more transportable, although the general format and the line numbering have been left unchanged to facilitate cross-referencing. The flow diagram is given in Fig. 3; bracketed numbers against the boxes are the relevant line numbers. For the sake of those without access to the September 1982 issue these program segments are provided in the Appendix, again with minimum changes. Any changes needed for a particular machine or dialect of Basic should be fairly evident.

One vital piece of information is required before computation can start, that is whether the first arm of the ladder is in series or shunt. This input sets the first element of the \( M(N) \) array to \(-1 \) or \(+1 \) respectively. Execution can then proceed to the setting up of the initial matrix, that corresponding to the input termination RI. Because the 'matrix' is now only a single row, array \( A(1,4) \) suffices. At the same time, the arm number \( N \) is set to \( 1 \).

The arrays of flags \( T(N) \) and \( G(N) \) are then interrogated to determine the type of reactance arm, the real part of the imaginary part of which are then determined by the appropriate program segment. These are next combined with the matrix \( A(1,4) \) either as series or shunt impedances as directed by the array \( M(N) \).

To the end of each pass \( N \) is incremented by \( 1 \) and the sign of \( M(N+1) \) is inverted compared with \( M(N) \), thus maintaining the alternating sequence of series and

---

**Passive networks are alive and well...**

In spite of some predictions, passive networks are still in wide-spread use, especially in the form of video low-pass filters. Their performance is defined in terms of the change in the transmission of a circuit having a definable impedance when opened and the filter inserted; the relevant parameters are insertion loss and group delay. To improve the transient response it is usually necessary to add constant resistance delay correction sections which ideally improve the group delay characteristics without modifying the loss.

In the August and September issues, a program showed how to compute all of this on a single domestic microcomputer. The basis was a matrix addition of the successive ladder impedances, which required a single algorithm. Dissipation could easily be taken into account. This program has been slightly modified and presented again in a more generalized form to enable readers to adapt it to individual needs.
The two values for \( \tan \beta \) are held in the arrays \( P(1) \) and \( P(2) \), hence \( \tan \Delta \beta \) can be computed from the familiar trigonometrical relation:

\[
\tan \Delta \beta = \tan \beta_1 - \tan \beta_2
\]

To obtain \( \Delta \beta \): with video filters the incremental angle in radians is so small as to be equal to its tangent to a high degree of accuracy. For example, suppose the group delay is 1\( \mu \)s, a likely value for a video filter. Then one can see by inspection that the angle will be about 0.006\( \pi \). The second term in the expansion of \( \tan \Delta \beta \) is \( (0.006)^2 \), the first being \( \Delta \beta \), so the error is evidently completely negligible. The group delay in \( \mu \)s is then \( \Delta \beta / (0.0021) \).

However, the last-mentioned values are shadow arms. This is an in-place calculation, so that as soon as \( N=N+1 \), the loss and \( \tan \beta \) may be computed from \( A(1,1) \) and \( A(1,2) \). However, the last-mentioned does not provide the group delay, which is defined as \( \Delta \beta \) \( \delta \text{do} \) where the \( \delta \) represent infinitesimally small increments in \( \beta \) and \( \omega = 2\pi F \). Although there are a few networks whose group delay can be calculated directly, the best one can do in the general case is to add a small increment to \( \beta \) and re-calculate \( \beta \). In the present instance this was chosen to be 0.001, although even smaller values are possible depending upon the quality of the arithmetic of the micro.

Although there be soon a group of \( D(R) \) such that

\[
D(R) = \frac{1}{(1+T^2)M}
\]

This will be evident completely negligible. The group delay in \( \mu \)s is then \( \Delta \beta / (0.0021) \).

The program is stopped. This allows the computed values to be listed, printed, or displayed as required.

One special point — the imaginary part of a capacitative impedance contains \( F \) in the denominator, so an error will be shown unless measures are taken. The simplest precaution is to replace \( F=0 \) by some very small quantity initially, and then to replace \( F=0 \) at the end of the relevant computation. This may be \( 1E-6 \), or even less depending upon the micro, so no practical error is involved. The published program used a more complex method where division by zero is avoided at each step, where it could occur, but the suggested alternative is just as effective. It is not shown in the flow diagram of Fig. 3 for the sake of clarity.

**Stage 3: group delay equalization**

Group delay equalization is carried out by means of constant-resistance equalizers, used as a combination of first and second-order sections. Although higher orders exist, they are rarely used because of their complexity and difficulty of adjustment. In any case, all possible characteristics are feasible with only first and second orders.

First-order sections are defined by a single resonant frequency only, whereas second-order types require as shape factor \( K \) in addition to the resonant frequency \( FR \). During the initial data entry it is convenient to make \( K=0 \) for a first-order section, providing an automatic indicator of the type of section. The only other input needed is the total number of sections \( V \). Because of alignment problems, it is advisable to use not more than four unless unavoidable.

In the flow diagram in Fig. 4 the variable \( M \) is used as a counter, and as \( FR \) and \( K \) are entered they are stored in the arrays \( F(M) \) and \( K(M) \) respectively. Then the already-computed group delay values for the filter in \( Z(R) \) are copied into the array \( Z(R) \). The reason for this becomes evident later. A maximum of 15 frequencies is assumed, but this number is convenient rather than significant, and can readily be changed.
to a very simple subroutine (line 2100). The published program gives the actual variations, but by adding another line just after line 1410 to hold the insertion loss figures B(i) in a new array D(R), it is simple to provide the sum of the two, that is the filter loss plus the delay equalizer dissipation loss.

NewBrain modification
To provide some check on the portability of the program, it was typed into a NewBrain AD with only minor modifications, such as the omission of all LET commands and GOTO's in conditional statements. The general format, and the line numbering were deliberately left intact. A useful feature of this micro is the ability to choose the dimension base of arrays to be unity, as in the ZX81, or zero as in many other machines, so there was no need to change any array dimensions as the program was entered.

The results were very satisfactory. The speed of the program was very noticeably increased, and the accuracy was estimated to be at least an order of magnitude better. In addition, the high-resolution graphics were a valuable aid. The program could obviously be improved still further by rewriting it specifically for this particular computer. In general, this is the approach recommended to anyone wishing to use this method of network analysis. Even then the flow diagram is not sacrosanct, and once the general principles have been grasped it may prove advantageous to modify it to suit one's own circumstances.

Flow diagram for delay equalization

```
(1620) 6 M = 1
V, FR, K ?
F(M) = F(R)
K(M) = K
M = M + 1
Go to

(1640) Compute 1st order delay
Add delay to [Z(R)]
if not M=V+1 then go to

(1800) Compute 2nd order delay
if not M=V+1 then go to

(1780) For R=1 to 75
Z(R) = X(R)
next R
R = 1
F = FO
M = 1

(1830) Z(R) = M
K(M) = 0 ?
Yes
Compute 1st order delay
(1860)
No

(1870) Add delay to [Z(R)]
if not M=V+1 then go to

(1960) If not F=F+M then 7
Print Z (1) print Z(R)-Z(1)
Stop

(2010)
```

LITERATURE RECEIVED
Flat cables and i.d.c. connectors along with suitable accessories and tools all constitute part of the Scotchflex system described in a 32-page brochure which also gives details of a breadboarding system for the rapid production of prototyping circuits. Copies are available from Carolyn Morris, Electronics Products Group, 3M United Kingdom Plc, PO Box 1, Bracknell, Berks RG12 1JU.

WW 401
Cable identification products, including cable sleeves and markers, tools to fit them, cable ties and heat-shrink tools are all described in a catalogue from Siegrist-Orel Ltd, Hornet Close, Pysons Road Industrial Estate, Broadstairs, Kent CT10 2LQ.

WW 402
A six-page fold-out brochure gives full technical information on an 'advanced' carrier frequency instrumentation amplifier which may be used with a variety of bridge transducers. It features an automatic system to balance the bridge in amplitude and phase. Once balanced, the amplifier may be locked by touching a switch. The balance values are automatically stored. The 5kHz carrier frequency allows measurements up to 2000Hz. The KWS 83 brochure is available from Hottinger Baldwin Messtechnik, Howard House, The Runway, Ruislip, Middlesex HA4 6TH.

WW 403
Advance product information has been received on the Ferranti ZN440/ZN441 video a-t-d converters. ZN440 has a 16MHz sample rate and the converters may be stacked so that the initial 6-bit resolution may be expanded to 7 or 8 bits. The ZN441 has a 10MHz sample rate. Applications include high-speed data acquisition, video and radar data conversion, digital signal storage and image processing. Ferranti Electronics Ltd, Fields New Road, Chadderton, Oldham OL9 8NP.

WW 404
A wide range of DIN two-piece p.c.b. connectors are detailed in a 26-page catalogue of the 100/101 range from Panduit Ltd, Lordswood Industrial Estate, 61-65 Revenge Road, Chatham, Kent ME5 BYT.

WW 405
British Standard 4727 is, or will be when it's complete, a glossary of electrotechnical, power telecommunications and electronics, lighting and colour terms. Group 01 of Part 1 gives the fundamental terminology of those terms common to power, telecommunications and electronics. In effect it is a useful dictionary of units, effects and functions. BS1, 2 Park Street, London W1A 8S.

The components catalogue of Ambit International seems to grow bigger each time it is issued. The latest version is in two forms: an industrial version available free to bona fide professional customers, and the consumer/enthusiasts edition available through newagents at 80p. All items are described and priced and there is the Rewtel system for ordering goods via a computer link-up. Ambit International, 200 North Service Road, Brentwood, Essex CM14 4SG.

WW 407
The services of C & S Antennas, who design and make broadcasting and specialised antennae, are described in a glossy brochure. Their extensive R & D facilities enable them to offer aers for almost any application. C & S Antennas Ltd, Knight Road, Strood, Rochester, Kent ME2 7AX.

WW 408
Computer peripheral equipment, including cartridge tape drives and storage systems, tape communications terminals and printers is described in the catalogue of Quantex equipment. Details are also given of the Diabolo-compatible user-programmable impact printer, Model 7040; and a Model 410 high-density cartridge tape streamer and Winchester backup system. The catalogue comes from Euro Electronics Ltd, Twyman House, 31 Camden Road, London NW1 1YE.

WW 409
A colourful wallchart provides full technical specification of the Sharp range of i.e.d.s and i.e.d. devices. Some 42 types are described with type number, colour, lens (shape and type), luminous intensity, viewing angle, current requirement and package outline. The chart is available from Implectron Ltd, Foundry Lane, Horsham, W. Sussex RH13 5PX.

WW 410
Until recently the design of l.s.i. circuits has been the exclusive province of the large semiconductor manufacturers. Now i.e.s can be designed by equipment engineers and to help this happen MEDL has produced a design guide, Designing on Silicon with MEDL. This 58-page introduction introduces the subject, guides an engineer through the various stages and lists the library of gate array cells and other building blocks available. Marconi Electronic Devices Ltd, Doddington Road, Lincoln LN6 0LF.

WW 411
More on p.56
The SC61 waveform analyser from Sencore stands head and shoulders above any other oscilloscopes for speed, accuracy and versatility even from semi-skilled operators — and we're prepared to come round and prove it.

For an on-site test and more information: Mike Dawson 01-897 6446.
**Marconi Type R1020 Hinged Antenna Column.**

**Easy to raise. Easy to lower.**

- Immensely strong, corrosion resistant MATHWEB® g.r.p. column in a rugged steel tabernacle.
- Lightweight, easy to install, and can be safely lowered by one man.
- Can support a number of VHF/UHF antennas.
- Column supplied in range of colours including ICAO orange/white, and requires no painting or maintenance.
- Available in heights from 11 to 19.5 metres.

**OTHER MARCONI SUPPORT STRUCTURES**

Include the MATHWEB® Lattice Antenna Mast Type R1010, and the Triangular Section Tubular Steel Self Supporting Tower Type R1060.

For more information talk to Chris Pettitt, Marketing Manager, Antenna Systems Division.

**Marconi Communication Systems**

Antenna Systems Division
Marconi Communication Systems Limited,
Lane Works, Waterhouse Lane, Chelmsford CM1 2QX, England
Tel: 0245 671111 Telex: 99201

A GEC-Marconi Electronics Company

---

**Sowter Transformers**

With 40 years’ experience in the design and manufacture of several hundred thousand transformers we can supply.

**AUDIO FREQUENCY TRANSFORMERS OF EVERY TYPE**
YOU NAME IT! WE MAKE IT!

**OUR RANGE INCLUDES**

- Microphone transformers (all types), Microphone Splitter/Combiner transformers, Direct injection transformers for Guitars.
- Multi-Secondary output transformers, Bridging transformers, Line transformers, Line transformers to G.D., Isolating Test Specification Tapped impedance matching transformers, Gramophone Pickup transformers, Audio Mixing Desk transformers (all types), Miniature transformers.
- Corrugated transformers for PCB mounting, Experimental transformers, Ultra-low frequency transformers, Ultra-high and other transformers for Transistor and Valve Amplifiers, up to 200 watts, Inductive Loop Transformers, Smoothing Chokes, Filter, Inductors, Amplifiers to 100 volt line transformers (from a few watts up to 1,000 watts), 100 volt line transformers to speakers, Speaker matching transformers (all powers). Column Loudspeaker transformers up to 300 watts or more.

**We can design for RECORDING QUALITY, STUDIO QUALITY, Hi-Fi QUALITY, or P.A. QUALITY. Our prices are highly competitive and we supply large or small quantities and even single transformers. Many standard types are in stock and normal dispatch times are short and sensible.**

**Our clients cover a large number of BROADCASTING AUTHORITIES, MIXING DESK MANUFACTURERS, RECORDING STUDIOS, Hi-FI ENTHUSIASTS, BAND GROUPS, and PUBLIC ADDRESS FIRMS. Export is a specialty and we have overseas clients in the COMMONWEALTH, E.E.C., U.S.A., MIDDLE EAST, etc.**

Send for our questionnaire which, when completed, enables us to post quotations by return.

E.A. Sowter Ltd.

Manufacturers and Designers

E.A. SOWTER LTD. (Established 1941) - Reg. No. England 303990
The Boat Yard, Cattistick Road, Ipswich, IP2 0EL, Suffolk
P.O. Box 33, Ipswich, IP2 0EL, England
Phone: 0473 87230 and 0473 210390
Telex 987703G Sowter

**WWW – 016 FOR FURTHER DETAILS**

**AEL AT SPEED**

TO BE CRYSTAL CLEAR

Tel: 029-34-5353 Telex 87116 Aero G
MOD approved CAA approved

**WWW – 028 FOR FURTHER DETAILS**

**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.**

**BROADFIELDS & MAYCO DISPOSALS**

21 Lodge Lane, N. Finchley, London N12 5mins. from Tally Ho corner
Telephone 445 2713/0749

**WWW – 022 FOR FURTHER DETAILS**

WIRELESS WORLD OCTOBER 1983
Program development with Occam

In advance of bringing out the Transputer, Inmos' advanced microprocessor, the company have launched development systems using their Occam language. The language has been available for nearly a year in an evaluation kit and has proved to be particularly useful for system designers, says Inmos, and so the 'system builders' workstation' has been developed with this in mind, giving some meaning to the phrase 'software engineering'. The language is based on the concepts of concurrency (doing different things at the same time) and communication. It is especially designed for use with multiple interconnected processors. Inmos claim that it is easy to understand, encourages structured programming with a syntax specially designed for interactive use. Many of the problems of programming microprocessors are solved with Occam by formalising the notions of input and output, interrupts, priorities and real-time. Using these eliminates the need to use real-time executives, or machine-code debugging. An Occam program by its nature reflects the structure of the application, describing how the hardware is arranged and providing the specification and implementation of each component. The formal structure of the language leads naturally to correct programs which may be transformed, preserving the function, much as logic functions may be transformed by Boolean algebra.

The workstation, based on a 16-bit 8088 processor, features 600K twin disk drives, 256K of memory, 800x400 pixel graphics. Software packages are available for the Sirius/Victor 9000 and for VAX/MMS computers. Further packages for the Intel iApX 8086, the Motorola M68000 and, of course, the Inmos Transputer, are planned.

Shy computer firm comes out of the closet

Founded in 1977 at about the same time as Apple Computers, the American company Alpha Micro has depended on word-of-mouth recommendations for new customers. Although sales were steady, they did not have the meteoric rise of some other manufacturers (though they did get some good customers; NASA use them for their Automated Management Information Centre, a central data base system). All this changed with the appointment of a new chief executive, the company's president Richard Cortese. He suggested an aggressive approach to sales and marketing and (for example) a UK branch of the company has been opened.

Alpha Micro computers range from the AM-1000 desk-top business computer which can support seven terminals up to the AM-1092 which can accommodate over 40 users. They are all based on the M68000 processor and offer multi-tasking facilities. Software has played an important part in the development of the company and their own operating system, AMOS is claimed to be faster than Unix, although Unix may also be used, as can CP/M and a variety of programming languages. Alphawrite is a multi-user word processing system. Alpha Microsystems (UK) Ltd, 56 Herschel Street, Slough, Berks SL1 1PY.

Surely one of the good things about crossing the Atlantic single-handed would be to get away from the telephone. Not so for computer programmer Mike Spring who has taken a radio telephone to the Azores and back. It provided a link back home for weather information and emergency uses. Mike was paralysed from the waist down after a motoring accident and his voyage was to help to publicise a fund-raising campaign by the Pain Relief Foundation.
End of the Newbrain?

The Newbrain microcomputer may have become one of the first casualties of the home computer boom following a decision by its manufacturers to go into liquidation. Grundy Business Systems, who bought the Newbrain design from Newbury Laboratories in 1981 have blamed ‘severe cash-flow problems’ – caused, it seems, by their attempts to expand production too quickly.

The Newbrain was designed at Sinclair Radionics by Sir Clive Sinclair; and on his departure to form his new company Sinclair Research, the design was transferred to Newbury Laboratories. The machine was put on sale in May 1982 by Grundy after Newbury had decided to redirect their efforts into computer peripherals. Described at the time as ‘the most powerful hand-held microcomputer in the world’, the Newbrain had come close to being chosen by the BBC as the machine to accompany their television series on microcomputers; and although the BBC went on to adopt the Acorn machine instead, the Newbrain was soon selling, according to its makers, up to 5000 machines a month at a price of £199. The Newbrain, however, lacked some of the features which computer buyers were coming to expect – such as sound output and colour and the availability of games software. Attempts by the makers to promote it as an economical machine for small business uses do not seem to have been enough to save it; nevertheless, Grundy hope to be able to find another buyer.

Ethernet wins one race

When Xerox developed Ethernet, the local area networking system, it was generally considered to be too late and not good enough to be accepted as a LAN standard. However IEEE study group 802 has presented its standardization proposals to the International Standard Organization. It is recommending a ‘carrier sense multiple access with crash detection’ (csma/cd) system which is closely based on Ethernet. This has been selected in preference to the ‘token ring’ (IBM) system and the wideband (Wang) system. Liaison between the IEEE and the European Computer Manufacturers’ Association to get a closer correspondence between the Ethernet-based standards adopted by both is to be carried out by Siemens.

News in brief

The Prime Minister is particularly pleased that there are now a million teletext tvs in UK homes. She pointed out at a recent conference that it is the most accessible information technology product and “paves the way for other new products based on the home tv set.” Also a healthy home market can lead to “a vigorous attack on overseas markets”. A recent survey showed that 98% of all teletext and viewdata installations throughout the world use British technology.

- The Japanese video market has found a need to be able to examine the gaps in video tape magnetic heads so that they may be manufactured to the fine tolerances required. The size of the gap varies from 3 to 0.3 microns and the makers have found that they can see these best with microscopes made by Vickers Instruments, originally developed for use in semicon- ductor manufacture.
- Telephones for the hard of hearing work on the induction loop principle. However the latest generation of telephones cannot be inductively coupled to present hearing aids. In answer to a Parliamentary ques- tion, Under-secretary for Industry John Butler has said that discussions with the Royal National Institute for the Deaf and the British Association for the Hard of Hearing are being held to find solutions so that the disabled people will also benefit from advances in technology. Provisions in the Telecommunication Bill will also protect the interests of the disabled.
- Amateur radio licensing has been transferred from the Radio Regulatory Division to the Post Office. The Post Office is to computerize the operation and it is prepared to guarantee a turn-round in normal conditions of five working days and at peak times of ten. The PO currently issues CB licences over the counter but all appli- cations for radio amateurs’ licences will be processed by post from the Post Office Headquarters in Chesterfield.
- Having attracted a number of ‘high technol- ogy’ companies to take space in their new Science Park, the University of Warwick suffers the embarrassment of not having any buildings ready until later in the year.
- To overcome this, Warwick University is offering room in the academic buildings to four companies: Warwick Computer Designs, ABCO Technology, both in the microprocessor applications field, a sur- face coating company and a M.Y Home Systems, who make a variety of devices for use in the home.
- John Alvey, the Chairman of the advisory committee on research into informa- tion technology, has been appointed Engineer-in-chief on the Board of British Telecom. He was formerly BT’s Senior Director, Technology.
- The Youth Training Scheme is providing 700 young people throughout the UK with one-year courses in electronics, data processing or ‘high technology office skills’. The scheme is to be managed by Contact Data, through their training Insti- tutes, at six different cities. The courses are to include 13 weeks of practical on-the- job training, a prerequisite of the YTS scheme, will take place in factories or offices near the Institutes which are biased towards computing or electronics.
- The pioneer in cheap micros, Sinclair’s ZX81, is now being sold with a 16K ram- pack and a software cassette for £45, inclu- sive. This price makes it suitable for buying as a dedicated controller, for example, being less than some control devices or time clocks currently available.
- Transatlantic teleconferencing has be- come possible because of some techniques developed by BT at Martlesham. Although it has been possible to send tv pictures across the Atlantic, the link capacity re- quired, equivalent to about 1000 telephone calls, has imposed excessive costs. The new digital service saves by sending only the changes in a picture and by using a new coder/decoder to send good quality pic- tures on digital links at 2Mbits/s, equivalent to 30 telephone calls.
- Unemployed engineers who have had experience in industrial research and de- velopment can apply for a Wolfson Industri- al Research Fellowship. Applicants must propose a project that they will work on during the tenure of their Fellowship. There is no restriction on the projects chosen, except that each should show reasonable expectation of commercial or industrial benefit in the medium term. Preference will be given to applicants in the age range 25 to 35 years. The scheme provides each research Fellow with a stipend appropriate to age and experience and to the laboratory where the research will be carried out to provide for overheads and expenses. Fellowship of Engineering, 2 Little Smith Street, London SW1P 3DL.
- A new British transistor manufacturer is soon to appear. Concentrating their efforts into testing and supplying semiconductors to BS and defence standards, Semelab in Lutterworth, Leicestershire also manufac- tures transistors from supplied wafers. They use stringent quality control tests to meet those same standards. A new factory has allowed them to expand their operation and they plan to get diffusion equipment to enable them to manufacture complete devices. One area that they aim to cover is discontinued transistors that the major companies can’t be bothered to make any more but for which there is a continuing demand.
Multi-function multiplexer for light fibres

Faced with the problem of getting the same information as they were getting down 200 pairs of twisted copper wires and yet using optical fibres, the BBC has developed a flexible control system for switching audio, communications and control circuits through small cables. Fibre optics were chosen because they are unaffected by electro-magnetic interference and can be routed through conduit carrying mains power cables, if necessary. A master circuit at each end of a link allows 16 data channels to be routed through it. Each channel can carry up to 255 different coded commands giving a capacity of 4080 commands. Because the system is inter-active and two-way 2040 executive actions may be switched or remotely controlled. Different interface circuits may be plugged in to allow a circuit to perform specific functions; a two-way digital control interface allows commands to individual switches, indicators and remote control devices to be coded and sent over the system, an RS232 or RS422 interface allows the system to be used with any equipment using these interface protocols as in computer peripherals, printers and display units, an analogue interface provides eight send and return lines and is for use with remote variable analogue controls. The channel port itself conforms to the Centronics 8-bit parallel standard, which enables any system to be fitted to any combination of the available interface circuits. The design is to be marketed by Pilkington Fibre Optic Technologies Ltd, and their first customer is – of course – the BBC who have ordered 50 of the multiplexers for use in remote switching of tape machines in their local radio stations.

Satellite news

Several hundred million pounds are to be spent by Marisat for their next generation of marine communications satellites. These will replace the current programme with capacity leased on nine spacecraft, three of which are still to be launched. They are requesting tenders from satellite manufacturers from all over the world and stipulate that the craft should be capable of being launched from Ariane, the Space Shuttle or from the Soviet rocket, Proton. The system is to have more power and more capacity than the existing system; 125 telephone channels, compared with 40 on the MARECS satellite. Possible extension to the use of the system could be in aircraft communication which could add significantly to the efficiency of air-traffic control and as the satellites will play an important part in maritime safety and distress systems, they should be powerful enough to be able to relay distress calls from small transmitters as might be carried by a life-raft or emergency beacon. Another use mooted is for land communication to particularly isolated areas, though Inmarsat stress that maritime communication must have first priority. However, exactly such access has been granted to the Australian research base in Antarctica and to an Italian offshore drilling platform in the Adriatic Sea. These services will be used chiefly for the transmission of data to analysis centres.

The European large telecommunications satellite (L-Sat) has recently been rechristened Olympus and is likely to be launched from an Ariane 3 rocket late in 1986. This has been the subject of a contract between ESA and Arianespace. Another contract between them is for the launch of three satellites which are to be improved versions of Meteosat.

Brains trust for electronic brain research

Following the Alvey Report, five members of the Alvey programme steering committee have been appointed. They are Philip Hughes, chairman of Logica Holdings; Dr Keith Warren, director of technology and strategic planning at Plessey; Colin Southgate, chief executive, Thorn EMI Information Technology; John Leighfield, managing director, BL Systems, and Professor Eric Ash, head of the department of electronic and electrical engineering at UCL. Professor Ash will also represent SERC and Colin Fielding (Ministry of Defence) with Roy Croft from the DTI will complete the panel under the chairmanship of Sir Robert Telford.

The Committee has been set up to coordinate research in industry, academic centres, research organisation and the Government to "mobilise UK strength in advanced information technology". Four particular areas have been selected: very-large-scale integrated circuits, software engineering, intelligent knowledge-based systems (often called expert systems), and man/machine interfaces. Much of the work will be directed towards the development of 'fifth-generation' computers.
World timing using h.f. broadcasts

Using the apparatus described, and a versatile h.f. receiver, time signals of several h.f. stations have been found to be in error – some fast, some slow, some varying from day to day.

by R. C. V. Marcario and G. R. Munro

than an error of time. For a full discussion of the relation between errors in time and frequency refer to reference 1. (For a valuable textbook on standards of frequency and time see ref. 2.)

It is common practice to indicate zone time by means of radio 'pips' or tones. In the UK the hour is marked by the beginning of the sixth of a set of five 100ms tones plus a sixth 500ms 1kHz tone. In many countries, one also has special standard frequency and time transmission, see reference 3. In the UK the 60kHz MSF Rugby transmitter, located at 52.35°N, 1.17°W, radiates a standard frequency, off modulated with coded one-second signals. This enables clock calibration to an accuracy of a few microseconds to be achieved over the UK (4).

Despite direct satellite broadcasting, the broadcasting of national news and views by means of short wave radio is as active today as ever. The World Radio & TV Handbook lists the frequencies and times of each nation’s transmissions in an extensive manner, and indeed if one receives such signals the hourly time marker tones are often heard. One therefore has access to that particular nation’s time bureau, except for the propagation delay. Fig. 1 illustrates the basic arrangement for comparing a local clock with a distant clock. With access to a number of hf receivers, multiple comparison can be arranged. This article describes some simple circuitry for setting up such an arrangement.

Comparison apparatus

Because of h.f. sound broadcast signals often being noisy, and also to more clearly separate the time marker tones from the programme material, a tunable bandpass filter, centred at say 1kHz, is placed between the hf receiver’s audio output and the signal recorder, as shown in Fig. 1. The most suitable signal recorder is a

The authors are in the department of electrical and electronic engineering, University College of Swansea

1983 is designated World Communication Year and one of its main objectives is to stimulate the development of improved communications infrastructures, most particularly in the developing countries. Often, improved communications means more rapid communications which implies good time keeping at all places. Even in everyday life, one now expects more rapid communications which implies communications between towns and countries well in advance of when they were possible in the past.

The master clock theory is not restricted to the use of a single clock. In each country the time used is determined by the nearest station to that country, but it is the problem of having a world time signal that is common to all.

Fig. 1. Signal received on h.f. receiver is compared with a minute pulse marker generated from an MSF 60kHz receiver and displayed on a storage oscilloscope.
Fig. 2. Trace (a) in timing waveforms is part of the MSF signal format, but is not necessarily displayed; trace (b) is the style of the time pip tone received from an overseas h.f. station; trace (c) is generated within the MSF receiver and acts as the oscilloscope trigger pulse.

Fig. 3. Minute marker in this typical time comparison display is seen followed by the time tone waveform, from Radio Prague on 5.93MHz in the example shown at top. Time scale is 2ms/div. (0915h 18 March 1983).

Fig. 4. Aerial amplifier for the 60kHz MSF signal. FET gives a high impedance input and so works off a short whip antenna. The cmos gates are operated in a linear mode and provide sufficient gain at 60kHz to drive a phase-locked loop detector. Fig. 5. This unit should be screened.

Storage oscilloscope because the time scale appropriate for the study is a few milliseconds. Examples of records are given below. In the other path is part of a receiver for the 60kHz MSF transmission and some logic for triggering the display on the minute on the hour, for example. One does not need to build a complete time-code receiver (5), just part, and an easily constructed system is described next. That part of the MSF signal which occurs around the minute time is shown in Fig. 2(a). The slow time code information is distributed over the 60 second interval, each second occurring at the negative edge of these long pulses. After the 60th second a set of short pulses (10ms duration) constitute the fast time code. The edge of interest is the negative 60th second edge, which is displayed on the oscilloscope and gives the marker for GMT Fig. 2(b). The oscilloscope is required to trigger on the fifty-ninth second plus a suitable delay. Therefore the trigger circuit counts 58 pulses from the last trigger, and after a variable delay triggers the oscilloscope ahead of the one minute marker (c). The
type of received time tone from the distant h.f. transmitter is shown at (d).

When these signals are combined together on the oscilloscope a pattern like Fig. 3 is observed. In this instance this was a time signal from Prague on 5930kHz at 21.30h U.K. time. The delay between the local g.m.t. and the received signal should correspond to the great circle path propagation delay, discussed below.

A practical front-end circuit for receiving the MSF signal using a short-wave antenna is shown in Fig. 4. The circuit conveniently fits inside a standard Eddystone box. The f.e.t. provides a high input impedance, followed by a double-tuned circuit. Because linearity is not important for the receiver a common amplifier using a feedback-coupled 4011 gate is used, providing a clean MSF signal carrier, except under very noisy signal conditions.

The carrier envelope contains the time information. The Signetics 567 p.i.l. time decoder will operate directly from the preamplifier, and a circuit is shown in Fig. 5. With buffering, a positive or negative code option at cmos level is available.

There are several options for triggering the display oscilloscope depending on how far one intends to make the system partially or fully automatic, because one needs to prime the trigger on the 58th second of the hour and have the 59th second produce a trigger pulse, delayed by about 990ms. We had the advantage of having a complete MSF time-code receiver and display and several options. The receiver would recognise the 59th second and give a delayed trigger pulse, using a 4098 monostable. The advantage of having a complete clock is that one now has a record of the time plus most of the required circuits already built; the type of display shown in Fig. 3 was therefore not difficult to arrange. To avoid further cmos circuitry we therefore leave the description of these circuits, as those already described set up the MSF code signal at cmos level (Fig. 2(a)) and one can arrange the required signal pattern according to any particular requirement.

**Expected results**

The negative edge marker is the local MSF GMT minute time, plus the propagation delay between Rugby and one’s location. In our case NPL inform us that the delay is 695±2µs; allowing for some circuit delay, we therefore took the delay as being 0.7ms. The start of the delay between these two marks, less the great circle path delay, plus 0.7ms. The h.f. path propagation delay would cause the distant station to appear later than the GMT marker, if its clock was on time.

The h.f. path delay can be estimated to be within about ±0.5ms using the data from reference 1 shown as Fig. 6, assuming the great circle path distance can be calculated from a knowledge of one’s own position and that of the distant transmitter. One does not know the transmitter’s exact location, as an error of a few hundred kilometers will only produce a time delay error of, say, ±0.5ms (Fig. 6), which is not too important in some cases. The calculation of the path distances requires access to haversine tables (references 1 and 6) and a procedure is given in the Appendix.

Using the apparatus described and a versatile h.f. receiver one can collect interesting results. For example, Fig 3 showed Radio Prague, which is some 1350km distance, whilst Fig. 7 shows the recording for Radio South Africa on 27.790MHz, and distilled at 9250km. The delay on the received time tone is such that the first marker pulse of the MSF fast code can also be seen on the display.

We do not intend to discuss which stations have clocks running exactly in synchronism with GMT, as many results and careful calibration would be necessary. But we should say that several stations appear to be in error by orders of tens of milliseconds, some fast, some slow, some varying from day to day. A study on the basis of the method of national clock keeping would appear to fit in with the spirit of WCT'83.

**Appendix**

**Calculation of great circle distance**

Require longitude of receiving and transmitting site, i.e. LOR and LOT, then let LRT = LOR - LOT. Require latitude of receiving and transmitting site, i.e. Lq and Ly. If the two locations are on the same side of the equator, let

\[ \Delta L = L_q - L_y \]

If the two locations are on the opposite sides of the equator, let

\[ \Delta L = L_q + L_y \]

Then the great circle distance (D) equation is

\[ \cos D = \cos L_q \cos L_y \cos \Delta L + \sin L_q \sin L_y \]

where \( D \) is the great circle distance in kilometers. Delay time will vary during the day because the propagation may be supported by alternate ionospheric layers as indicated.

**References**

1. Frequency and Time Standards, Hewlett-Packard application note, AN52.
4. Time and Frequency Service Notices, National Physical Laboratory, Teddington, Midds, TW11 0LW.

**LITERATURE RECEIVED**

The new edition of the MS Components' Catalogue has increased considerably in size to reflect the addition of some 2,500 new products. A useful addition is the index to semiconductor i.c.s. MS Components Ltd, Zephyr House, Waring Street, West Norwood, London SE27 9LH.

**WW 412**

A 625-page hard cover book is needed to describe the full range of Wandel and Goltermann precision electronic measuring instruments. It includes details of a.f. and r.f. voltage and level generation and measuring equipment, analogue and digital data communications meters, distortion measurement, some general-purpose instruments and automatic measuring systems. Wandel and Goltermann, Postfach 45, Muhleweg 5, D-7412 Eningen, F.R.G.

**WW 413**

Interfacing the Real World to Your Computer is the title of a 16-page booklet which illustrates methods of interfacing sensors, transducers, output actuators and other devices. Products described include signal conditioners, two-wire transmission, alarm systems, analogue input/output subsystems and remote, intelligent i/o subsystems. Analogue Devices Ltd, Central Avenue, East Molesey, Surrey KT8 OSN.

**WW 414**

More on p.48
Multicharacter dot-matrix display

Designed as the display section of a terminal emulator for computer fault diagnosis, this expandable circuit drives a 16-character alphanumeric display from ASCII code. The four character Hewlett Packard HDSP2000 display is a seven-by-five dot-matrix type comparable in cost to 16-segment devices but it has constant-current I.E.D. drivers and is larger and easier to read. LCD modules with more functions exist but would limit the circuit to very low data rates. Electrically the display is a 28-stage first-in-first-out shift register with programmable constant-current I.E.D. drivers; character display is by external column strobing.

ASCII data may be asynchronous or read from ram addresses by the 7493 counter whose division factor n is equal to the number of display characters. Upper-case characters generated by the 74S262 are selected on lines B1_7 and converted to serial form by gating on each column output (shown abbreviated for clarity) while IC1 cycles through row addresses n times. Display blanking occurs while data is clocked in. On completion of the character count the divide-by-n period signal goes low, triggering the 74121 monostable i.c. which stops the clock and unblanks the display for 2ms. After the pulse, column address counter IC3 is incremented and the cycle repeats. Quinary counter IC3 ensures that any random state at switch on synchronizes with IC1,2 during the first count sequence. This method will not work with 2513 character generators which have no row address-zero output.

For flicker-free display each column must be strobed at least 100Hz hence the choice of a 2ms display period; clock frequency determines the duty cycle by seven times the number of display characters. Component values shown drive a 16-character display.

N. A. C. Simons
London W10

Regulator with negligible i/o voltage

When high or medium current is required from a voltage regulator, input/output voltage difference must usually be greater than 1V. Using a converter to increase the input voltage allows this differential to be reduced to the series-pass transistor saturation voltage. The basic circuit shown for a load of a few hundred mA can be used to provide a regulated 5V supply from a 6V battery. Ratings of the 7660 limit the input to below 10V.

A. Kerim Fahme
Autolight
Aleppo, Syria
**6-digit decade counter**

This circuit for up to six digits counts up or down between .000000 and 999 999 and gives over and underflow indications. Positive edge transitions on the count-up line increment the least-significant digit and positive-edge transitions on the count-down line decrement the same digit. Buffered signals C_0 and C_d represent carry and borrow indications respectively from the second most-significant digit.

When the counter under or overflows the 74156 decimal-point, decoder 1Y3 output goes low, causing the under/overflow line to go high. This keeps C_u and C_d inputs of the lowest-order counter low and disables decimal-point decoder outputs. In this situation the counter is disabled and must be reset by the active-high clear input.

G. A. M. Labib
Cairo
Egypt

---

**Logarithmic dividers using equal resistors**

These circuits, one a bar-display VU meter and the other a step attenuator, illustrate a logarithmic potential divider in which only the last section of the ladder, consisting of R_2 and R_z in parallel, need contain a non-preferred resistor value. All other resistors in the ladder are one of two values. Where A is the voltage drop for each stage equations for values are as follows

\[
(dB) = 20 \log_{10} A
\]

Z is the ladder impedance. As only one resistor is equal to Z it is better to choose either R_1 or R_2/Z as a standard value so that resistor packs may be used.

\[
R_1 = \frac{Z(A^2 - 1)}{2A}
\]

\[
R_2 = \frac{Z(A + 1)}{A - 1}
\]

John D. Thompson
Lewes
East Sussex

---

*58 WIRELESS WORLD OCTOBER 1983*
One-out-of-seven rom selector

Designed for the Acorn Atom which has only one spare rom socket though several roms are available, this circuit selects one rom from a possible total of seven by polling address A0000 with the required rom number (0-7). Zero is automatically selected on power up (and reset if required) allowing a specific rom to be selected by default, e.g. a utility rom.

The circuit is based on the fact that a rom is never usually sent data from the processor. A write operation to the block Axxx is indicated by R/W and CE both being low; this is detected by the two enable inputs of IC1 — a 74173 four-bit register which latches the data lines D0, D1 and D2 to its outputs on a rising edge at its clock input.

Now R/W and CE are both set when the address lines are stable (ignoring propagation delays of about 50ns), however, the data is not present and stable for 650ns. IC2, a 74121, is a monostable which provides a rising pulse 700ns after R/W goes low latching the data bus contents to the outputs of IC1.

The latch outputs provide the input data for IC3, a 74155, which is a dual 2-to-4 decoder configured as a 3-to-8 decoder (active low). IC3 has a clear input which is active high and can be driven in two ways. Firstly it can be taken to RES giving a clear operation (sets decoder output 0 low) on any system resets including power up. However, remember that if the rom is part of the operating system (e.g. a utility rom) then system vectors will have to be changed before a new rom is selected. This can be overcome by using the second method, that is, clear on power up only (POW). The system vectors can be reset by executing BREAK from the keyboard immediately after selecting a new rom. For example say rom 5 is wanted then:

?#A000=5

is typed in direct mode followed by RETURN and BREAK. Any rom can be elected from within a program by:

?#A000=n(n=0, 1 ... 7)

All the control lines required are available at the original rom socket (IC0) with the exception of R/W which can be taken from b30 of p16. The circuit should work with any 1MHz 6502 processor.

D. C. Grindrod
Sutton Coldfield
West Midlands

Cheap voltage doubler

Originally designed to enable a 12V stack of NiCd cells to be charged from a 12V car supply without splitting the stack, this doubler can deliver around 2A depending on the type and value selected for the pump capacitor.

To prevent a large current flowing through the two output transistors during the transition period, a four-phase clock is used. The slave RC network has a 90 degree phase lead over the oscillator. The outputs of the slave RC network and the oscillator may thus be combined to produce non-overlapping output pulses. These pulses are fed direct to power Darlington transistors which have sufficient gain for the power stage.

The pump capacitors actually require a value of only a few microfarads, but must be able to handle the currents involved. The cheapest solution is to use larger-value electrolytics.

Paul Stephenson
Hull

WIRELESS WORLD OCTOBER 1983
Improving stereo at l.f.

Spatial effect in a stereophonic sound system decreases at frequencies below 800Hz in comparison with a concert hall. This method for increasing the l.f. spatial impression of two-channel stereo reproduction can also be used to add ambience in mono reproduction.

The spatial impression obtained when listening to sound in a room is related to the human biaural hearing property. When one hears sounds of the same amplitude and phase at both ears, one has a spatial impression. The degree of spatial impression with steady-state random noise can be related directly to the interaural cross-correlation coefficient (i.c.c.), viz. the simple cross-correlation coefficient between sounds at both ears introduced by Damaske1. Curves of equal spatial impression using an i.c.c. depending on frequency of an applied random noise were given by Anazawa2, but this measure cannot express well the difference between the spatial impression given by mono and stereo sound reproduction. In a room of reverberation time of more than 0.3s, there is no clear difference between the coefficients in mono and stereo sound fields. The spatial impression discussed here is the sort usually called ambience or ‘surrounding sound’ in audio.

The spatial sensations created by musical sound that involves many transient or pulsive sounds and steady-state random noise are different providing that the i.c.cs are the same, which is easily examined by experiments. Our hearing has an ability to locate a pulsive sound that is followed by many echoes of different incident angles. In other words, our hearing is less sensitive to early reflections that reinforce the direct sound. Such a hearing property is important and should be reflected in quantifying spatial impressions for musical sound. The rate of subjective intensity of a direct sound reinforced by early reflections is approximately given by the definition of Thiele5 as the ratio of the energy of early reflections within 50ms, including the direct sound, to the total energy arriving at a given location in a room. We use this definition, D, tentatively as the weighting of the subjective intensity of a direct sound, and define the perceptual interaural cross-correlation coefficient (p.i.c.c.) by:

$$\text{PICC} = DR_0 + (1-D)R_E$$

where $R_0$ is the i.c.c. of the direct sound, unity for normal incidence, and $R_E$ the i.c.c. of reverberant (incoherent) sounds, expressed by

![Fig. 1. Family of perceptual interaural cross-correlation (PICC) curves of equal acoustic spatial impression (ASI). Full spatial impression is indicated by ASI=100% and no impression by ASI=0% (below).](image)

![Fig. 2. Plan view of arrangement of loudspeakers and a listener for compiling p.i.c.c. curves shown in Fig. 3 for stereo reproduction.](image)

The author

Born in Tokyo, 1940, Yoshimutsu Hirata graduated from Waseda University in 1965 and received the degree of Dr Eng. by work on the acoustic property of mufflers with air flow in 1970. He was a researcher at Waseda University from 1970 to 1981, and from 1982, Dr Hirata became an independent researcher and consultant in the areas of room acoustics, noise control, electroacoustics, signal processing, and audio in general. A previous article investigating listening tests of amplifier sound in the October 1981 issue, described a new technique for quantifying amplifier sound using an asymmetric test signal with no d.c. component. We reported one of his earlier techniques back in 1974 when we met Dr Hirata at a London acoustics congress presenting a paper on multiplexing by digital comb filtering (News, October, 1974).
ASI = 60%

where in reproduction Fig. 3.

which verberation chamber impression, which D source should be accounted for. Such an effect, neglected here, should be given special consideration.

From equation 1, PICC = 1 for a single source in an anechoic room (free field) where D = 1, and PICC = Rg in a reverberation chamber (diffuse field) where D = 0. In an anechoic room one gets no spatial impression, while one gets full spatial impression in a diffuse field such as a reverberation chamber or stone cathedral which might have a reverberation time as long as 10 seconds. For convenience we introduce here ASI as the index of acoustic spatial impression, expressed by

ASI = (1 - D) x 100 (%).

(3)

Full spatial impression is indicated by ASI = 100% and no spatial impression by ASI = 0. Fig. 1 shows a family of p.i.c.c.

curves depending on the frequency with ASI as parameter. The definition at a middle seat position in a concert hall is typically 0.4, where the p.i.c.c. is given by the curve indicated by ASI = 60%. Because one does not localize reverberant sounds, one gets the maximum ASI of 100% instantaneously at all seats in a hall for reverberant sounds heard, for example, at a rest after the stop of a fortissimo. Widespread plural sound sources of the same timbre also gives one a spatial impression, expressed by eqn 1, where the mean ICC for plural direct sounds of several incidence angles is used for Rg. The grey area of Fig. 1 indicates the region where one gets a feeling of unnaturalness, viz., an excessive spatial impression or a separate impression when PICC approaches -1.

In a typical listening room of reverberation time 0.3 s, the definition at a location 3 m apart from a single source is about 0.9, where the p.i.c.c. is given by the curve indicated by ASI = 10%, assuming the reverberant sound is diffuse. Thus, one gets but insufficient spatial impression for mono sound reproduction in a listening room. The p.i.c.c. for stereophony using two loudspeakers is

\[
\text{P}IC\text{C} = D_h R_{\text{rep}} + (1 - D_h) R_{\text{E}}
\]

where R_{\text{rep}} is the i.c.c. of the direct sounds emanating from two loudspeakers, which is a function of D_h, RH, and e, and R_E being the definition of a recorded sound, R_H the cross-correlation coefficient between sounds recorded from two microphones placed at a distance from one another in a concert hall, and e an angle at the listener of the configuration shown in Fig. 2. In the case of stereophonic recording, two microphones (or two sets of microphones) for picking up reverberant sounds in a concert hall are usually placed at a distance so that RH = 0, which is empirically done by recording engineers. The typical value of the definition of a recorded source for symphonic music is 0.5, given by Yamamoto at NHK. Using the values RH = 0, DI = 0.5 and 0 = 60°, and assuming that the distance between a listening position and each loudspeaker is 3 m, one gets the p.i.c.c. curves for stereo sound reproduction from eqn 4. The results are shown in Fig. 3 in the range 0 ≤ T_L ≤ 1 s, T_L being the reverberation time of a listening room, where a broken line shows T_L = 0.3 s. Figure 3 shows that the ASI in the stereophonic sound field is small at frequencies less than 800 Hz and large at frequencies greater than 800 Hz in comparison with that in the concert hall, where ASI = 60%. The maximum spatial impression given instantaneously by the reverberant sound reproduced in a stereo system is expressed by the p.i.c.c. curve with RH = 0, DI = 0 and 0 = 60° in eqn 4 and shown in Fig. 4. In comparison with the curve indicated by ASI = 100%, which is the maximum spatial impression given in the concert hall, the spatial impression for reverberant sounds reproduced in a stereo system is small at frequencies less than 800 Hz. Fig. 4 also suggests that the reproduced reverberant h.f. sound gives an impression such as hearing two different reverberant sounds emanating from each loudspeaker.

Curves for stereo sound reproduction where the definition of a recorded source DH is varied from 0.3 (too reverberant source) to 0.7 (too dry source) are shown in
increasing the
decreasing the
tage
spaciousness
one
degrees less
room and the reverberation time of

one

Fig. 5, a broken line showing \( D_H = 0.5 \), and the reverberation time of a listening room is fixed at 0.3s. This indicates that one cannot fully increase the ASI of reproduced sound at low frequencies by simply reducing the definition of the recording source. To create natural spaciousness, one must decrease the p.i.c.c. at frequencies less than 800Hz and increase it at frequencies more than 800Hz. The p.i.c.c. decreases when the distance between two loudspeakers increases and vice versa.

One method for getting a natural spaciousness uses additional loudspeakers, some for low frequency and some for high frequency reproduction. But this brings the disadvantage (to a listener, an advantage to the maker) of spending money for the additional amplifier and loudspeaker system. To avoid increasing the number of loudspeakers, one can create natural spaciousness by using a simple circuit for decreasing the p.i.c.c. at low frequencies together with the geometrical method for increasing the p.i.c.c. at high frequencies. The block diagram of the circuit is shown in Fig. 6. When the delay time \( T_D \) and/or the amplitude of the delayed signal increases, the spatial impression increases, which is explained by the decreasing of the p.i.c.c.\(^1\). Incidentally, dropping the 'p' in p.i.c.c. makes this effect inexplicable, i.e. the i.c.c. remains unchanged for variable \( T_D \).

The circuit of Fig. 6 is also available for adding ambience to the mono sound transmitted by a.m. radio or tv stations. This may bring up the basic question of whether a.m. or tv stereo broadcasting is really necessary.

References

WIRELESS WORLD OCTOBER 1983

---

Fig. 6. Block diagram of the circuit for increasing spaciousness for frequencies less than 800Hz. Delay line consists of an analogue shift register in the form of a bucket-brigade device. Delay time from b.b.d. is 45ms in circuit shown.
Ever since Einstein’s special theory of relativity became a prominent part of physics, it has been a subject of some controversy. One of the foremost critics of the theory was the late Herbert Dingle (1890-1978), who spent much of his time and energy during the last two decades of his life in trying to persuade the scientific world that the special theory, although mathematically valid, contains an inconsistency in its physical application. Although most scientists seem to be convinced that the controversy stirred up by Professor Dingle’s criticisms has been conclusively settled in favour of the theory, a close examination of the relevant literature shows many inconsistencies in the arguments by which the special theory has been defended. The present article does not attempt to settle the matter, in fact it shows that the issue has not yet been satisfactorily settled. It is hoped that scientists and philosophers may be encouraged to continue the search for the truth of the matter, whatever it may be.

Simple example of inconsistency

Readers who are not experts on relativity may feel convinced that the inconsistencies that have been mentioned are beyond their understanding; on the contrary, many of them are perfectly obvious to anyone who takes the trouble to read them. To take a specific example, consider two inconsistent statements that were made in the British journal *The Listener* in 1971.

Professor J. Taylor claimed¹ that the results of the well-known experiment of Hafele and Keating, which had then been recently performed, supported Einstein’s special theory. Professor Dingle published a letter rebutting Taylor’s article, and further correspondence continued to be published, in the course of which another scientist, Professor M. A. Jaswon, published a letter² which disagreed with some of Dingle’s points, but which agreed with Dingle that the experiment in question had “no relevance whatever for the special theory”. Although that statement was directly contrary to Taylor’s claim, Taylor later published another letter³ which continued to criticise Dingle but which took no notice whatever of Jaswon’s statement.

Some observers of the controversy may believe that inconsistent statements like these result from attempting to express abstruse technical matters in simple language, and that such inconsistencies may therefore be dismissed as being inconsequential. But the inconsistency between the statements mentioned above cannot be dismissed in that way. A statement that the results of a particular experiment support a certain theory is a perfectly simple factual statement (however abstruse may be the reasoning by which that statement is justified), and the same applies to the contrary statement. The fact that Taylor’s and Jaswon’s statements are contrary to one another (that is, they cannot both be true, though they could both be false) shows that, unless there is an inconsistency in the special theory itself, one or other of the two scientists (or both) misunderstood either the theory or the experiment (or both).

It will also be clear to any reader, scientist or not, who reads the whole of the correspondence that includes the above items (refs 1-3), that no attempt was made to resolve the inconsistency between Taylor’s and Jaswon’s statements. If science is the search for truth, wherever the search may lead, the serious inconsistency between the statements of the two scientists ought to be followed up to find out which statement, if either, is true. The fact that both statements have been accepted in spite of their obvious incompatibility is evidence that there is not enough scientific curiosity about the truth of the matter. The remainder of this article presents further evidence in support of the same point of view.

Further examples of inconsistency

Professor Dingle’s criticisms of special relativity are presented at length in his book *Science at the Crossroads*, and it is in the published reviews of that book that many of the inconsistent attempts to defend the theory have been made. To study some of these attempts, consider Dingle’s crucial question, which is central to his book, and which is worded as follows:

“According to the special relativity theory, as expounded by Einstein in his original paper, two similar regularly-running clocks, A and B, in uniform relative motion must work at different rates. In mathematical terms, the intervals \(dt\) and \(dt'\), which they record between the same two events are related by the Lorentz transformation, according to which \(dt' - dt\). Hence one clock must work steadily at a slower rate than the other. The theory, however, provides no indication of which clock that is, and the question inevitably arises: How is the slower-working clock distinguished?”

In a review of Dingle’s book, Professor J. M. Ziman quoted the above question and then wrote: “This is a perfectly reasonable question to which science should indeed give an answer.” Later in his review he gave his own answer, in the following words: “In fact, the answer to Dingle’s ‘question’ is simple: the fastest-working clock between any two events is one that travels between them by free fall.” But, as Dingle subsequently pointed out⁴, neither of the events need be at either of the clocks concerned. Also, since the question asked for a distinction between two clocks, not for a choice among all possible clocks, Ziman’s answer, whether or not it is a true statement, is simply not an answer to the question that was asked.

Dingle also supplemented his question by referring to a specific example in Einstein’s original paper on special relativity, in which Einstein had stated that a balance-clock at the equator would work more slowly than an exactly similar clock at one of the poles. Dingle stipulated that any answer to his question should specify what it was that entitled Einstein to conclude, from the special theory, that the equatorial and not the polar clock worked more slowly. Dingle stressed that the special theory did not take any account of possible effects of acceleration, gravitation, or any difference at all between the two clocks except their state of uniform relative motion. It should be strongly emphasised, however, that he did not assert that acceleration and gravitation were absent from the situation described by Einstein, but that those phenomena are not dealt with by special relativity, and consequently it is not legitimate to invoke those phenomena to explain what entitled Einstein to conclude from the special theory that the equatorial clock worked more slowly.

The attempts to answer this supplemen-

---

Professor McCausland is in the department of electrical engineering, University of Toronto, Ontario, Canada.

---


WIRELESS WORLD OCTOBER 1983

63
tary question show an interesting diversity. In the first place, it is obvious that Ziman’s answer, quoted above, does not apply to this situation; after the two clocks are in their positions at the pole and at the equator, there is no event at which both clocks are present, so there is no way in which Ziman’s criterion can distinguish between them unless some pair of events is specified.

Consider now some of the other attempts to answer the question about the polar and equatorial clocks. For example, Professor G. J. Whitrow wrote as follows:

“For a supporter of relativity, the essential difference between the two clocks is that relative to the centre of the Earth (which for the purpose concerned can be regarded as the origin of an inertial frame) the clock at the equator describes a circle and so cannot be associated with an inertial frame, whereas the polar clock is at rest and can be associated with an inertial frame for a period of time during which the curvature of the Earth’s orbit can be neglected. The time difference mentioned by Einstein can be demonstrated by means of the Minkowski diagram, in which the track of the polar clock will be rectilinear whereas that of the equatorial clock will be curved.”

Two comments may be made about this. First, if the equatorial clock is not in an inertial frame, then its motion lies outside the scope of the special theory, which applies only to inertial frames; it is therefore invalid to deduce from the special theory any conclusion about the relative rates of the two clocks. Second, the answer raises the equally difficult question of why a clock that moves in a large closed curve is in an inertial frame, while one that moves in a smaller closed curve is not.

Compare Whitrow’s answer with the following answer, which is found in an unsigned editorial article in Nature:

“It seems now to be accepted that Einstein’s original argument was uncharacteristically loose. The point of the illustration is that a clock at the pole of rotation may be taken to be in an inertial frame which is nearly (but not quite) perfectly defined by the direction of the Earth’s motion around the Sun. The clock at the equator is in another. Einstein’s lack of clarity concerns the inertial frame of the observer of the two clocks.”

This statement implies that the answer to the question is about which clock moves more slowly depends on the observer. But Einstein’s statement clearly implies that the slowing of the equatorial clock is a real effect and not merely an effect of observation, and this is confirmed by the fact that he added a footnote to say that his statement did not apply to pendulum clocks. The answer also states that the equatorial clock is in an inertial frame, and this explicitly contradicts Whitrow, who states that it is not.

Another answer to the same question is given by Stadlen, who writes:

“But the relative motion involved in this case, being circular, is non-uniform. I submit, therefore, that Einstein was wrong in saying that his prediction followed from the special theory, which deals only with the effects of uniform motion. This is not to say that the prediction was invalid. For Einstein was, intuitively, anticipating his later general theory, according to which the equatorial clock runs faster because of the centripetal force exerted upon it.”

This answer is inconsistent with both the previous answers, since it disagrees with Whitrow about whether the result follows from the special theory, and it disagrees with the Nature editorial about whether the slower working is real or dependent on the motion of the observer. Furthermore, the fact that the prediction follows from the general theory does not make Einstein’s prediction from the special theory valid, as Stadlen implies it does. As is well known to logicians, the fact that the conclusion of an argument is true does not guarantee that that argument is valid.

Another interesting attempt to identify a false step in one of Dingle’s arguments was made by McCrea, who wrote:

“The false step is that Dingle regards the situation treated by relativity as the symmetric comparison of one single clock with another identical single clock (in relative motion). This is not the situation. Actually many colleagues have pointed this out, or given an equivalent answer.”

Unfortunately McCrea does not identify any of the “many colleagues” whom he claims to support his argument, but it is clear from the foregoing that Ziman, for example, has already identified that Dingle’s question is perfectly reasonable, and the question, as he correctly quoted it, includes a statement that if there are two clocks in uniform relative motion, the special theory requires one to work steadily at a slower rate than the other. McCrea’s statement is also inconsistent with Einstein’s statement that a (single) clock at the equator would work more slowly than an exactly similar (single) clock at one of the poles.

Other illogical arguments

In addition to the inconsistencies already mentioned, some of the arguments used in defending special relativity are lacking in logical rigour. To illustrate this, consider some examples.

In one of the earliest attempts to refute Dingle’s criticisms, Born wrote as follows:

“The simple fact that all relations between space co-ordinates and time expressed by the Lorentz transformation can be represented geometrically by Minkowski diagrams should suffice to show that there can be no logical contradiction in the theory.”

As the Lorentz transformation is contained in the special theory, but is not the whole theory, it is not logically valid to claim that some property of the Lorentz transformation is a sufficient condition for the whole theory to be free of logical contradiction.

In another attempt to refute Dingle, Professor I. R. Roxburgh discusses Dingle’s argument that if there are two clocks A and B in uniform relative motion, the special theory requires A to work faster than B and B to work faster than A, and this makes the theory intrinsically inconsistent. Roxburgh states that Dingle does not even discuss what he means by “faster”, and then goes on to say:

“Secondly, why is it impossible for A to go faster than B and B to go faster than A? This depends on the definition of faster. To illustrate this, consider the following two statements:

“The moon is bigger than the sun.

The sun is bigger than the moon.”

Are these statements mutually contradictory? This depends on the meaning of bigger. For terrestrial beings the first statement is true, for Martians the second is true. The relative size depends upon the position of the observer. So it is with time and clocks.”

If it is important to define “faster”, it is also important to use other words precisely; yet it is clear from the quotation that Roxburgh does not literally mean “is” in the two contrasted statements, but something like “appears to be”. Thus, the two contrasted statements are not analogous to the two statements that Dingle claims to be inconsistent. Or, if Roxburgh does mean the pair of contrasted statements to be taken literally, then he, as a terrestrial being, is asserting that the moon is bigger than the sun. Although we are terrestrial beings, we know that the sun is bigger than the moon, and we know it from observations that have been made from the earth.

To put the matter in terms of logical relations, the expression “is bigger than” represents an asymmetrical relation, whereas Roxburgh’s pair of contrasted statements asserts that “is bigger than” is not an asymmetrical relation; there is therefore a contradiction inherent in what Roxburgh has written. Of course, a contradiction between two statements can be avoided if one is free to disregard literal meanings of words and interpret the meanings of the statements in such a way as to avoid the contradiction. This is similar to the technique described by Dingle (ref 4, page 180) for avoiding the inconsistency in special relativity: “When the theory appears to lead to incompatible objective results, they are written off as merely different appearances, but claimed as realities when some actual phenomenon has to be explained.”

Whitrow has also published an argument which purports to refute Dingle’s claim that the special theory is inconsistent in showing that two incommensurate clocks could be made to work faster than the other. The last sentence of his argument is:

“Dingle’s requirement is therefore equivalent to introducing the Newtonian concept of universal time, and this is incompatible with special relativity.”

Now whether or not Whitrow’s statement about Newtonian time is true, the sentence quoted does not prove that Dingle is wrong; all it states is that either Dingle is
wrong or special relativity is wrong. As the point at issue is the validity of special relativity, and as the context obviously implies that the argument that ends with the quoted sentence proves that Dingle is wrong, Whitrow’s argument shows an excellent example of the textbook fallacy known as begging the question. Since Whitrow has subsequently published the same argument two more times, in obituary notices on Professor Dingle, the pointing out of this logical fallacy is overdue.

The foregoing examples of inconsistencies and logical fallacies in the arguments used to defend special relativity do not in themselves prove that Dingle is right, or that special relativity is wrong. However, if two scientists make inconsistent statements about the same theory, one or other of them must have made an error in deduction, or else the theory itself contains an inconsistency. In other words, the inconsistencies in the statements have been made by the defenders of the special theory actually support Dingle’s case that there is an inconsistency in the theory, rather than refuting it.

Although scientists may be convinced that the conclusion they have already reached is true, they should also be concerned with whether the arguments by which that conclusion has been reached can withstand scrutiny without revealing inconsistencies. I suggest that the scientific ideal toward which science should strive in this case is that stated by T. H. Huxley when he wrote that “the scientific spirit is of more value than its products, and irrationally held truths may be more harmful than reasoned errors.” It is time for the truth of this matter to be actively and carefully sought.

References

Ron Slater investigates career possibilities for electronic engineers. Training, qualification requirements, salary to be expected and the areas of the country where jobs are on offer are all considered by Mr Slater, who has a great deal of experience in finding work for engineers.

David Taylor-Lewis presents a versatile tone-burst gate, which provides an integral number of on and off cycles, each adjustable from 1 to 9999. It will also give a variable duty cycle square wave between 1:9999 and 999:1 and pulse bursts or gaps from one trigger.

Philip Barker describes a method of using a computer, a video disc player and a television receiver to construct an interactive information display system for education, training or archival purposes.

On sale October 19
Using a micro to process 30 line Baird television recordings

Early television recordings on gramophone records – Phonovision – were crude in the extreme. The author describes a method for improving picture quality by correlation and digital filtering

by D. F. McLean
B.Sc. (Hons)

In the late 1920's, J. L. Baird performed some experiments on the recording of television pictures onto wax discs. This he called 'Phonovision' and for a time caught the imagination of the prospective viewing public with this and other television-related inventions. Surprisingly few of these early recordings are still in existence.

It is hoped that this article will allow people to 'look back' to those early television pictures and will show that the old and the new technologies can be brought together by anyone having access to tape copies of the recordings and a personal computer.

The requirements for the computer are not strict. A minimum specification would include sufficient memory for a long sequence of frames, some sort of graphics capability allowing the pictures to be displayed with a few grey levels, an analogue-to-digital converter and a sampling clock for the converter and the computer. In my case, there is enough memory for 32 frames at less than 1 Kbyte per frame and a converter capable of sampling at 15KHz to 8 bits of accuracy (256 levels of voltage) under control of the computer and the sampling clock. For more detailed pictures either the sampling rate can be increased or the playback speed of the recording decreased.

Although the author had known about mechanical television for some time, it was only comparatively recently that examples were first heard on a BBC documentary record. Out of interest, I decided to display the sounds on this record as images, using a computer, as it was able to store the pictures as a sequence of samples. These pictures could be 'replayed' over and over again to check for movement, features and details. The replay was viewed on a graphics display, but an oscilloscope with control of X, Y, Z modulation by the computer would have been just as good.

It was clear from the start of these experiments that there were no synchronization pulses for identification of the start of lines and frames: the frames appeared to roll and drift in position due to playback speed variations. Synchronization of the early disc recordings was obtained by having the record platter rotation directly linked through a gearing arrangement to the scanning apparatus – figs. 4 and 5 show this arrangement clearly. The more common recordings of the mid 1930's were not linked in this way and relied on the record platter inertia to reduce picture 'hunting' or slippage.

If the original synchronous recordings had been available for these experiments a sampling clock for the computer could have been derived from the rotation of the record player, to ensure synchronization independent of playback speed. In their absence, I have evolved a method for realigning the sequences of pictures and inserting new synchronizing pulses, in an attempt to get nearer to re-creating the original scene quality.

30 line Baird standard

In a similar fashion to broadcast television today, the 30 line picture was created by scanning a spot of light of varying brightness in a particular pattern to form the display area. To re-create the scene as recorded, the spot had to follow this raster pattern exactly in synchronism with the video signal. If exact synchronization was not maintained, the picture would roll or slip in a similar fashion to an out-of-adjustment 'vertical hold' control on a modern TV receiver. Modern tv standards include provision for sync. pulses to 'tell' the receiver where the start of line and frame is; hence picture slippage is rarely a problem. A form of sync. on 30 line transmissions was obtained from a mixture of the inertia of the scanning disc and the actual scene content (as the television waveform was used to control the disc's rotational speed).

Synchronizing the transmitter and receiver to mains frequency was only successful within the area served by a particular generator.

The scanning action on Baird 'Television' types of receiver was performed by a rapidly spinning disc which had a spiral pattern of holes spaced at equal angles around

*See references 1-6 for details of 'Phonovision'.
Correction of picture drift
In many applications of signal processing, the correlation or matching technique has grown in use throughout the years to become today a very powerful tool. Its main ability is, given two signals, to calculate a value whose magnitude indicates how similar the signals are. If one of the signals is delayed or shifted with respect to the other, repeated application of this matching technique can indicate how much one signal has to be shifted to match the other.

Variations of this technique were applied to short sampled extracts of recordings of early mechanical television pictures stored in computer. The aim was to find a method of accurately re-aligning a free-running sequence of frames for viewing and further processing.

Figure 2(a) shows a typical sequence of 10 frames digitized and stored in the computer memory: the first frame is on the right and all subsequent frames are to the left. The nature of the drift in frame position is quite evident. In the short space of time represented, the left and right edges of each frame have not drifted detectably, but the images suffer from severe vertical drift in the position of line start and end (top and bottom), caused by wow and flutter in the recording medium of between 1 and 2%. The extremes of this variation would be equivalent to the difference between an image being perfectly level and one that is tilted by about 60°, corresponding to a change in the line start position from beginning to the end of a frame of about 1/2 line length. Figure 2(b) shows an estimate of the line-by-line positional error.

Also of importance is the frequency spectrum of this playback speed fluctuation. Figure 2(b) shows that fast fluctuations in speed are of much smaller amplitude than the slower frame-to-frame variations. The difficulty lies in obtaining correction methods able to cancel out all of these variations.

Method
Line matching. Figure 1 shows two waveforms, A and B. A is considered to be the reference and B is to be shifted to find the best match. As these waveforms represent two TV lines, the start and end of lines define limits. For this method to work, line B is assumed to be periodic, so that when shifted in one direction, the last sample in the line wraps around to become the first sample in the shifted line. Thus, the shifting appears to be a rotation. Waveform B is rotated a sample at a time. For each rotation, a matching score is calcu-
Mechanical gearing of original apparatus provided steady sync.

System of Fig. 4 in use, recording the 'dummy head.'

Phase correction by all-pass filter.

Digital filtering was carried out within the computer.

Further examples of digital filtering to reduce effect of head-cutter resonance.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

For each line in the current frame, the current line was matched against the corresponding line in the reference frame. The position of maximum score for the above equation was taken to be the value by which the current line had to be shifted to match best the line in the reference image. Initially the reference frame corresponded to the first frame in the sequence. After each line was corrected, the line in the reference frame was averaged with a fraction of the current line to take into account any scene change at the horizontal position of the line. The average was stored back in the reference frame.

The results of one-dimensional matching were somewhat mixed in success. For clear, stable and simple scenes, the results were excellent, leaving an extremely stable sequence of rectified frames with very low jitter in vertical position from one frame to the next. However, for fast-moving complex scenes, the performance was poor with unstable breaking up of the picture structure and consequent severe degradation in image quality.

Line-jitter removal. One of the recordings suffered from severe timebase jitter, causing large changes in the position of the start of the line on subsequent lines within a frame. In this case only it was considered worthwhile to use a different form of one-dimensional matching.

Instead of matching the current line in the frame being processed with the same line in the reference frame, the current line was matched against the previous line in the same frame. I have used this technique successfully with slow-scan television pictures received on the amateur bands. Line-to-line jitter is removed in a fairly uncontrolled way at the expense of geometrical distortion of the picture. As it was considered important to maintain the picture geometry, this technique was not used on the other recordings.

The one recording which was processed using this technique suffered from static errors in the position of the start of each line in any frame. This was presumably caused by errors in the position of the holes in the scanning disc, causing some lines to start earlier or later than adjacent lines. Figure 11 shows a typical frame before and after correction of this fault.

Frame matching. The problem with the line matching technique was that it could only allow a small amount of lateral movement in the scene before instability degraded the picture quality. Because the matching algorithm was essentially one-dimensional in nature, it could not cope with
any sideways movement. The algorithm had no ‘knowledge’ of any structure in adjacent lines. To attack this problem, a variation on the original method was devised and tested with excellent results.

This new method was based on the fact that the scene content (not position) varied little from frame to frame. There was no abrupt scene changes. Each frame can be thought of as a two-dimensional brightness distribution where each point (x,y) has an associated brightness value B(x,y). Using one frame as a reference, the idea was to ‘slide’ the frame to be corrected horizontally (in x) and vertically (in y) until a best match was found. The equation for calculating the matching score at any shift value (s,t) was derived from the one-dimensional equation given earlier and is given below

\[ CS(s,t) = \sum_{x=1}^{L} \sum_{y=1}^{M} A(x,y) \cdot B(x-s,y-t) \]

where A(x,y) is the brightness in the reference frame at point (x,y), B() is the brightness in the current frame being processed at the shifted (x,y), L,M are the max. no. of samples and lines in x and y respectively, and CS(s,t) is the score for a possible match at shift value (s,t).

The ‘sliding’ of the frames is similar to the cyclic shift used when matching lines (Fig. 1) but is extended to two dimensions. A cyclic shift of the current frame was performed for each shifted position (s,t), and all possible shifted positions of one frame with respect to the other was used to create a list of scores for matching.

Using the position of maximum score, the current frame was cyclically shifted from its original position in both x and y directions to match it with the reference frame. Each point of the current and reference frames was then averaged with a user-selected weighted value. The averaged result was stored to become a new reference frame for the next frame in the sequence, which served to accommodate increasing differences between the successive and reference frames.

The positional errors that had to be corrected were only in the vertical direction, however. During the time taken for a short sequence, the horizontal drift could be ignored as it was 1/30th of the amplitude of the vertical drift in this case. Correction only in the vertical direction was achieved simply by removing the calculated lateral \((x)\) shift after the full two-dimensional matching and shifting had been applied and the reference frame updated with the weighted average. The averaging of the reference frame with a fraction of the current frame had to be done by using the current frame shifted in both horizontal and vertical directions to track lateral movement in the scene.

The effect of using two-dimensional processing but only correcting vertically was to allow horizontal motion without any loss of stability in the processed sequence of frames. It is indeed most fortunate that the line scanning direction of the early mechanical television experiments was vertical as most scene motion in natural objects is typically only from side to side.

Figures 2(a) to 2(e) show the performance of the basic two-dimensional correction method described in the previous subsection. Figure 2(a) is the original digitized sequence showing significant vertical rolling of the frames in the sequence. Figure 2(b) shows an estimate of the actual positional error in the vertical direction on a line by line basis. Figure 2(c) displays the actual calculated result of how much each line in each frame had to be shifted. Each line in a particular frame was shifted by the same amount so that the correction function (Fig. 2(c)) shows only a stepped approximation to the actual positional error. Figure 2(d) is the residual error after applying the offset of Fig. 2(c) and Fig. 2(e) is the corresponding corrected sequence of frames.

By comparing Figures 2(b) and 2(c), a closer approximation to the actual positional drift could be made by performing a linear interpolation between the vertical shift values of adjacent frames. The method was quite simple to implement and provided considerable improvement to frames distorted by sampling at a slightly incorrect sampling rate.

Figures 3(a) to 3(d) show the result of processing a sequence digitized at slightly too high a sampling rate. The result here is equivalent to a 0.7% increase in the desired sampling rate. Figure 3(b) shows the linearily-interpolated error derived from the vertical shift calculated using the matching equation: the error wraps around as the shift value has cyclic symmetry. Applying this interpolated set of values (Fig. 3(b)) to the original sequence gave rise to the processed sequence as shown in Fig. 3(b). Figure 3(c) shows the residual error. The most significant result from this example is the removal of the overall tilt from each frame.

A natural extension of the original line matching idea resulted in a stable and robust method of accurately re-aligning a sequence of TV frames with no further information than the scene being transmitted. The restriction of only applying vertical correction resulted in the

---

**Fig. 10.** Good example of removal of hum by digital filter.

**Fig. 11.** Correction of variation of position of line starts within a frame.

**Fig. 12.** Set of pictures produced by system from noisy and distorted taped recordings. Pictures are still crude, but are enormous improvement on untreated versions.
preservation of horizontal motion with no loss in stability. Further correction for speed variations proved to be a powerful method for removing the 'tilted' effect on certain frames. This required little computational overhead.

Although not able to remove fluctuations faster than the frame rate, the frame matching technique has proved to be a useful tool in aiding the analysis of these early mechanical recordings.

Image quality
The quality of recording on wax discs in the 1920's was adequate for voice or music reproduction although it was far from fidelity. When used for recording Baird's 30 line television signal, wax discs proved themselves to be quite a poor recording medium. The recording apparatus was not capable of recording the very high or the very low frequencies in the signal, and yet the shape of the recorded waveform — much less important for voice or music recording — had to be free of distortion for accurate reproduction of the scene being televised.

The limitations of base-band (unmodulated) recording on wax discs resulted in various types of distortion of the television waveform. The most common types observed on the discs of the period are: phase distortion — poor low frequency response, giving rise to phase shifts; low-frequency noise — eg, main hum aggravated by reduced signal level at low frequencies; high-frequency instability generated by head cutter resonance; noise caused by disc surface granularity; and residual timebase errors, giving rise to ragged edges to each frame.

Image filtering
One-dimensional filtering. Most types of distortion present on these recordings can be reduced by one-dimensional digital filtering techniques. This means that the television signal is treated as if it were an audio signal: the relationship between lines and frames is ignored in the processing.

Phase distortion can be reduced by processing the signal through an all-pass phase shifter. It is the author's experience that using a simple electronic circuit to perform this function relieves the computer from time-consuming processing and gives instant feedback on the correction being applied to the signal. Figure 6 shows the result of phase correction.

Head-cutter resonance is predominant on one particular recording. Although external pre-filtering can reduce the effect of the resonance, digital filtering within the computer was found to be much more flexible and was able to reduce the resonance without adversely affecting the resolution of the picture. Figures 7 and 8 show the reduction possible by digital filtering.

Low-frequency noise was more effectively reduced again by using digital filtering. In one of the recordings, mains hum was present at a high level after attempting to filter out low frequency information in the signal. The reduction of interfering signals on early Baird recordings is demonstrated well on Figs 9 and 10.

Although the waveform is by nature one-dimensional, the correlation between lines and frames can be used to suppress some types of irregularities in the signal. One particularly powerful technique involves processing the points in the scene exactly one frame apart, a process called temporal filtering.

Temporal filtering. One of the most effective processes on the frame- or line-matched sequence of frames was the temporal filter. Both surface noise and residual errors in the position of the lines were considerably reduced without affecting detail in the individual frames significantly.

The idea is that points having the same position along the same line in adjacent frames should be very close in value of brightness. The filter creates a new point from the brightness values of the same point on three successive frames, chosen to be the middle value in brightness amongst the three. Using this median value allowed isolated errors to be corrected completely: line jitter, noise and to a lesser extent movement were suppressed without the blurring action of a spatial filter (i.e. one acting along or across lines). Reference 9 describes this technique applied to high resolution television.

Temporal filtering is both difficult and expensive to implement in high-resolution television because of the large amount of high-speed memory required to store two (or more) frames. The memory and speed requirements for 30 line television however make it very much simpler to demonstrate powerful image processing techniques such as this.

Software
A program for acquiring data, displaying the result, re-aligning and processing a digitized sequence of 30 line television was written in machine code for acquisition and re-transmission: the processing routines could have been written in any language. A decisive factor in using machine code for the matching algorithms was the vast number of calculations required to match-up and re-align the frames. For line matching, this included about one million multiply operations for a sequence of 32 frames. Matching up 32 frames took 150 seconds in Z80 machine code with the processor running at 4MHz. Performing the multiply operation in hardware reduced the execution time to 65 seconds for a 32 frame sequence.

The implementation of the two-dimensional frame matching took considerably longer to execute than that of the one-dimensional line matching, since line matching needed a greater number of multiply and accumulate operations (30 times) plus higher precision in the score value for matching. Considering that an image or frame in this case had 960 samples, point-by-point multiplication and score accumulation gave the staggering figure of just under one million of these operations per frame. The software implementation took 3 minutes per frame — 96 minutes in total for a complete 32 frame sequence. Performing just the multiply operation in hardware reduced this execution time to 80 seconds per frame — 40 minutes per sequence. A similar routine in Basic was estimated to take about 75 hours per sequence, while a compiled PASCAL routine on the same machine took 17 hours per sequence.

The one-dimensional and temporal filtering all required between 2 and 10 seconds to process a 32 frame sequence of 960 bytes per frame. For high-resolution processing with 1920 bytes per frame, fewer frames could be held in memory. Because the amount of data was similar in both the low and high-resolution sequences, the processing time for each was similar. Fourier analysis of the signals to determine which filter to use took a few minutes for each frame.

Acknowledgements
Thanks go to Doug Pitt of the Narrow Band TV Association, Ronald Gibb of Strathclyde University AV unit, Ray Herbert, Ben Clapp, H. Spencer, Len Firmin MBs, John Iwe and Mike Hallet of the IBA and Tim Voore for assistance in researches into mechanical television.

References
4. 'Television and Short-Wave World' June 1935, p308 and p363.
7. For details of correlation techniques
10. Details of temporal filtering: 9. Huang, T.-S. 'Image Sequence Analysis' Springer-Verlag, 1981, Chapter 4. Short extracts from one of the recordings can be heard along with interesting commentary on the following:
10. 'We seem to have lost the Picture,' BBC documentary l.p. REB 239 from the series '40 Years of TV,' 1977.
Assembly language programming

Parts of these lists were illegible when originally printed in Bob Coates’ sixth tutorial in the September issue. We apologize for any inconvenience caused by the poor printing.

### List 1. Assembly language for summing numbers on the Picotutor.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>024</td>
<td>4F</td>
<td>CLRA</td>
</tr>
<tr>
<td>025</td>
<td>AE52</td>
<td>LDX #VALUE1</td>
</tr>
<tr>
<td>027</td>
<td>FB</td>
<td>LOOP ADD 0.X</td>
</tr>
<tr>
<td>028</td>
<td>5C</td>
<td>INC</td>
</tr>
<tr>
<td>029</td>
<td>3A51</td>
<td>DEC #VALUE1</td>
</tr>
<tr>
<td>02D</td>
<td>B750</td>
<td>STA RESULT</td>
</tr>
<tr>
<td>02F</td>
<td>0CB0</td>
<td>JMP START</td>
</tr>
</tbody>
</table>

### List 2. Summing numbers using the 6800.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>4F</td>
<td>CLRA</td>
</tr>
<tr>
<td>1001</td>
<td>BE1052</td>
<td>LDX #VALUE1</td>
</tr>
<tr>
<td>1004</td>
<td>AB00</td>
<td>LOOP ADD 0.X</td>
</tr>
<tr>
<td>1006</td>
<td>0B</td>
<td>INC</td>
</tr>
<tr>
<td>1007</td>
<td>7A1051</td>
<td>DEC #VALUE1</td>
</tr>
<tr>
<td>100A</td>
<td>26F8</td>
<td>BNE LOOP</td>
</tr>
<tr>
<td>100C</td>
<td>871050</td>
<td>STA RESULT</td>
</tr>
<tr>
<td>100F</td>
<td>7E7037</td>
<td>JMP START</td>
</tr>
</tbody>
</table>

### List 3. Summing numbers using the 6809.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>4F</td>
<td>CLRA</td>
</tr>
<tr>
<td>1001</td>
<td>BE1052</td>
<td>LDX #VALUE1</td>
</tr>
<tr>
<td>1004</td>
<td>AB00</td>
<td>LOOP ADD 0.X</td>
</tr>
<tr>
<td>1006</td>
<td>3001</td>
<td>DEC 0.X</td>
</tr>
<tr>
<td>1008</td>
<td>7A1051</td>
<td>DEC #VALUE1</td>
</tr>
<tr>
<td>100B</td>
<td>26F7</td>
<td>BNE LOOP</td>
</tr>
<tr>
<td>100C</td>
<td>871050</td>
<td>STA RESULT</td>
</tr>
<tr>
<td>1010</td>
<td>7E7037</td>
<td>JMP START</td>
</tr>
</tbody>
</table>

### List 4. 280 number summing program.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>305120</td>
<td>LD #VALUE1</td>
</tr>
<tr>
<td>2003</td>
<td>47</td>
<td>LC B:A</td>
</tr>
<tr>
<td>2004</td>
<td>4F</td>
<td>VCR A</td>
</tr>
<tr>
<td>2005</td>
<td>212250</td>
<td>LD HL #VALUE1</td>
</tr>
<tr>
<td>2008</td>
<td>0G</td>
<td>LOOP ADD A(HL)</td>
</tr>
<tr>
<td>2009</td>
<td>23</td>
<td>INC HL</td>
</tr>
<tr>
<td>200C</td>
<td>10FC</td>
<td>ADDNZ LOOP</td>
</tr>
<tr>
<td>200E</td>
<td>325029</td>
<td>LD L RESULTL.A</td>
</tr>
<tr>
<td>200F</td>
<td>C00000</td>
<td>J#0</td>
</tr>
</tbody>
</table>

### List 5. Multiplication program for the 6805.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>024</td>
<td>3F62</td>
<td>MUL CLRA</td>
</tr>
<tr>
<td>026</td>
<td>3F63</td>
<td>MUL CLRA #1</td>
</tr>
<tr>
<td>028</td>
<td>AE06</td>
<td>LDX #8</td>
</tr>
<tr>
<td>02A</td>
<td>3963</td>
<td>MUL LSL</td>
</tr>
<tr>
<td>02C</td>
<td>3962</td>
<td>MUL ROL</td>
</tr>
<tr>
<td>02E</td>
<td>3861</td>
<td>MUL MPLIER</td>
</tr>
<tr>
<td>030</td>
<td>2408</td>
<td>BCC MUL2</td>
</tr>
<tr>
<td>032</td>
<td>869C</td>
<td>LDA MCAND</td>
</tr>
<tr>
<td>034</td>
<td>8863</td>
<td>ADD #PROD1</td>
</tr>
<tr>
<td>036</td>
<td>8763</td>
<td>STA #PROD1</td>
</tr>
<tr>
<td>038</td>
<td>4F</td>
<td>CLRA</td>
</tr>
<tr>
<td>03B</td>
<td>8962</td>
<td>ABC PROD</td>
</tr>
<tr>
<td>038</td>
<td>8762</td>
<td>STA #PROD</td>
</tr>
<tr>
<td>03D</td>
<td>5A</td>
<td>DECK #MUL2</td>
</tr>
<tr>
<td>03E</td>
<td>20EA</td>
<td>MUL BNE</td>
</tr>
<tr>
<td>040</td>
<td>0CB0</td>
<td>JMP #START</td>
</tr>
</tbody>
</table>

### List 6. 15-by-7 bit division using the 6805.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>024</td>
<td>AE08</td>
<td>DIV LDX</td>
</tr>
<tr>
<td>029</td>
<td>0B01</td>
<td>DIV LSL</td>
</tr>
<tr>
<td>032</td>
<td>3960</td>
<td>POL</td>
</tr>
<tr>
<td>034</td>
<td>3860</td>
<td>LDA</td>
</tr>
<tr>
<td>02C</td>
<td>2662</td>
<td>JMP</td>
</tr>
<tr>
<td>02E</td>
<td>2505</td>
<td>SCS DIV2</td>
</tr>
<tr>
<td>030</td>
<td>8062</td>
<td>SUB D/DEND</td>
</tr>
<tr>
<td>032</td>
<td>3760</td>
<td>STA D/DEND</td>
</tr>
<tr>
<td>034</td>
<td>3661</td>
<td>INC D/DEND+1</td>
</tr>
<tr>
<td>036</td>
<td>5A</td>
<td>DIV D/DEND</td>
</tr>
<tr>
<td>037</td>
<td>26ED</td>
<td>BNE DIVI</td>
</tr>
<tr>
<td>039</td>
<td>8C80</td>
<td>JMP #START</td>
</tr>
</tbody>
</table>

### List 7. S multiplication of the 6800 DAA instruction included in the Picotutor.

* DAA - THIS ROUTINE SIMULATES THE DAA INSTRUCTION OF THE 6800 ETC. IT SHOULD BE CALLED AFTER AN ADD OR AL ADDITION AS...HTR DAA. ON EXIT, A IS BCD CORRECTED AND C IS SET FOR MULTIPRECISION BCD ADD.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>386</td>
<td>871E</td>
<td>DAA STA TEMPA</td>
</tr>
<tr>
<td>388</td>
<td>6F1F</td>
<td>STA TEMPF</td>
</tr>
<tr>
<td>390</td>
<td>8E08</td>
<td>DAA</td>
</tr>
</tbody>
</table>

### List 8. Example of 101D and subsequent instructions.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>388</td>
<td>871E</td>
<td>DAA STA TEMPA</td>
</tr>
<tr>
<td>389</td>
<td>6F1F</td>
<td>STA TEMPF</td>
</tr>
</tbody>
</table>

### List 9. Example of 101D and subsequent instructions.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>390</td>
<td>8E08</td>
<td>DAA</td>
</tr>
</tbody>
</table>

### Continued over

**Note:** The listing for the 15-by-7 bit division using the 6805 is incomplete and includes a comment about the DAA instruction and its usage. Further instructions follow.
List 7. (continued).

3A3 SF $188DNE $X8A CORRECTION GOES INTO A
3A4 BB1 $E81 $E4D $75A AND IS ADDED TO ORIGINAL VALUE
3A5 BE1 $F81 $D8X $D8X
3A6 250 $4E $BC $DAAZ BRANCH BUT IF CARRY ALREADY SET
3A7 01 $D4D $01D1 $BA5 $DAAZ OR IF IT WAS CLEAR ON ENTRY
3A8 9S $88 $SEC BUT SET CARRY IF IT WAS ON ENTRY
3A9 B1 $88 $DAAZ RTS

List 8. Adding two numbers using the simulator of List 7.

024 A98E LDA #$19B 024 A927 LDA #$277
028 A849 A00 #$448 028 A948 LDA #$148
028 B3 81H $1A Z $DAA 028 A82A LDA #$718
028 BD83 JSR $871 028 A82A LDA #$718
028 83 81H $1A Z $DAA 028 A82A LDA #$718


024 A927 LDA #$277
028 A948 LDA #$148
028 A82A LDA #$718

List 10. Assembly language for Picotutor subroutine BCDBIN.

BCDBIN: * CONVERTS A 4 DIGIT PACKED BCD NUMBER IN
BCDCH1: POINT TO 14 BIT BINARY, AND PLACES
BCB2: RESULT IN 0X1X1B BCD NUMBER
BCB3: UNALTED, SETS CARRY IF A NON-DECIMAL
BCB4: DIGIT ENTERED.

List 11. (continued).

BCDBIN: * CONVERTS A 4 DIGIT PACKED BCD NUMBER IN
BCDCH1: POINT TO 14 BIT BINARY, AND PLACES
BCB2: RESULT IN 0X1X1B BCD NUMBER
BCB3: UNALTED, SETS CARRY IF A NON-DECIMAL
BCB4: DIGIT ENTERED.
Forth language

Complementing his description of a 6809-based microcomputer, Brian Woodroffe details the language used — Forth — and why he chose it, in this second series.

by B. Woodroffe

Forth is a language well suited to modern microprocessors and is widely used in such diverse applications as word processing, database management, instrument and process control, video games and data acquisition. In a kernel of less than 10Kbyte the following features are provided

- An interactive system.
- A high-level compiler with all standard control features.
- Fast execution, comparable with machine code because of the compiler.
- The language system is largely processor independent; only around 20% of the code written in assembly language need be changed to suit the computer.
- Virtual memory and application-oriented program modules.

Further, the system may be readily extended to suit new applications because the compiler can be modified by the user and new data structures introduced. These features are achieved by defining a virtual machine which is easily simulated by any target machine. Using "threaded code", transferring control from one virtual machine instruction to the next is quick and easy. Instructions of the virtual machine are used to build the monitor and compiler. Using the monitor the user may examine the effect of a series of Forth instructions and use the compiler this series may be added to the instruction set for future use.

Background

Forth is a computer language for fourth generation computers1. The language would have been called Fourth but six letters would not fit in the IBM1310 job-control language that its inventor, C. H. Moore, was then working with. Today Moore's company Forth Inc. is foremost in marketing FORTH for many different applications, besides the field of astronomy where it first found favour2. Other companies such as Miller Microcomputers, Services and Laboratory Microsystems sell their own versions of Forth but the prime mover of Forth in the home-computer/hobby field is the Forth Interest Group* (FIG). They have made versions of Forth available for many computers including the PDP-11 and for 8080/8080, 8086/8088 and 6502 processors. There are many versions of Forth and while all are similar no two are necessarily identical. For example, Poly Forth, FIG Forth and Forth 79 are all Forth but they are not the same. They differ primarily because of differences in the processor on which they run (16 or 8 bit memory, port or memory mapped I/O, etc.). FIG Forth will be used in all following examples.

*Forth Interest Group, PO Box 1105, San Carlos, CA 94070, USA.

Forth is a collation of different software concepts forming a coherent whole. As an operating system, it is not as powerful as most but it takes care of all terminal and disc input and output. Small assembly-language routines must be supplied by the user to interface his hardware to the relevant system calls. It is also possible that memory-allocation changes may also have to be made. Most of Forth is written in Forth. It may seem strange that a language may be defined in terms of itself but one would use English words to explain the English language. Defining the language in this way means that programs may be transferred between different computers and implementations. There is a base instruction set which must be written in the machine code of the host computer. This is the only machine code required and the process is known as simulating a virtual Forth machine.

Most computer languages are programs which, recognizing statements in a source language, convert them into a target language. Usually the source language is text readable by humans in ASCII form and output is machine code of the computer. This is not always the case: cross compiling results in the target code being different from the host computer machine code. More exceptionally there are cases where the machine code can only be executed by a hypothetical computer, an example being O-code for the language BCPL3 and P-Code for certain implementations of Pascal4. This is also the case for Forth and the virtual-machine execution mechanism will be explained first.

Threaded code

Explanation is simplified by visualizing a machine-code program for the processor concerned as a succession of subroutine calls. These calls transfer program control to each subroutine in turn. A stack, i.e., last-in-first-out list, would be the mechanism by which each subroutine returns control to the correct point in the main program. Knowing that the main program is solely a succession of calls it is now possible to reduce the main program to a list of subroutine addresses by removing the subroutine op-code, and to have a special program known as an address interpreter to transfer control down the main program address list. This is called threaded code, for the main program is the thread into and out of which the address interpreter takes control5, List 1.

In List 1, letters A, B and C denote machine-code subroutines, ip is the threaded-code instruction pointer and parentheses indicate one level of indirection. Threaded code trades the cost of the code for each call saved for address interpreter speed. In a long program the code cost of the address interpreter will be negligible. Further savings can be made by replacing the subroutine return statement by a jump to the address interpreter and changing the address interpreter as shown below. This releases the stack pointer used for subroutine calls and returns. It is important that the instruction pointer can be speedily accessed, for example by keeping it in a processor register, so as not to slow down the address interpreter by causing unnecessary memory activity.

If the lists are considered to be the actions of a virtual machine then a software routine NEXT represents the hardware execution fetch of the virtual machine. In a threaded-code computer the time of interpreting these lists is dominated by the time of the NEXT operation so it is best to run threaded code on a computer that handles NEXT efficiently or to use microcode.

Code routine including return

A: xxx
   jmp NEXT

New address interpreter

NEXT: ip+1 -> ip
   jmp [ip]

Indirect threaded code

The next improvement is to allow called routines to be not just pure machine code but also address lists. This is done by having a special routine that knows that the following data in the list are not code but addresses that must again be interpreted. Further, the routine must suspend interpretation of the main program while interpreting this new list of addresses. Return of control to the suspended list is done using a stack to save and restore the instruction pointer which is similar to the machine-code subroutine call/return operation. There must be an equivalent code routine to return control to the main list.

<table>
<thead>
<tr>
<th>List 1. Comparisons of hard code and direct threaded code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal code</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Address interpreter</td>
</tr>
<tr>
<td>call A</td>
</tr>
<tr>
<td>call B</td>
</tr>
<tr>
<td>call C</td>
</tr>
</tbody>
</table>

WIRELESS WORLD OCTOBER 1983
Threaded routine
P:  sp−1 → sp
    ip → −[sp] (push current ip)
#L−1 → ip (start interpreting new list)

jmp NEXT

L:  (code routine)
B
C

Return routine
[sp] → ip (pop ip)
sp+1 → sp

As most routines are likely to be lists and not machine code this stacking method, similar to subroutine calling, will take a lot of code area. Considerable space would be saved if there was just one copy of each routine. The address interpreter would normally jump to this routine but it would also have to execute code routines. This is done by making the first element of each list a pointer to code rather than the code itself. In the case of lists the pointer points to the stacking operation but with code routines it points to the next code address.

New address interpreter
NEXT:  ip+1 → ip
       {ip} → w
       jmp [w]

Stacking operation
DOCOL:  sp−1 → sp
        ip → −[sp]
        w+1 → ip
        jmp NEXT

Destacking operation
SEMSI:  [sp] → −ip
        sp+1 → ip
        jmp NEXT

Code routine
A:  $+1 (point to next location)
    xxx
    jmp NEXT

List routine
DOCOL
P
Q
SEMSI

This is the equivalent of machine-code subroutine call and return instructions. In Forth, the stacking and destacking operations are called DOCOL and SEMIS respectively. At the beginning of each address list, the extra address introduces a level of indirectness — this is indirect threaded code. In Forth the lists are divided into two parts, one being the code field which points to the address and the other known as the parameter field where the code is. These two parts and dictionary data, to be described, form a WORD. Code pointed to by the code field determines how the parameter field is interpreted. In the case of code words, the code field points to the parameter field. When the code field points to DOCOL, the parameter field is to be interpreted in a similar way to a subroutine. It is possible for the code field to point to some other routine which may make different use of the parameter field. Two examples of this in Forth are DOCON and DOVAR. The former treats the value in the parameter field as a constant and pushes it onto the data stack, to be described, whereas DOVAR pushes the address of the parameter field which is used as the storage location for that variable. To enable these routines to access the parameter field a third register, known as ‘w’, is required.

The address interpreter for indirect threaded code is more complicated than that for direct threaded code and so it is even more important to choose a processor with a suitable instruction set. Surprisingly for direct threaded code, NEXT can normally be coded using the processor subroutine-return op-code provided that the processor uses a stack that may be placed anywhere in memory. As the stack pointer is pointing to the thread, the processor must not receive interrupts for the status cannot be saved without destroying the thread. NEXT for indirect code is more complicated as it involves an extra level of indirection.

Choosing a processor, stack and language-control structures are subjects of the next Forth language article.

An i.e. in the Forth computer switch-mode power supply on page 61 of the July issue was incorrectly designated the MC3045. The correct designation is MC3405.

References
1. C. Moore, Forth dimensions, vol. 1, no. 6, FIG
5. J. Bell, Communications of the ACM, vol. 16, no. 6, pp. 370-372

Glossary

Machine code. The representation, usually in hexadecimal, of the instruction and data encoding that is understood by the computer.

Assembly code. A human readable form of machine code. There is a one-to-one correspondence between assembly code and machine code. Assembly language is used to write instructions in a high-level language which can then be translated into machine code. Forth code is rendered in assembly code.

Interpreted. A computer works by sequentially fetching and executing instructions. The instruction fetch is made from the interpreter pointed to by the program counter. The program counter is incremented one instruction at a time unless a jump (branch etc.) occurs.

Virtual machine. At any level of analysis the computer will have a repertoire of instructions that it can execute. This normally the machine assembly and instruction set. However by running a program on this machine it can be made to look as though it has a different instruction set. It is possible to time share the computer between two or more users so that they both think they have a separate computer. These techniques are known as creating a virtual machine.

Op-code. Each different instruction is encoded into a unique symbol (usually binary, known as an op-code).

Host computer. The computer on which the program is currently executing.

Target computer. The computer on which the program being developed will execute.

Crase compilation. A cross compiler runs on one machine and produces output for another. Host and target machines have different op-code encodings or instruction sets, or both.

Compiler. A program recognizes that the input language agrees with a grammar. If it agrees it will usually produce an output in some other level defined language, or error messages as to why the input is not in the source language. Normally, input is English-like (e.g. Forth/Forth-like) and output is machine code.

Microcode. Microcode is a mechanism used to build computers to understand machine-code instructions. Within a microcoded computer there is another computer with its own microcode instruction set. By writing new microcode, the assembly-language machine can be made to...

Kernel. A central program on whose resources all application program rely and interface to.

Operating system. A computer program which manages the computer's resources. It will take care of all input-output etc. so that the application programmer need not worry about how to get characters to and from a terminal, etc.

Software driver. A small program specific to each input/output device that is included in the operating system.

Terminal. Visual-display unit and keyboard, teletype.

Indirection. An addressing mechanism. An instruction requires data to act upon — the instruction gives details of how to find that data. Normally it will give the address of the data, but in the cases of indirect addressing it will give the address at which the address of the data may be found. That is one level of indirection. Up to three levels, the address which contains the address which contains the address which contains the data, are common.

Cell. A subroutine call is a mechanism whereby machine-code execution is temporarily suspended while the subroutine is executed. Execution will restart at the instruction after the call when the subroutine terminates. The return address (return address) is often kept on a stack.

Code field. A part of a Forth Word definition. The contents of the code field always point to machine code of the target machine.


Monitor. A program that monitors user requests as typed in at the terminal. Usually gives message (<OK>) when the command has successfully executed. Monitor is also the name given to a technique used in real-time programming, developed by C.A.R. Hoare et al.

Virtual Forth machine. The assembly-language programmer creates a virtual machine that executes lowest-level Forth instructions.

Virtual-machine execution mechanism. These means by which the assembly-language programmer makes the virtual Forth machine transfer control from one instruction to the next.

WIRELESS WORLD OCTOBER 1983

www.americanradiohistory.com
A surplus teletypewriter provides a very economical means of obtaining good-quality hard copy of Nanocomp programs, the only drawbacks being the unit's size and its relatively low speed and somewhat noisy operation. Two points on the Nanocomp connector, p.i.a. line PB1 and 0V, feed the input of this simple interface and its output consists of two connections which drive the teletypewriter selector magnet. Hard and software described was designed around the Creed 7E teletypewriter which has a 230V a.c. motor and is probably the most common on the second-hand market.

**Hardware**

The complete circuit consists of the teletypewriter-drive interface, Fig. 1, the power supply. Construction is straightforward. Two rails are provided by the p.s.u., between 80 and 100V to drive the teletypewriter selector magnet and 5V supplying the 7400 i.c. An alternative 5V source might be the Nanocomp's own p.s.u. In the original power supply I used a 20VA transformer built from a kit (RS207-728) with secondary windings consisting of 845 turns of 36 sw.g. wire, centre-tapped, to provide 65-65V and 46 turns of 34 sw.g. wire for the 5V secondary winding.

**Software**

Designed for the 6502 Nanocomp, the 397-byte program shown in List 1 resides in the top ram area starting at address $1264_{16}$. When run the program displays an S to prompt entry of the printing start address and when that is entered an F prompt appears to indicate that the finishing address is to be entered. When the finishing address is entered the teletypewriter prints all memory contents between the specified addresses. Prompt functions make use of the Nanocomp monitor BADDR subroutine at $7CB$.

**List 1. Machine code for driving a teletypewriter using the 6502 Nanocomp see List 2 for details.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>0001</td>
<td>position counter</td>
</tr>
<tr>
<td>0002</td>
<td>data store (one hex. digit)</td>
</tr>
<tr>
<td>0003</td>
<td>figures/letters flag</td>
</tr>
<tr>
<td>0004</td>
<td>start address</td>
</tr>
<tr>
<td>0005</td>
<td>finish address</td>
</tr>
<tr>
<td>0006</td>
<td>drop memory</td>
</tr>
<tr>
<td>0009</td>
<td>temporary store</td>
</tr>
<tr>
<td>000A</td>
<td>(4 m.s.b. data byte)</td>
</tr>
<tr>
<td>000B</td>
<td>byte flag</td>
</tr>
<tr>
<td>000C</td>
<td>byte count (CR, LF, spaces)</td>
</tr>
<tr>
<td>000D</td>
<td>look-up table temporary store</td>
</tr>
<tr>
<td>13C9</td>
<td>start of look-up table</td>
</tr>
</tbody>
</table>

**List 2. Memory locations used by the 397-byte interface program starting at location 1264, and subroutines.**

By P. C. Barton

One inconvenience with using teletypewriters is that when letters have been printed a figures code has to be sent before figures can be printed and likewise a letters signal has to be sent before letters can be printed. Unfortunately, hexadecimal notation consists of approximately $\frac{2}{3}$ numbers.

Fig 1. Nanocomp-to-teletypewriter interface in which high-voltage output transistors are driven by a phase-splitting circuit consisting of a 7400 i.c. and buffers.

**Teletypewriter interface and p.s.u.**

WIRELESS WORLD OCTOBER 1983
and 1/3 alphabetical figures and the extra code characters required to change between the two slow down printing.

Carriage returns, CR, and line feeds, LF, are set as needed and if the position counter is below six the address is also printed, see flow diagram. If the next data byte is a letter and the teletypewriter is set for figures, the appropriate code is sent to convert to letters, and vice versa. Using a look-up table, data are converted to teletypewriter code and sent through 'drop' memory at address location 0008 to the teletypewriter interface using the transmit subroutine at 13AA. When the required section of memory has been printed, the program is terminated by a software interrupt instruction, SWI, which returns control to the monitor. List 2 is a memory map for those of you who want to make further use of the subroutines. If the teletypewriter races or prints rubbish try interchanging the selector magnet connections.

Bob Coates described the 6502 Nanocomp microprocessor trainer in the January 1981 issue, pp.32-36, and the 6809 version in July 1981, pp.33-37. An eprom programmer for both versions was described in the January 1982 issue, pp.30-33, and interfaces for expansion in November of the same year, pp. 32-34. A set of photocopied copies of these articles can be obtained by sending £2.55 and a large s.a.e. to Wireless World Trainer, Room L303, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS.

**Interface details**

The teletypewriter selector magnet can be in one of two states corresponding to logical one or zero. This magnet converts electrical impulses provided by two high-voltage output transistors, see Fig. 1, into mechanical movement which prints the appropriate character. Sections A and B of the i.e. form a phase splitter which drives the output transistors in opposition, causing the magnet to shift from one state to another.

Teletypewriters use the CCITT No. 2 International 5-unit Teleprinter Code in which five units, or bits, form the character to be printed. In addition, one start bit and one and half stop bits are used, giving seven and a half bits in all. Each bit is 20ms long so each character including start and stop bits is 150ms long, Fig. 2. The complete code is shown in Fig. 3.

Fig. 2. In teletypewriter code, five bits specify the character to be printed, one bit is the start bit and one and a half bits form the stop code.

Fig. 3. International 5-unit teleprinter code. A letter code changes from figures to letters and vice versa for a figure code. Channel numbers are the equivalent of bit numbers and a punched hole represents a logical one.
RECHARGEABLE
H.T. BATTERY

May I comment on Mr Pash's letter concerning the Milnes rechargeable h.t. battery.

This was first produced in the late 1920s by the Milnes Radio Company of Yorkshire. The cells were nickeld-cadmium type with alkaline potassium hydroxide electrolyte, producing a potential when charged of about 1.1/2V. All the cells were connected in series to give 120V for normal operation; but could be connected in a series-parallel arrangement with a built-in switch, so that the unit could be recharged from a normal 6V battery charger.

Unlike lead-acid accumulators, nickeld-cadmium cells can survive to a ripe old age and it is very interesting to learn that the unit Mr Pash has found bears this out. The makers at the time claimed that they were 'virtually indestructible'.

D. P. Leggatt
Engineering
Information Department
Bexhill
Yorkshire.

HERETICS GUIDE

One year and some twenty five printed pages have finally brought Dr Scott-Murray's 'Heretic's Guide to Modern Physics' to a close. Considering that he holds a Ph.D in a physics subject it is hard to believe that he could have expected to get away with some of the things asserted there. Thus almost everyone working with oscillating systems is aware that in them energy is continually changing to and fro between kinetic and potential forms, while the total energy remains nearly constant. According to quantum mechanics the total energy of an electron bound in a hydrogen atom is quantised and therefore constant, but its kinetic energy is not. In attempting to score a point against quantum theory Dr Murray in his very first article ('Wireless World' June 1982, p81, col 1, question and answer session) glossed over, not only the distinction between the kinetic and the total energy of the electron, but also the distinction between its angular momentum, which is quantised, and its linear momentum, which for a hydrogen atom may take a range of values that according to the uncertainty principle is inversely proportional to the mean distance of the electron from the proton, a spread thoroughly checked experimentally. Anyone indulging in such antics can hardly complain if at this point the discussion takes on 'a testiness of tone'.

Dr Murray wasted time and time again that no experiments bearing on his 'heresies' have been performed, but when faced with the results of experiments made with gamma rays from radioactive sources adopted Nelson's tactics for dealing with information he didn't wish to know about. As an aerial designer he might at least be expected to take an interest in the polar diagrams for atomic and nuclear phenomena, but when discussing the Compton effect (December 1982) he ignored this aspect of the topic completely. Nowhere does he give even a hint that the quantized angular momentum of, say, a hydrogen atom, is closely associated with the complexity of the polar diagram of any photon emission from the atom about the direction of its axis of spin. This type of association has been confirmed by many measurements on radioactive nuclei aligned at low temperatures, and by angular correlation measurements, but on the evidence of his articles the nature, interpretation, and significance of such experiments appears to be a closed book to him.

WIRELESS WORLD OCTOBER 1983

77
In attempting to justify the notion that microphysics is deterministic in retrospect (March 1983, p 45) Dr Murray selected his example with some care. If he had considered instead the theoretical experiment with electrons, there are arguments which show that an experimental arrangement which defines the slit through which any particular electron passes destroys the interference pattern on the far side of the slits. Thus coupled observations of an electron as it leaves the source and as it subsequently passes some point in the shadow zone between the geometrical images of the two slits do not make it possible to say through which slit the electron passed. The Copenhagen doctrine to which he is so bitterly opposed asserts that if you can't tell which way the electron went with the baffle and slits present you are not logically entitled to conclude that it must have travelled by the direct path; if similar observations are made with the baffle removed.

In the April 1983 issue Dr Murray questioned the existence of the neutrino and of discrete energy levels in nuclei. The existence of the latter is demonstrated by the spectra of the alpha particles emitted by many of the natural radioactive elements. The fact that some of them emit groups of alpha particles with several well-defined and distinct energies was known long before he took his degrees. As for the neutrino, measurements on nuclei recoiling after beta decay show that in general the nucleus does not recoil in the opposite direction to that in which the beta particle is ejected, so that from the conservation of linear momentum some other particle must be present. The energy of decay can then split between the electron and the neutrino in any way consistent with the conservation of total energy of linear momentum, since the linear momentum of a free particle is not quantized. Dr Murray's statement (p.61, col. 1) that 'according to the new ideas the mechanics of everything small is also quantized' is far too sweeping.

There is no space here to go into the dramatic experimental consequences of the fact that the angular momenta of all the particles concerned in beta decay are quantized, and that in beta decay parity is not conserved. Incidentally parity was not invented by the nuclear theorists (p.62, col. 3), and in fact has well defined values for the electric and magnetic field distributions generated by dipole and by loop aerials, to come back to Dr Murray's own field.

On the same page he quoted a text book account of the use of virtual processes in calculations. These processes are used according to well defined rules, and always occur in cascaded pairs the overall effect of which is to satisfy the conservation laws. If permissible virtual processes are arbitrarily omitted from a calculation the results will not in general be in agreement with experiment, demonstrating in another way that the indeterminacies of quantum theory refer to the properties of the natural world, and do not simply arise from the limitations of experimental techniques.

Finally we come to Dr Murray's account of the experiments carried out by Dr Aspect and his colleagues in Paris in an attempt to resolve a clash between certain predictions of quantum mechanics and of Special Relativity. In the May letters I included a reference to their own account of their work given in Physical Review Letters 1, which included a theory of the theoretical predictions, such as the quantum inequality, which their experiments were designed to test, and a very clear description of the experimental arrangements, which might almost be described as classical, give or take a couple of lasers and the use of photon counters. If Dr Scott-Murray had bothered to look up that reference instead of ruminating about the theoretical null results, he would have spared himself and Wireless World the dubious honour of having produced the most garbled discussion of a key scientific experiment that has been seen for many years. There are indeed none so blind as those who will not see.

References

C. F. Coleman,
Grove, Nr Wantage,
Oxfordshire.

The author replies:
Mr R. J. Lamb (WW letters, August) says that any attempt to prove the Causality law on the lines proposed in my March ‘83 article must involve a circular argument.
Finally we come to the mechanism of quantum mechanics, and the how restricted the coverage of this theory is, and how little it has to say even within the field it claims to cover.

Thus Mr C. F. Coleman, who would seem to have assumed the mantle of Defender of the Faith in these columns (May, June, and now), has raised many points which show the superiority of his argument over the ‘newer’, ‘classical’ physics. Several of his points I have already dealt with, superficially I admit, in letters and in the text of the articles themselves. But I question the relevance of any of them to my heresy, since I am not advocating a return to Victorian ideas. I am merely suggesting that we should look now for a credible alternative to the quantum/wave theory, with the accent on the ‘credible’. However, since Mr Coleman has twice provided literary reference to Dr Alain Aspect’s 1981 paper (and has suggested that I did not even read it before misleading Wireless World readers), perhaps I had better analyse that most recent E-P-R experiment at the level of detail as shortly as possible, from the heretical viewpoint. The following amplifies my June article.

Rather than use ‘annihilation’ photons, which are high-energy gamma rays whose polarizations cannot be measured (why not, wonder?), Aspect et al. generated pairs of associated photons of visible light by means of a cascade process in the spec-

he says, not negative matter. But did I misquote him? What Professor P. A. M. Dirac, F. R. S., actually wrote (in the second paragraph of Proc. Roy. Soc. 167, p.148, 1938) was:

“Secondly, we have the [Dirac] theory of the positron – a theory in agreement with experiment so far as is known – in which positive and negative values for the mass of an electron play symmetrical roles. This cannot be fitted in with the electron's theory of mass, which insists on all mass being positive, even in abstract theory.”

Not much doubt about that; also the term “abstract theory” is interesting. The whole page is greatest fun and should be prescribed reading for heretics. Mr Niman seems to have been unaware of the fanciful nature of his high priest’s real views.

The purpose of my article was not to review the sequence of argument and counter-argument that led to the establishment of the Copenhagen paradigm. That sequence is accessible in every textbook, where the student will find all the successes of current theory fulsomely recounted but only rarely, between the lines, any hint of the truth that all may not be well. He will find there no consideration of how big a triumph might be, or of the structure of an electron, or of the nature of electric charge or electron spin, or of the mechanism of polarization. Adherents of the theory simply decline to discuss such matters, and seek to patronize or ridicule anyone who does. Very soon one comes to realise just how restricted the coverage of this theory is, and how little it has to say even within the field it claims to cover.

Thus Mr C. F. Coleman, who would seem to have assumed the mantle of Defender of the Faith in these columns (May, June, and now), has raised many points which show the superiority of his argument over the ‘newer’, ‘classical’ physics. Several of his points I have already dealt with, superficially I admit, in letters and in the text of the articles themselves. But I question the relevance of any of them to my heresy, since I am not advocating a return to Victorian ideas. I am merely suggesting that we should look now for a credible alternative to the quantum/wave theory, with the accent on the ‘credible’. However, since Mr Coleman has twice provided literary reference to Dr Alain Aspect’s 1981 paper (and has suggested that I did not even read it before misleading Wireless World readers), perhaps I had better analyse that most recent E-P-R experiment at the level of detail as shortly as possible, from the heretical viewpoint. The following amplifies my June article.

Rather than use “annihilation” photons, which are high-energy gamma rays whose polarizations cannot be measured (why not wonder?), Aspect et al. generated pairs of associated photons of visible light by means of a cascade process in the spec-
trum of calcium atoms. These photons travelled in opposite directions away from the point of generation, and their planes of polarization where measured (i.e., inferred statistically) by passing them through polarizers. The performance of each polarizer, filter and detector was measured separately, together with the losses inherent in the light-collection system; from these calibrations the statistical correlation to be expected between the photons' polarizations as measured could be calculated, on the assumption that the photons were polarized identically when radiated. This “prediction” is the sinusoidal curve in the second figure.

The experimental measurements fitted this “prediction” perfectly. The apparatus as a whole performed during the experiments exactly in accord with the calibrations of the two photons of any given cascade pair were closely correleted. That is what this experimental result says, and that is all it says. It doesn’t seem to conflict with Special Relativity, or to depend upon γ-waves, or to have to do with wave mechanics at all. As Mr Coleman remarked, “the experimental arrangements might almost be described as classical”.

Then why the fuss? I will tell you. It has got firmly into the heads of all these people that Bohr and Heisenberg were right, in that the result of a measurement performed on one photon of a pair must affect the physical polarization of its distant sibling (A metaphysical quantity is misunderstood with a physical quantity). Some weird “action”, it is claimed, must pass from one detector to the other faster than the speed of light. In an attempt to rationalize this claim a number of “locally realistic theories” have been proposed, involving the assumed properties of a mythical sub-structure of sub-physical “hidden variables”. (I tell no lies: this is what our modern physics has come to). An extra-ordinarily complicated mathematical argument known as Bell’s theorem, which I confess I have not bothered to understand, says that if these “hidden variables” or their equivalents existed, the result of Aspect’s experiment would not be the result he actually obtained.

What Dr Aspect has reported in the paper referred to by Mr Coleman is the failure of Bell’s theorem. Some people say this proves that the postulated “action” travelled through the apparatus faster than light. Dr Aspect himself did not say this, and neither do I. Perhaps Mr Coleman does?

Aspect’s experimental result can be explained simply and naturally on classical or on slightly neo-classical reasoning. But now, just watch how fast a house of cards collapses! The experiment has disproved Bell’s theorem, which was concerned with “locally realistic theories”, which were based on “hidden variables”, which were invented to support the argument of the “reduction of the wave-packet”, which a specious take-it-or-leave-it consequence of the supposed existence of “γ-waves”, which in their turn were an elaboration into pseudo-scientific fantasy of an innocent speculation by a post-graduate student in 1925 . . .

Everybody nowadays should keep his Occam’s razor handy. Using it, if one is not blinded by the conventional prejudice, one sees that Dr Aspect’s experiment is just another nail in the coffin of the Copenhagen theory. It seemed to me that his contribution to the common weal was important enough to rate a mention, superfluous though it perforce had to be, in the final article of the Heretic’s Guide series. I am grateful to Mr Coleman for giving me this opportunity to explain why.

Scott Murray Kipford Galloway

**ELECTRIC CHARGE FROM A RADIO WAVE**

I am at a loss to know whether Professor Jennison was really serious in writing this article, for the conclusions he draws from his experiment seem somewhat extended.

The experimental apparatus he describes is an electronic polyphase generator, being 8-ph or 32-ph, according to how you count the nodes. As is well known in the art, polyphase machines are associated with rotating fields, and if what is normally the stator is driven backwards at synchronous speed, its field pattern will be stationary with respect to the laboratory floor. However, apart from that being an example of relative motion, what can be deduced from it? The complexity of Professor Jennison’s apparatus goes some way to mask a well-known principle, the multistage phase shifter. With two stages we have the multivibrator, but with three or more a near sine-wave generator may result. The diagram shows a 3-stage RC oscillator, or should it be more properly a 3-ph generator? That depends on the purpose to which it is put. Clearly, if it is used in its 3-ph capacity, it will have when mechanically stationary, an associated rotating field. That field can be stopped by suitable mechanical rotation but can we draw any conclusions about field and charge from that?

If indeed we wish to freeze a travelling wave on a transmission line, then it is in principle easier to adopt the proposal in the letter from R. J. Hodges, also in the August issue. Admittedly that pattern came from a pulse generator at the left hand end of the line, but it could just as easily have come from energy received by an aerial.

As for all that 3K stuff, that is just confusion worse confused. Chris Patton Dept of Electrical and Electronic Engineering Bell College of Technology Hamilton

**TECHNOLOGY AND PEOPLE**

Those who have read Prof. H. J. Campbell’s most excellent book The Pleasure Areas (Eyre Methuen) will be fully aware that the analogy between electronics and the brain is very much stronger than a mere appearance: Campbell, a neurophysiologist of no mean standing, makes it clear that everything we do is done ultimately for stimulation of the pleasure areas which have evolved out of the “smell brain” of the fish.

Apparently there is stimulation from the peripheral receptors (broadly the senses): there is stimulation from the movement of muscles: and above all, there is stimulation from the thought processes at work in the vast neo-cortex that makes us different to the lesser beasts.

This latter point is where the importance comes in of the pyramid programme which I mentioned in my letter of February this year — it provides a very wide base of information wherefrom an entry into genuine abstraction becomes possible, whereas that entry is impossible from a narrow specialist base simply because the subject does not have enough information to think about, i.e. to compare. Indeed the “research” of a genuine specialist tends to be little more than a good old grope in the dark!

Obviously, the more information one has to think about the more interested one becomes in systems outside one’s animalistic self: Adam was more like a wasp that will not be taught to keep out of the marmalade: Cain killed Abel to appease his own introvert jealousy: Lamech’s ego caused him to think that he could dispose of whom he wished. On the other hand, Noah may be thought of as the first extravert creative, not only saving the animals two by two, but planting the first vineyard and then, sadly, imitating a newt! Obviously he still had some interest in his own material pleasures.

To put it plainly, Noah was the first to get some way into the abstract with due stimulation of his frontal lobes. Campbell makes it clear that this stimulation is electrical, and electrical activity in the brain is the one sure sign of remaining life. Action, the verb of the sentence, has
three dimensions: speed, priority, and direction. These three dimensions will qualify fully any action at all. What is interesting here is that any emergency (or any threat, real or imagined) brings about an increased sense of priority, and that priority is to the self in the sense of survival; I have long believed that the autist is in a mental state of high priority, a sort of absolute "converger".

As I see it, this priority may stem from two possible causes, the one being genetic, and the other perhaps from (shock) interaction with the environment, as it appears that it must be with all matters of intelligence. I remember seeing an autist on television many years ago who could do virtually nothing but play the flute: in this respect he could be considered not unlike what one imagines an absolute specialist would be like, and as far as communication goes, appeared to display the sort of symptoms which one might expect.

Your words about the blocking effect of too much information, and the removal of stress for communication, do suggest to me that the subject needs to be taught to use the function of "comparison" in a state of relaxation, because "comparison" is the thought process at work: it is also an electrical stimulation to the pleasure areas which might help to break down the unuseable vertices bounding the existing preferred pathways for electrical signals in the brain, and so assist the subject to "break the shell", and arouse natural curiosity over a wider spectrum.

The three basic functions of any computer (at abstract level) are perception (i.e. the intake of information), memory (the storage of the information) and comparison by which it is processed. If one thinks of a simple diode gate, the one that gets there first biases off the others: the action is one of comparison through time. Thinking inspection demonstrates that these three dimensions must have evolved in that order: it appears perhaps that the autist may have failed to evolve his function of comparison, or else have some kind of block against using it.

However, as Campbell mentions, the new-born babe is born with hardly any neo-cortex having developed — it is virtually an animal — and the cortex develops with the input of sensory information of one kind or another: might not the function of comparison be assisted to evolve with patience?

It is important to realise that an efficient function of comparison will actually call for information to process so that pleasure may be obtained from the electrical stimulation which ensues: it is my own belief that it is the frustration of this information-seeking in a society which pressures "what" but seldom teaches "how", that causes creativity to twist into animal introversion such as hooliganism and crime, away from that understanding that brings care and responsibility in its wake from an interest in systems outside the self.

As to your use of the word "mind", may I suggest that "mind" is brain plus information taken in and processed? Thus "mind" would tend to be the overall integration of electrical activity within the brain, and demonstrable by the effects of that electrical activity in that it ultimately controls all our behaviour patterns.

For those interested in the subject of intelligence and creativity generally I unhesitatingly recommend Arthur Koestler's "Act of Creation" and "The Dragons of Eden" by Carl Sagan: but Campbell's "Pleasure Areas" is some kind of vital starting point.

Finally, I would like to congratulate Mr Young over his efforts within a specialist society which itself seems to me to demonstrate at least mild symptoms of autism!

J. A. MacHarg
Wooler
Northumberland

THE NEW BUREAUCRACY

I note that I am not the only one to dispute Ivor Catt's various assertions. The small comfort afforded by such sentiment is, however, offset by the impertinence of the man in presuming to judge a stranger's qualifications and experience. His assumption that there is some link between von Neumann and large-scale integration is of some slight interest to the psychologists, but of no relevance to the rest of us.

His loyalty test — which I am quite prepared to do — confesses small-minded bureaucratic bungling with the job at hand, which is to rid us of the pernicious von Neumann architecture which he so despises. He — and MAPCON — still have not realised that machine architecture need have little to do with its technological implementation. To object to their insistence in the first place, Does this insistence block the development of parallel-array machines? Of his own wafer-scale integration techniques? (I do, incidentally, deny that any programmer was responsible for the statement he quotes — programmers think in terms of structure, not composition).

The von Neumann hand that feeds me is a difficult slave and worse master, the result of an unholy marriage of mathematical theorem-proving and "if it works, it's perfect" business approaches. I do not mind biting the hand of that bastard child, for I am not fed by it, but by those who ask me to tame it. I should regard its passing with equanimity if its successor is the sort of beast which allows dealing with sets of data, rather than bytes.

Let us sort out technology from architecture. Then we can start discussing the alleged antipathy between programmers and engineers — which starts with the architecture. Until then, the battle lies between him and his simple-minded bureaucrats.

D. W. Scott
Challston Ltd
Nettlestead Green
Kent

MIXED LOGIC

M. Butler's article on the use of mixed logic (WW, July 1983, pp.28 ff.) should be mandatory reading to anyone studying, or even teaching, digital techniques. He clearly emphasizes the often overlooked distinction between the actual working of circuit and its logical function(s).

M. Butler should, however, have made a passing reference to the IEC system of symbols for logical gates, that was started around 1970, and is now of standard use at such giants as the Phillips and Texas Instruments. It became official norm in Germany in 1976, and also in The Netherlands. May I infer that BS failed suit? And when is WW to switch?

As to Mr Rudge's Letter (p.51), may I suggest the following alternatives. They are self-explanatory, I suppose.

J. Eyckmans
Sint-Truiden
Belgium

CALL SIGN

I was interested to read of the call sign 2MT on the Amateur Radio page of the August issue of Wireless World.

I have a copy of Harmsworth's Wireless Encyclopedia and, although it is undated, Sir Oliver Lodge writes in the introduction, "... to what is now in 1923 ..."

The call sign 2MT is listed as belonging to 'Marconi Scientific Instrument Co., near Chelmsford Station, for specially authorised transmissions to amateurs.'

Another item is a 'Hanging Set': how to make a receiving set with simple controls suspended from the ceiling and giving light for the table as well as entertainment. The valves are the ordinary bright emitter type (Marconi-Osram R valves). Six valves are used — two stages of r.f. amplification, one detector valve and three stages of low frequency amplification.

Keith Ellis
Spondon
Derby
HOSPITAL RADIO TRANSMITTER
With ‘WW’ emblazoned on the front of it, Wireless Workshop produce a medium wave transmitter for use in hospitals, universities and other private services. Using loop transmitting aerials throughout the buildings covered, the transmission can be picked up on ordinary receivers.

MACHINE-CODE MONITORS
Basic in personal computers has its limitations and much more computer commands at a higher speed are obtainable if the user is prepared to the computer’s own operating language or ‘machine-code’. To make this easier software programs allow the display of a computer’s memory and allow programs to be entered and displayed in their machine code format and sometimes in the mnemonics used to make this numerical language more intelligible. One such program is the N-Bug, written by Kuma for the Newbrain computer. With it, a single display shows a complete memory dump which may be scrolled through, the display also shows the state of each register, and a screen editor allows programs to be edited easily entered and corrected. Other features include hexadecimal/decimal interconversion, relative jump calculations and the setting of breakpoints. Another display screenful offers menu selection of printer and tape input/output and allows the saving, verifying and loading of machine-code programs. N-Bug is complemented by Zen an assembly language editor/assembly, both are available from Kuma Computers Ltd.

REAL-TIME CLOCK FOR SINCLAIRS
A time controller for the ZX81 and Spectrum computers has been developed in Ireland. The battery-backed circuit can control eight inputs and eight outputs and also provides the computer with date and time, including seconds. The controller has its own rom program and only a single instruction is needed from the computer to give the date and time. The circuit plugs directly into the computer’s expansion port and provides another port for the addition of a ram pack, printer or other peripheral. It may be used as an electronic diary, with an alarm for important appointments; as a controller for household appliances or intruder alarms; to time sound effects or games and in process control, laboratory experiments etc. The version for the ZX81 costs £34.50 and for the Spectrum, £38.50. Glanmire Electronics Ltd., Westley House, Trinity Avenue, Bush Hill Park, Enfield, Middlesex EN1 1PH.

MASS MEMORY IN SOLID STATE
Plugging into the disc drive port of many popular computers, the MegaRAM storage unit offers memory capacity of between 1 and 32M bytes. The advantages of using solid state memory, according to the distributors, is that it operates much faster than magnetic disk and this is particularly noticeable when running programs with a lot of input/output activity, such as data base management, file sorting and merging and similar tasks. Another advantage is the lack of any moving parts, hence better reliability and no noise. At the end of a computing session, the memory can be copied onto a disc for long-term storage.

The MegaRAM circuitry includes automatic error checking and correction for any single-bit errors. An optional power supply includes battery back-up giving time to transfer the contents to back-up storage in the event of a mains failure. Compass Peripheral Systems, 67 Milford Road, Reading, Berks RG1 8NA.

D-TO-A CONVERTER RUNS COOL
Monolithic construction and low power dissipation make the DAC80 run a lower operating temperatures and allow the use of low-cost plastic packaging, claim Analog Devices.

The 12-bit converter with selectable voltage output has also claimed for it a higher reliability, a wider temperature range, and more accuracy than those of competing models. Analog Devices Ltd, Central Avenue, East Molesey, Surrey KT8 6SN.

FSK MODEM ON A CHIP
To construct a low speed modem (300 or 600bits/s) all that is needed is the XR-14412 integrated circuit and a few external components. The crystal-controlled circuit can operate simplex, half or full-duplex modes with self-test and echo facilities. It needs a single supply rail and inputs and outputs are t.t.l. or c-mos compatible. Using a suitable transformer, the modem can connect directly to a telephone line or may be used with an acoustic coupler. For phase-shift key (p.s.k.) modems a self-contained bandpass filter is available, the XR 2120. Full details of both from Rastra Electronics Ltd, 275 King Street, London W6 9NF.

York Road, Maidenhead, Berks SL6 1SQ.

A very similar program, written this time for the Oric-1 computer, is the Extension Monitor by Kenema Associates. There are some useful additional facilities; the ability to step through a program, to search for byte or character strings, to set or eliminate breakpoints. Other commands may be defined by the user. Hexadecimal display also translates any character codes embedded in it and displays these in a separate column. A disassembled mnemonic display is included. Kenema Associates Ltd, 1 Marlborough Drive, Worle, Avon BS22 0DQ.

Kuma WW 302
Kenema WW 303

WW 301

WW 304

WW 305

WW 307

WIRELESS WORLD OCTOBER 1983
TOROIDAL TRANSFORMERS

Fully encased in an ABS plastic shell, the ILP range of lower power toroidal transformers have been produced in answer to public demand. Starting at 15VA, available now, the range is to be extended to provide transformers up to 120VA. ILP Electronics Ltd., Graham Bell House, Roper Close, Canterbury, Kent CT2 7EP.

WW 308

BENCH POWER

A series regulated power pack can give a constantly variable output between 0 and 18V, and 0 to 5A. Course and fine manual controls are provided or the output may be controlled by an external potentiometer. The Trio PR 655 is provided with two large meters to indicate current and voltage. A fixed current protection circuit may be switched in, as can regulated current or voltage operation. Remote sensing is possible and the supply may be configured in a series or parallel, master or slave mode. House of Instruments, Clifton Chambers, 62 High Street, Saffron Walden, Essex CB10 1EE.

WW 309

LOW POWER SOLID-STATE LASER

A series of monolithic GaAs GaAlAs pulsed lasers has been extended to include the LAS-02, with an output of 6W peak at a wavelength of 940nm. The emitted beam width of 150µm makes it suitable for proximity detection, ranging and security systems. STC Components, Laser Unit, Brixham Road, Paignton, Devon TQ4 7BE.

WW 310

COMPUTER CONNECTOR KIT

Suitable for RS232 and V24 computer interfaces, a kit of housings, contacts, cable clamps and extraction and crimping tools can be used for rapid repair or replacement and in experimental use. It will help to overcome those frustrating moments when the plug on a cable doesn't fit the socket on the peripheral. Amplehousing.

Terminal House, Stanmore, Middlesex HA7 4RS.

WW 311

If you would like more information on any of the items featured here, enter the appropriate WW reference number(s) on the envelope reply-paid card bound in this issue. Overseas cards require a stamp.

SIDeways PRInT ON EPSON MICRO

NON-VOLATILE RAM

A 16K static RAM that has a miniature lithium back-up battery is claimed to last for more than five years. The battery is contained within the RAM package and the device fits a standard 24 pin socket and can replace any existing 16K ram or 2716-type eproms, at a similar price. The MK48Z02 comes from Mostek UK Ltd., 1 Valley Drive, Kingsbury Road, London NW9.

WW 313
**CHUM ONE Industrial Computer**

**£189**

- Basic and Z80 Assembly Language
- Detachable Hand-Held Keyboard
- 8K Bytes of Non-Volatile Memory
- 8 Analogue Inputs
- 1 Analogue Output
- Up to 512 Optical Coupled Inputs/Outputs
- 4 Programmable Frequency/Timers
- Serial Input/Output Port
- Real Time Clock
- 32-Character by 2-line Display

**WARWICK DESIGN GROUP, 12 ST. GEORGE’S ROAD LEAMINGTON SPA CV31 3AY (0926) 34311**

**Your own customised Communications Monitor**

...just 16 lbs

The vast range of available options allows you to customise the FM/AM 500 Micro-Monitor to suit your specific needs, and weighing in at just 16 lbs your ‘field-tests’ can now be precisely that!

For a practical demonstration to prove our point contact:

Mike Dawson on 01-897 6446.

**Hitachi Oscilloscopes**

performance, reliability, value

New from Hitachi are three low-cost bench scopes with bigger screens and extra features in a new slimline ultra-lightweight format.

The range now extends to 13 models:

- 4 dual trace single timebase models 20MHz to 40MHz
- 2 dual trace sweep delay models 20MHz and 35MHz
- 2 dual timebase multi-trace models 60MHz and 100MHz
- 2 miniature field portable models, 20MHz and 50MHz
- 3 storage models, one tube storage, two digital storage

Prices start at £295 plus vat (model illustrated) including 2 probes and a 2-year warranty.

We hold the range in stock for immediate delivery.

For colour brochure giving specifications and prices ring (01480) 63576.

**ELECTRONIC POWER UNITS**

FOR XENON ARC AND MERCURY ARC LAMPS

UNITS AVAILABLE FOR LAMPS RANGING FROM 75 TO 6500 WATTS.

Lamp housings and lens systems manufactured as standard off the shelf models or to specific design.

**K. T. Manners Design Ltd.**

P.O. Box 936, London, W4 4NW Telephone: 01-994 7152 Telex: 28604

**Bird Electronic**

**THRULINE® Wattmeters**

**TERMALINE®** loads

and accessories from stock

Aspen Electronics Limited

The exclusive

UK representative for Bird Electronic

2/3 Kildare Close, Eastcote, NW9 3UR

Telephone 01-868 1188 Telex 8812727

**WIRELESS WORLD OCTOBER 1983**

WWW 046 FOR FURTHER DETAILS

WWW 048 FOR FURTHER DETAILS

WWW 050 FOR FURTHER DETAILS

WWW 057 FOR FURTHER DETAILS

WWW 029 FOR FURTHER DETAILS

WWW 048 FOR FURTHER DETAILS
Discover the Microcomputer Age

Come along to The Northern Computer Fair and discover for yourself the excitement of the microcomputer age. All you need to know about personal computers, home computers and microcomputer systems for business will be on display at Belle Vue, Manchester from November 24-26. All your questions will be answered at the North's premier personal computer exhibition.

Enthusiasts can see the latest software and hardware technology in action, and for those new to the world of computers this show is a great introduction. Being sponsored by Practical Computing and Your Computer, the leading microcomputing magazines, you can be sure of value for money at £3 a ticket for Adults and £2 for Children under 16.

Travelling to the show is also easy as the organisers have arranged special reduced price tickets with British Rail which include the cost of admission. For further information ring British Rail Enquiry Bureau on 061-832-8353 before November 11.

The Northern Computer Fair is open between 10.00 am and 6.00 pm every day so come along and bring the microcomputer age alive for you.

For special party rates and further information contact:
The Exhibition Manager,
The Northern Computer Fair,
Reed Exhibitions, Surrey House,
1 Throwley Way, Sutton,
Surrey SM1 4QQ

Belle Vue Manchester November 24-26, 1983
NEW PHASE-MODULATION SYSTEMS

Until recently, atomic time and date information was only available on v.f. transmissions using amplitude modulation. The RCC 8000AM series of equipment uses these transmissions to offer high noise immunity and high accuracy, particularly at very long range. The new RCC 8000PM series of equipment uses, for the first time, phase modulated transmissions with massive radiated powers of up to 2 Mega-Watts to offer long range, excellent noise immunity and no scheduled maintenance periods.

NEW PRODUCTS

The AM and PM series of Radiocode Clock equipment has been further expanded to include seven new models (from top) 8000S - combined clock, frequency standard and optional stopclock. Internal standby power supply - with dual rate constant current charger. Time-event log - prints hours, minutes, seconds, milliseconds and day of year, on receipt of a log pulse. Speaking clock - time announcement or audio recording. Slave controller - total control of single-standard master/slave systems is one pulse/sec. Dual standard slave controller - total control of two different and independent slave systems, i.e., one pulse/sec and one pulse/half min. Slave distribution amplifier - maximum flexibility for the largest master/slave installations requiring dual standard operation, multiple circuits and complete master/slave backup.

NEW OPTIONS

A continuously expanding range of fully integrated software and hardware is available for both series of Radiocode Clock equipment. Standard options now include:

- IRIG B precision serial o/p
- RS232/V24 1MS resolution
- General purpose parallel o/p
- FSK record/replay system
- Keypad entry of alarm times
- Keypad entry of time/date
- Time code generators
- Intelligent slave systems
- Standard frequency outputs
- Stopclock operation
- Calibrated systems for increased accuracy

Radiocode Clocks Ltd
Unit 19, Parkengue, Kernick Road Industrial Estate
Penny, Falmouth, Cornwall Tel: Falmouth (0326) 76007
(*A Circuit Services Associate Co.)

WWW - 025 FOR FURTHER DETAILS

CUBE

Your partner in electronic enterprise

Share in the Success Story of Industrial Microcomputing.

The spectacular growth in the use of microcomputers in the home, in education and in the office is merely the overture to the real revolution - the micro-computerisation of industry.

Your role as an OEM

If you are planning a product which includes microprocessor control, then CUBE modules can both perform the development task and be economically configured as part of the end product. Development time and costs will be radically reduced because of the high level of performance that already exists in CUBE. Delivery time of a finished product to your customers can be reduced from months to weeks.

Technical support? Your engineers will have direct access to our Cambridge design team responsible for the entire CUBE range.

Your role as a Distributor

The CUBE concept is now becoming widely known as a result of press coverage, advertising and for its success stories in industrial implementations. CUBE modules are such good value and so flexible that they can be profitably incorporated into nearly every electronic control application. Your task as a distributor is to present the latest developments to potential users and advise on product customisation using CUBE products.

Control Universal Limited is a company with a solid reputation for designing and manufacturing computers in Cambridge. An impressive record of growth both in sales and in the range of products offered allows us to offer a solution to nearly every machine and process control application. Full details of the CUBE range, and how they are now fully supported by software tools (such as BBC BASIC and FLEX cross-compilers) are in our catalogue, free on request.

Let's work together and aim for electronic industrial control for a more prosperous world!

Please write to me directly:
Jon Dane, Managing Director
Control Universal Ltd, Unit 2, Andersons Court
Newnham Road, Cambridge CB3 9EZ
telephone: 0223-358757 telex: 995801-G, GLOTX

WWW - 044 FOR FURTHER DETAILS
Looking for a Distortion Measurement System?

The Amber model 3501 is quite simply the highest performance, most featured, yet lowest cost audio distortion and noise measurement system available.

It offers state-of-the-art performance with THD measurements to below 0.0008% (-102dB), maximum output level to +30dBm and noise measurements to below -120dBm.

It has features like automatic operation, optional balanced input output and powerful IMD measurement capability. It includes comprehensive noise weighting with four user changeable filters. Unique features like manual spectrum analysis and selectable bandwidth signal-to-noise measurements.

The 3501 is fast, easy to use and its light weight and small size make it very portable. It can even be battery powered.
WIRELESS WORLD OCTOBER 1983

HEAVY METAL PLINTHS
Post £1

RECTIFIER TRANSFORMERS
Post £1

MAINS PRE-AMP FOR MAGNETIC CARTRIDGES to low gain amplifiers 10m to 1m mono, £5 stereo. £7 P&P £1

BATTERY ELIMINATOR Mains to 5 Volt D.C.
Stabbing type (cable included) with Zener diode printed circuit. case 4 x 3 x 11/2" £3. less case £4. For brush motors, etc.

R.C.S. LOW VOLTAGE STABILISED
_PACK KITS
£3.95. Post £6
All parts and resistors, transformers, etc., with Zener diode printed circuit, mains transformer 240v. output 6 or 7 or 8 or 12 volt d.c. up to 100mA. Please state voltage required.

REELS
6V DC 95p. 12V DC £1.25, 18V £2.15, 24V £2.30.
110V £1.50, 230V £2.75.

PICK-UP CARTRIDGE 9TAHC £13.80

BRIDGE RECTIFIER 200V £1.10.

ZENER DIODE £5.31.

TRANSISTORS
2N3904, 2N2222, 2N5551 50p each. 30p per six.

THREE WIRE MINIATURE FUSE £3.50.

22/23x14x37/2 in £7.25. £5.75 inc P&P.

240V 6W £1.25; 12W £3.25; 200W £8.75.

100W £15.75; 50W £6.95; 10W £2.10.

15W £4.25; 25W £7.95.

12/15v 20mA/50mA £1.25.

15v 20mA £2.50.

240V 25W £1.25; 5W £2.95.

36V 25W £2.05.

30V 25W £2.25.

250V 25W £2.75.

TRANSISTOR MOSFET
2N7003 £1.25.

TRANSISTOR TOGGLE SWITCHES £0.45.

AMPLIFIER VALVE MODEL 802 £1.10.

PHONO PICK-UP turnover £11.30.

Speaker plugs 25p; Sockets 25p; Double sockets 30p. £12.50 inc VAT. £11 inc VAT.

VERNIER DRIVE DIALS, MICROSWITCH SINGLE TRIMMERS 30pF, 500pF, 10p 100pF, 400pF ±0.05% 2/500V 45p

MICROSWITCH DOUBLE TRIMMERS ±0.05% 100pF 45p. 4p£25p.

GEARED TWIN GANNS 365 ±35-35 ±25p £2. £2.50 inc VAT.

R.A. GEAR REDUCTION for 365 GANNS £2.50 inc VAT.

GARRARD 91/2x3x2in. £4.50 inc VAT (250V) £2 inc VAT.

GARRARD 8 1/2 x 2 1/2 x 1 3/8 in £3.50 inc VAT (500V) £2 inc VAT.

时钟．收音机．扩音器：有线或无线，价格从£1起．

SPECIALISTS IN ALL TYPES OF 1200mF 76V 80p, 1200mF 80V 110p.

MOTOROLA PEZO ELECTRIC TUBE TWEETER 36N, square £3.50 inc VAT.

DIAPHRAGM TWEETER 36N, square £3.50 inc VAT.

CROSSOVERS: TWO-WAY 3000 £3.50 inc VAT. £10 inc VAT.

3-way 3500 £6.50 inc VAT. £15 inc VAT.

2-WAY 3500 £6.50 inc VAT.

**SPECIALS**

BROADCAST HEADPHONES (365 GANNS) £2.50 inc VAT.

WIRELESS WORLD OCTOBER 1983

NEW BAKER MICROPHONE PA AMPLIFIER (£129)
4 channel inputs, dual impedance, 500-600 ohm channel mains, volume, treble, bass, Presence controls, Master volume control, echo tare return switch. Speaker sockets.

NEW BAKER WATTS GOODMANS PA AMPLIFIER 4 Inputs £99
For Discussion, Vocal, Public Address. Three speaker outputs for up to 1000 watts high gain outputs, 20 mkm individual volume control, 2500 Watts total, 8 ohms RMS, Music Power. Speaker output 500 V, 20kHz. Response: 20Hz - 20kHz - 8 ohms. £150 inc VAT.

Baker mobile PA amplifier. All transistors, 80 watts RMS. 120V, 240V, 250W inc VAT. £235 inc VAT.

Baker Mobile PA Amplifier 4 Channel amplifiers £295 inc VAT.

Baker Mobile PA Amplifier 4 Channel mixing. Master, treble and bass volume controls. 3 Speaker output, 8 ohms, Disco group £145. £25 inc VAT.

Baker Mobile PA Amplifier 4 Channel mixing. Treble and bass and 3 volume controls. £120 inc VAT.

FAMOUS LOUDSPEAKERS

HORSEPOWER £25 inc VAT.

Motorola PEZO ELECTRIC TUBE TWEETER 36N, square £3.50 inc VAT.

DIAPHRAGM TWEETER 36N, square £3.50 inc VAT.

CROSSOVERS: TWO-WAY 3000 £3.50 inc VAT. £10 inc VAT.

3-way 3500 £6.50 inc VAT. £15 inc VAT.

2-WAY 3500 £6.50 inc VAT.

**SPECIALS**

BROADCAST HEADPHONES (365 GANNS) £2.50 inc VAT.
MARK 1983 WITH GAPS IN CIRCUIT FILES WELL-PLUGGED

WIRELESS WORLD CIRCARDS last year benefited many ‘new generation’ readers who bought at 1976 bargain prices + 10% discount for 10 sets! Most sets are still available although companion volumes CIRCUIT DESIGNS 1, 2 and 3 are out of print (CIRCARDS sets 1 to 30).

The Offer stands, so order now your sets of 127 x 204mm cards in plastic wallets. These unique circuit cards normally contain descriptions and performance data of 10 tested circuits, together with ideas for modifying them to suit special needs.

1 Basic Active filters  2 Switching Circuits, comparators and Schmitts (But these gaps cannot be filled)  

*Photocopies only: 3 Waveform generators 4A.C., measurement 5 Audio circuits @ £3.20 each set.

To Electrical-Electronic Press
General Sales Department
Room 108
Quadrant House
Sutton
Surrey SM2 5AS

Company Registered Number: 151537 (ENGLAND).
Registered Office: Quadrant House, The Quadrant
Sutton, Surrey SM2 5AS

Please send me the following sets of CIRCARDS..................................................£2 each, £18 for 10 post free.
Remittance enclosed...........................................payable to BUSINESS PRESS INTERNATIONAL LIMITED
Name (Please print) .................................................................
Address (Please print) ..............................................................
**VALVES**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A105</td>
<td>E129</td>
<td>£2.99</td>
</tr>
<tr>
<td>A128</td>
<td>E179</td>
<td>£1.85</td>
</tr>
<tr>
<td>A129</td>
<td>E189</td>
<td>£1.50</td>
</tr>
<tr>
<td>A130</td>
<td>E199</td>
<td>£1.25</td>
</tr>
<tr>
<td>A131</td>
<td>E219</td>
<td>£1.00</td>
</tr>
<tr>
<td>A132</td>
<td>E229</td>
<td>£0.75</td>
</tr>
<tr>
<td>A133</td>
<td>E239</td>
<td>£0.50</td>
</tr>
<tr>
<td>A134</td>
<td>E249</td>
<td>£0.25</td>
</tr>
<tr>
<td>A135</td>
<td>E259</td>
<td>£0.10</td>
</tr>
</tbody>
</table>

**VALVES VAT**

Minimum Order £1: 25-99: 100 up

WIRELESS WORLD OCTOBER 1983

**FIELD TELEPHONES TYPE "J"**

Tropical in metal casings.

10-line MAGNETO SWITCHBOARD. Can work with every type of magneto telephones.

**VALUES MAY VARY**


**COLOMOR**

(ETHIONICS LTD.)

170 Goldhawk Road, London W12

**Happy Memories**

<table>
<thead>
<tr>
<th>Part type</th>
<th>Capacity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>411-500ns</td>
<td></td>
<td>£2.99</td>
</tr>
<tr>
<td>461-100ns</td>
<td></td>
<td>£1.85</td>
</tr>
<tr>
<td>461-200ns</td>
<td></td>
<td>£1.25</td>
</tr>
<tr>
<td>461-300ns</td>
<td></td>
<td>£0.75</td>
</tr>
<tr>
<td>461-400ns</td>
<td></td>
<td>£0.50</td>
</tr>
<tr>
<td>461-500ns</td>
<td></td>
<td>£0.25</td>
</tr>
<tr>
<td>461-600ns</td>
<td></td>
<td>£0.10</td>
</tr>
</tbody>
</table>

**WIRELESS WORLD OCTOBER 1983**

**hi! performance hi!**

Probably the BEST VALUE FOR MONEY DMM AT £29.50 inc P+D. VAT extra

- **with FREE**
  - TEST LEADS
  - BATTERY
  - OPERATING MANUAL
  - SPARE FUSE
  - PLUS a FREE
  - CARRYING CASE
  - FULLY GUARANTEED FOR 12 MONTHS

**ONE large 'easy to use' rotary switch**

30 protected ranges to 1000V

10 Amps and 20 Meg Ohms

**Other features inc. small compact hand held size – basic 0.5% accuracy**

- high reliability using CMOS circuitry
- large clear LCD display – auto zero, polarity, overange and LO Batt. indication
- diode test – tilt stand with non skid feet
- high surge voltage protection etc. etc.

**AVAILABLE from HOUSES OF INSTRUMENTS and LOCAL DISTRIBUTORS**

Just ask for METEX 3000 FREE DATA

**Easy to Order:** Fill in and post the coupon enclosing cheque/P.O./Credit Card details or Official Order.

**hi!**

**reliability hi! service hi! performance hi!**

**hi! competitive hi!**

House of Instruments. Clifton Chambers, 62 High Street, Saffron Walden, Essex CB10 1EE

Telephone: 0799 24922 Telex 818750

**hi! competitive hi!**

WWW - 020 FOR FURTHER DETAILS

**WWW**

170 Goldhawk Road, London W12
CASSETTE RECORDER
SANYO Data Recorder ORIO
A superior quality data recorder with dedicated computer output and monitoring facility on both Front and Rear. 
£39.50 + £1.50 carr.
SLIMLINE Cassette Recorder complete with counter and remote control
£24.50 + £1.50 carr.
Computer Grade Cassettes
£0.90 each. £4.50 for 10 - £1 carr.
Cassette lead £3.50.

NEC PC 8023 BE - N
120 CPS, 80 cols
Logic Seeking, Bi directional
Forward and Reverse
Line Feed
Proportional Spacing, Auto Underline, Hi-Res and Block Graphics, Greek Chars.
Set
Only £320 + £8 carr.

SIDEWAYS ROM EXPANSION BOARD
This board provides 8 high quality 78 pin sockets for expanding the computer's sideways ROM capacity by a further 128K. An 8K Eproms consume about 10W, less than the 15W of each 640K. In our opinion addition of 8 extra ROMS will not overload the computer power nor cause internal overheating. All ROM sockets are of turned pin type gold contacts to ensure that numerous insertions and extractions will not wear out or deform the contacts. The board is fully buffered and also dimenioned to ensure non interference with other breakout components. Full wiring instructions supplied £25 + £5 p&p.

TORCH Z-80 PACK
For little more than the cost of an 800K disc drive, you can now considerably extend your BBC's capabilities. The twin drives, together with the 280 card, gives you 64K of memory and includes a database, word processor etc. Comes complete with manuals of O.N. Operating System, Demonstration and Utility programs etc. The system is fully compatible with CP/M* thus allowing the use of prototype business software. £825 + £8 p&p.

DISC DRIVES FOR THE FORTH COMPUTER
5¼" Teac FD55 Slim Line Mechanisms.
FD55A 40 track SSD3 250bytes unformatted Bare: £135, Cased: £158
2 x FD55A 40 track SSD3 500bytes unformatted Cased: £350
FD55E 80 track SSD3 500bytes unformatted Bare: £180, Cased: £220
2 x FD55E 80 track SSD3 1Mbyte unformatted Bare: £475
5¼" Mitsubishi M4853 Slim Line mechanism 80 track
DSD3 1Mbyte unformatted Bare: £225, Cased: £245
2 x M4853 3 Mbytes Single drive cable £8, Dual Drive cable £12

NEW COMPREHENSIVE CATALOGUE AVAILABLE PLEASE SEND FOR PRICE LIST

FLOPPY DISC INTERFACE
Incl. 1.2 Operating System
£95 & £20 installation

FLOPPY DISC DRIVES
Single Drive 9¼" 100K £230 + £6 carr.
Double Drive 5¼" 800K £599 + £8 carr.

BBC COMPATIBLE 5¼" DISC DRIVES
These drives are supplied in BBC matching card cases and with necessary cables.
SINGLE DRIVES 100K £150, 200K £215 400K £265
SINGLE DRIVES with PSU 100K £185, 200K £260*, 400K £330
DUAL DRIVES with PSU 2 x 100K £355, 2 x 200K £475*
2 x 400K £995
*These drives are provided with a switch to change between 40 and 80 tracks.

DRIVE CABLES: SINGLE £8, DUAL £12.
DISC MANUAL & FORMATTING DISKETTE £12.50

Phone or send for our BBC leaflet.

MONITORS
MICROVITEC 1431 14in Colour Monitor £230 + £8 carr
MICROVITEC 2031 20in Magna Monitor £319 + £8 carr
KAGA 12in RGB Monitor £255 + £8 carr
Lead for KAGA/SANYO RGB £10
SANYO HI RES GREEN Monitor £99 + £6 carr
SANYO HI RES RGB Monitor £445 + £8 carr

PRINTERS
SEIKOSHA GP UX175 00
GP 250X £235.00
ULTRA 1040 £425.00
Silver Reed EX44 Daisy Wheel with Serial Interface
£365, with Parallel Interface £385
Carriage/Printer £8.00

Parallel Printer lead for BBC/Atom to most printers £13.50

DIL SWITCHES
40 pin £8.00
60 way £12.50
10 way £4.00

EURO CONNECTORS
24-pin £110
36-pin £150
50-pin £190

ENGINE CONNECTORS
2 x 3 way £25.00
2 x 2 way £20.00
2 x 2 way + £15.00
2 x 2 way + £10.00

DIL HEADERS
Solder Type IDC Type
14 pin £25.00
25 pin £50.00
36 pin £50.00

TEST CLIPS
40-pin £50
510 Conn £60

UV ERASERS
UV18 up to 6 Eproms £47.50
UV100 with Timer £60
UV140 up to 14 Eproms £75
UV141 with Timer £80

All erasers are fitted with UV protective glasses and safety interlocks.

WIRELESS WORLD PROJECTS
Semiconductors Inc.
1,2,3 Transistors, Displays, Connectors and Sockets for most projects are stocked by us.

PROJECT EXECUTION PROGRAMMER Type P8000
It will blank check, copy and verify up to 8 Eproms at a time.
Eprom types 2716 to 27128 can be selected by a single rotary switch.
£695 + £6 carriage.

UV PARTS SUPPLIERS

BOOKS
(No VAT p&p £1)
CRT Controller Manual £8.50
Programming the Z80 £11.50
280 Microcircuit Handbook £6.95
Programming the 6502 £10.25
6502 Assembler £12.10
6502 Applications £10.20
6502 Software Design Kit £9.05
6502 Games £10.25
Large selection of databooks, interfacing books, books on BBC etc in stock.
Ask for our list.

OFFICIAL DEALER
Please phone for availability.

BUSINESS, EDUCATION AND FUN SOFTWARE IN STOCK.

TELEFAX ADAPTOR £195
WORD_PROCESSOR 'VIEW'
16K ROM £52

WIRELESS WORLD OCTOBER 1983

www.americanradiohistory.com
6010 & 7030 Models

**Accurate Digital Multimeters at Exceptional Prices**

**Features:**
- 10% off any model
- Battery: Single 9V dry cell; Life: 200 hrs
- Dimensions: 170 x 85 x 38mm
- Weight: 400g incl. battery
- Mode Select: Push Button
- AC/DC Current: 200mA to 10A
- AC Voltage: 200V to 800V
- DC Voltage: 200mV to 100V
- Resistance: 200Ω to 20MΩ
- Input Impedance: 10MΩ
- Display: 1½ Digit 0.6mm LED
- Overload Protection: All ranges

**ARMMON ELECTRONICS LTD.**
Cottrell House, 33-64 Wembly Hill Road
Wembley, Middlesex HA8 8EH, England
Telephone: 01-923 4211 (3 lines)
TELEX No. 32935

**NEW**

**HM105 8.95**

**Quantity discount for trade on application**
Add 15% to your order for V.A.T. Payment by cheque with order

**OTHER features:** Auto polarity, auto zero, battery low indicator. ABS plastic case with 5th stand, battery and test leads included, optional carrying case.

**28 RANGES, EACH WITH FULL OVERLOAD PROTECTION**


**2N6101 6.85**

**w w w . a m e r i c a n r a d i o h i s t o r y . c o m**

**The smaller the cable... the greater the hazard.**

**New Mini Strippax from Klippon**

Stripping small cable with anything but the correct tool can cause unseen damage. and a damaged conductor can be a hidden hazard.

The new Mini Strippax with built-in cutter, provides a perfect finish with one simple stripping action. Cuts and strips cables from 0.08mm to 1.0mm

So don't rule your reputation on chance. Get the right tool for the job.

**Klippon**
Klippon Electron Ltd. Power Station Road
Sheerness, Kent ME12 3AB
Telephone: (0755) 663322 Telex 96176

**WW - 069 FOR FURTHER DETAILS**

**WWW - 067 FOR FURTHER DETAILS**
Thandar's comprehensive range of professional specification instruments now includes 8 and 16 channel logic analysers to expand your test capabilities. Both analysers feature DC to 20MHz sampling rates, synchronous or asynchronous clocking and 16ns glitch capture or latch modes. There is also a powerful compound trigger delay by event and/or clock. Two level triggering on TA2160, selectable trigger location, variable trigger width and clock quality and arm level are available.

If threshold, both have a composite video output to drive an external display or video printer and allow disassembly for component monitoring. Both are available for serial data capture and hard copy record points.

TA2080 (8 CHANNEL) Full system information always shown in display; 8 bit data and reference memories, 256 bytes deep; 23 bit triggering (8 data bits, 15 trigger bits); Timing display shows all 256 bytes of the timing diagram format with x2, x4, x8 all expansions available. State display shows 24 sequential bytes in each binary plus ASCII or hex plus octal plus ASCII; Automatic or manual compare between trigger points and reference memories for equality or inequality.

TA2160 (16 CHANNEL) 16 bit data and reference memories, 256 samples deep; Both data and reference memories configurable as 16 bit x 256 samples, 8 bit x 512 samples, or 2 x 8 bit x 256 samples, ±3 bit triggering (16 data, 12 trigger and 6 qualifiers), independent clocks and clock data latches in x 8 bit modes; Sample or latch assignable on a per pod basis; Timing display shows 256 bytes of any 8 channels in timing diagram format with x2, x4, x8 expansions available; State display shows 16 sequential store locations of any 4 channels in 4 columns; each memory can be displayed in either binary, hex, dec, decimal, ASCII or EBCDIC; Automatic or manual compare between any part of any 2 memories for equality or inequality. TTL level variable threshold assignable on a per pod basis; RS232 interface permits dumping and loading of reference memories and all system parameters.

Send for our complete catalogue and price list.
Thandar Electronics Ltd, London, S. Ives, Huntingdon, Cambridgeshire, PE17 4JU.
Telephone (0480) 64646. Telex 32250.

**Thandar**
**ELECTRONICS LIMITED**
**THE LOGICAL CHOICE**

**WWW - 055 FOR FURTHER DETAILS**

---

**LINSLEY-HOOD 100 WATT POWER AMPLIFIER**

Our compact kit for this brilliant new design is the same size as our Linsley-Hood Cassette Recorder 2. Kit includes all parts for two power amplifiers with large heat sinks, high power isolation and speaker protection circuit. Total cost of all kits is £114.46 inc. VAT and post.

**DOLBY 'B' NOISE REDUCTION IC LM1011**

Marvellous opportunity for home experimenters, build your own noise reduction system. Supplied complete with circuit showing typical application. Absolute knockout price only £3.50 for two inc. VAT and post.

**COMPLETE STEREO CASSETTE DECK**

Brand new high quality top-loading Cassette Deck complete with Record/Play electronics. Supplied with connection data and circuit diagram. Automatic chrome/ferric switching. Only £18.34 inc. VAT and post.

**COMPLETE STEREO TUNER MODULE**

Three band LW/MW/FM Stereo Tuner fully assembled on PCB. 185 x 85 mm. Supplied with Ferrite rod aerial and switch fully wired. Facility provided to drive tuning meter and stereo led. Only needs 12v DC supply. FM sensitivity 2.5uV. Price only £7.99 inc. VAT and post.

**ALPS FG17 FM FRONT END**

Beautiful, precise made High Quality variable capacitor tuned FM Front End with Dual gate MosFet. The tuning capacitor also has 2mR Gands and built-in 3.7 reduction gear. Cover full FM range of 87 to 109 MHz. Supply needed is 12v at only 30mA Max. Inputs are provided for AOC and AFC signals. These have recently been on special offer from another supplier at £4 plus VAT O/R. This is only £3.99 including VAT and postage! Circuit is required 35p.

---

**HIGH QUALITY REPLACEMENT CASSETTE HEADS**

Do you have tape drive troubles? A worn head could be the problem. Finding one of our replacement heads could restore performance so much better than what you thought was possible. We have three different types to suit your needs; higher, normal and the lower grades which may be what your current head came with. The following is a list of our most popular heads, all are suitable for use on Dolby machines and are ex-stock.

**HC20 Ferrnlnalloy Stereo Head**

This is the standard head fitted as standard on Dolby machines. Only £3.80 plus VAT and 50p postage. A hard-wearing, high-performance head with metal capability.

**HC10 Ferrnlnalloy Super Head**

The best head we can find. Longer life than Fermlnloy, higher output than Ferrnlnloy, fantastic frequency response. Only £9.20

**HOSY1 4-Track Head**

For auto-reverse or quadrophonic use. Full specification record and playback head. Only £7.40

---

**HARD TRIPLE-PORE TEST CASSETTE TC1**

One inexpensive test cassette enables you to set up your VU level, head azimuth and tape speed. Invaluable when fitting new heads. Only £2.86 plus VAT and 50p postage.

**TAPE HEAD DE-MAGNETISER**

Handy size mains operated unit prevents build up of residual head magnetisation causing noise on playback.

---

**OVERSEAS**

Orders under £10 - 50p postage. Over £10 - £1.50

**PLEASE ADD VAT TO ALL PRICES**

---

**WIRELESS WORLD OCTOBER 1983**

93

---

[www.americanradiohistory.com](http://www.americanradiohistory.com)
Dwight Cavendish now have available a 7 channel Video Distribution Amplifier plus twin channel sound (stereo) for £189.

This rugged, high performance device comes complete in a 1U high 19" rack mount unit. Many of the latest design features are incorporated including vertical interval switching, switchable balf-balun input options on audio, on-board switchable equalisation etc.

For further information contact Dwight Cavendish Sales

Dwight Cavendish
Paxton Hall, Gt. North Road, Little Paxton, Huntingdon, Cambridgeshire, PE19 4EL
Telephone: 0480 215778 215753

W W - 604 FOR FURTHER DETAILS

MASTERING MICROPROCESSOR BEGIN WITH LS6802

LS6802 is a complete learning system to master microprocessor hardware and software. It is based on the 6802 CPU, an improved version of the renowned 6800 and is a good starting point to master the varieties of 6800 family microprocessors so widely used in industry.

Its features include:
2K monitor program with 20 editing, debugging functions; 2K RAM, spare socket for 2K RAM or 4K EPROM; built-in breadboarding system for hardware experiments; speaker, cassette tape interface; 16 programmable I/O lines (6821 PIA); 3 user keys; the full capabilities of 6802 CPU and an AC/DC adaptor to power the LS. An ideal tool for learning, teaching, experimenting and prototyping at only £109.00.

Distributors invited

Binary System, Maxwell Road, P.O. Box 1583
Singapore 9031, Republic of Singapore

Send me... units) of LS6802 at £109 each. Which will be paid for on receipt of invoice by International Money Order/ Bankdraft/Visa/Master Card/American Express.

There will be a delivery period of six weeks.

Name...................................................
Signature...........................................
Address................................................

94 WIRELESS WORLD OCTOBER 1983
AF & RF MICROVOLTMMETERS

LEVELL A C MICROVOLTMMETERS AND BROADBAND VOLTMETERS are part of our comprehensive range of test and measuring instruments. They are housed in robust steel cases and are powered by long life batteries. These voltmeters give accurate readings over a wide range of frequencies. Mains power units and leather carrying cases are optional extras.

A.C. MICROVOLTMMETERS

| VOLTAGE & dB RANGES | 15uV, 50uV, 150uV ... 500V fsd. | type | £140
| Acc. ±1% ±1% fsd ±1µV at 1kHz. | TM3A |
| Scale : 20dB/6dB ref. 1mW/600Ω. | |

RESPONSE

| ±3dB from 1Hz to 3VHz. | type | £156
| ±0.3dB from 4Hz to 1MHz above 500µV | TM3B |
| TM38 filter switch; LF cut 10Hz. | |
| HF cut 10kHz, 10kHz or 350Hz. | |

INPUT IMPEDANCE

| Above 50mV: 10Ω < 20Ω | On 50uV to 50mV: >5Ω <50Ω. |

BROADBAND VOLTMETERS

L.F. RANGES

| As A.C. Microvoltmeters | type | £220
| 1mV, 3mV, 10mV ... 3V fsd. | TM6A |
| Acc. ±2% ±1% fsd at 30MHz. | |
| ±50... -40 +20dB | |
| Scale : 10dB/3dB ref. 1mW/50Ω. | |

H.F. VOLTAGE & dB RANGES

| +3dB from 300kHz to 400MHz. | type | £240 |
| ±0.7dB from 1MHz to 50MHz. | TM6B |

Send for data covering our range of instruments. Prices are plus carriage, packing and VAT.

LEVELL ELECTRONICS LTD.

Moxon Street, High Barnet, Herts. EN5 5SD

Tel: 01-449 5028/440 8686

WW - 013 FOR FURTHER DETAILS

If you missed out on Breadboard '79, '80, '81 and '82 . . .

Now's the time to catch up with THE PREMIER SHOW FOR THE ELECTRONICS ENTHUSIAST!

CUNARD INTERNATIONAL EXHIBITION CENTRE, CUNARD HOTEL, HAMMERSMITH, LONDON W6.

Friday November 25th 10am-6pm
Saturday November 26th 10am-6pm
Sunday November 27th 10am-5pm

Improved Venue

Offering improved facilities to the visitor, including car parking and ease of access by rail, tube and car, in a modern attractive setting.

Holiday Weekend

Why not bring your partner to the show and enjoy a weekend in London? A complete hotel package is available to our visitors to the exhibition with all inclusive rail tickets. Send now for details of what we, the organisers, can offer you.

Write to:
Breadboard '83
ASP Exhibitions
145 Charing Cross Road
London WC2H 0EE

This year's features include:

- Computer controlled model railway competition (send off for entry form now)
- Kits components and tools to build all sorts of projects
- Robotic display
- Components and tools at bargain prices
- Technical advice on electronics projects and Ham Radio technique
- Computer Corner - Try before you buy
- Lectures by professionals covering aspects of electronics and computing
- Holography and Producing Printed Circuit Boards
- Pick of the projects - Demonstration of the best from ELECTRONICS TODAY INTERNATIONAL, HOBBY ELECTRONICS AND ELECTRONICS DIGEST.
To obtain further details of any of the coded items mentioned in the editorial or advertisement pages of this issue, please complete one or more of the attached cards entering the reference number(s). Your enquiries will be passed on to the manufacturers concerned and you can expect to hear from them direct in due course. Cards posted from abroad require a stamp.

These service cards are valid for six months from the date of publication.

Please use capital letters.

If you are way down on the circulation list, you may not be getting the information you require from the journal as soon as you should. Why not have your own copy?

To start a one year's subscription you may apply direct to us by using the card at the bottom of this page. You may also apply to the agent nearest to you: their address is shown below.

OVERSEAS SUBSCRIPTION AGENTS

Australia: Gordon & Gath (Australasia) Ltd, 389 Lonsdale Street, Melbourne 3000, Victoria.

Belgium: Agence et Messageries de la Presse, 1 Rue de la Petite-ILE, Brussels 7.

Canada: Davis Circulation Agency, 153 St. Clair Avenue West, Toronto 189, Ontario.

Cyprus: General Press Agency Ltd, 131 Piso- dounou Street, P.O. Box 4528, Nicosia.

Denmark: Dansk Blandedistribution, Hovedkreditgætte, Dk. 1123 Kopenhagen.

Finland: Reunia OY, Konnusveentie 2, 01640 Vanta 04, Finland.

France: Daxion-France S.A., B.P.40, F-91121, Palaiseau.

Germany: W. E. Saabach GmbH, 5 Kaul 1, Follerstrasse 2.

Greece: Hellenic Distribution Agency, P.O. Box 315, Syngrou Avenue, Nea Smyriv, Greece.

Holland: Van Ditmar N.V., Oostelijke Handelskade 11, Amsterdam 1004.

India: International Book House, Indian Mercantile, Manson Ext, Madina, 49, Road Bombay 1.


Israel: Steinmuller's Agency Ltd, Citrus House, P.O. Box 829, Tel Aviv.

Italy: Intermontinational s.a.s. Via Vassallini 9, 20124 Milano.

Japan: Western Publica- tions Distribution Agency, 194 Shinkuju-Ku, Tokyo 150.

Lebanon: Levanti Distribu- tions Co., P.O. Box 1181, Atheneum Street, Hamra, Beirut.


Malti: W. H. Smith Continental Ltd, 18a Scotts Street, Valletta.

New Zealand: Gordon & Gath (New Zealand) Ltd, 102 Auckland Road, Wellington 2.

Nigeria: Daily Times of Nigeria Ltd, 3 Kekewa Street, P.O. Box 139, Lagos.

Norway: A/S Narvassan Kioskompani, Bringnadavenes vei 2, Oslo 0.

Portugal: Livraria Bertrand S.A. 1, Avenida 37, Amadora.

South Africa: Central News Agency Ltd, P.O. Box 1033, Johannesburg.

Spain: Comercial Athenea S.A., Consolata de Ciento, 130-130 Barcelona 16.


Switzerland: Neville & Cie SA, Rue Lavri 5-7, CH-1211 Geneve 1.

United Kingdom: Gordon & Gath (Great Britain & Ireland) Ltd, 170 Nashi Kabu, Tokyo 190.

The information is valid for six months from the date of publication.

To become a subscriber to Wireless World please complete the reverse side of this form and return it with your remittance to:

Subsription Manager, Business Press International Ltd, Oakfield House, Perrymouth Road Haywards Heath, Sussex RH16 3DH

Wireless World: Subscription Order Form
Please arrange for me to receive further details of the products listed, the appropriate reference numbers of which have been entered in the space provided.

Name
Position in Company
Name of Company
Address
Telephone Number
Nature of Company/Business
No. of employees at this establishment

VALID FOR SIX MONTHS ONLY

Do not affix Postage Stamps if posted in Gt Britain, Channel Islands, N Ireland or the Isle of Man

BUSINESS REPLY SERVICE
Licence No CY258

Wireless World Subscription Order Form

UK subscription rates
1 year: £14.00
Overseas 1 year: £17.00

USA & Canada subscription rates
1 year: $44.00

Please enter my subscription to Wireless World for 1 year

I enclose remittance value...made payable to

BUSINESS PRESS INTERNATIONAL Ltd.

Name
Address

Company Registered No: 151537 (ENGLAND)
Registered Office: Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS

OVERSEAS ADVERTISEMENT AGENTS


Italy Sig. C. Epiis Easos-Kopass, S.p.a. - Servizio Esteri, Via Mantegna 6, 20154 Milan - Telephone 347051 - Telex: 37342 Kopass

Japan Mr. Inatsu, Trade Media - IBPA (Japan), 8212 Azabu Heights, 1-5-10 Roppongi, Minato-Ku, Tokyo 106 - Telephone: (03) 585-0581


Canada Colin H. MacCulloch, International Advertising Consultants Ltd., 915 Carlton Tower, 2 Carlton Street, Toronto 2 - Telephone (416) 364 2269

*Also subscription agents
AN OSCILLOSCOPE &
FUNCTION GENERATOR
IN ONE PRECISION INSTRUMENT
FOR JUST £295 plus VAT

You can now buy a dual trace oscilloscope and function generator and have it delivered anywhere in the UK mainland for less than £300.
Or, if you have a Scopex dual trace scope, the function generator can be supplied separately for you to fit.
Only Scopex offers this total add-on compatibility.

SCOPEXTEA FG Combined oscilloscope and function generator
£295 plus VAT.

FG4, FG14/25 Function generator for mounting on Scopex dual trace scopes £69 plus VAT.

FG1 stand-alone function generator in instrument case £79 plus VAT.

Scopex Instruments Limited,Pixmore House, Pixmore Avenue, Letchworth, Herts SG6 1HZ
Telephone (04626) 72771

WW - 061 FOR FURTHER DETAILS

Largest range?
Superior paint finish?
Best ex-stock delivery?

Familiar claims? Study the Sarel range and decide for yourself. You’ll find answers to all your own questions on enclosures — small, large, metal, plastic, glass-fibre reinforced polyester, monobloc, modular, with every imaginable accessory from gaskets to swing racks, chassis to brackets, locks, handles, glands and ventilators.

Sarel’s range answers all your questions. No fuss, no bother, no compromise. Contact us for a quotation.

Send me my free copy of the new Sarel Electric catalogue, fast!

Name
Position
Company
Address
Telephone

WW10/83

WW - 070 FOR FURTHER DETAILS
ELECTRIC SHOCK

2 WAYS TO RECOVERY

Display the ELECTRICAL REVIEW shock first aid chart (356 x 508mm) supplied in thousands to destinations world-wide. Recent deliveries include consignments to Bermuda, Egypt, Kenya, Oman, Pakistan, W. Germany, apart from UK commercial and industrial, educational, central government, local authorities’ orders.

Carry the ELECTRICAL REVIEW pocket-size shock card (92 x 126mm) designed to help safety and training officers, medical and welfare personnel. Supplied to the Royal Navy, other Defence establishments, lighthouses, North Sea gas terminals, nuclear and hydro-electric power stations, docks, breweries, road and water authorities; enterprises in Ghana, Ireland, Kenya, Kuwait and South Africa as well as UK commercial, educational and industrial organisations.

BE READY TO SAVE LIFE.
SOMEONE MIGHT SAVE YOU.

To Electrical-Electronic Press,
General Sales Department,
Room 108,
Quadrant House,
Sutton. SM2 5AS,
Surrey,
England.

Company registered in England
No 151537. Registered Office
Quadrant House, The Quadrant,
Sutton, Surrey SM2 5AS.

Please send ... ... copy/copies as
dicated.
Pocket Card @ 70p each
Paper Chart @ £1.00 each Post
Card Chart @ £2.00 each free in
Plastic Chart @ £3.00 each UK
Cheque/p.o. enclosed for £... payable to
BUSINESS PRESS INTERNATIONAL Ltd.
(Overseas surface and air mail rates
supplied on application. Tel. 01-661
8668; Telex 892084 BISPRS G.)

Name ........................................................
Address ....................................................

WIRELESS WORLD OCTOBER 1983

www.americanradiohistory.com
**WIRELESS WORLD OCTOBER**

**HARD DISK DRIVES**

Carriage. 13A £4.50. 2B/C baud async MODEM over may be and working for Join MUFFIN -CENTAUR standard Current cost £32.00.

**8” FLOPPY DISK DRIVES**

Unbelievable value the DRE 7100 8” floppy disk drive is an advanced technology to give you 100% brand compatibility with most drives available today. The original Generic PRICE and manufacturing quality! The 7100 single sided drive accepts hard or soft sectored IBM A drive settings. Formats giving a massive saving on IBM. Supplied SHUGART, BASF, SIEMENS etc. MODEMS supplied with IBM new manual and full 90 day warranty. 7100 Single sided £225.00 + Carriage and insurance price.

**DATA MEDIANS**

Join the communications revolution with our range of EX TELECOM data media. Made to most stringent spec and designed to offer long life and reliable transfer to the CCITT tone spec. With RS232 1.2v to 7.2v a 90 24v + line. Data is sold in a tested and working condition with data. Permission may be required for connection to PO lines.

**TELETYPE ASR95**

**8” WINCHESTER price SLASH**

£100 Bus 19 Mb. Sbusystem. A cancelled order and change of policy by a major British disk drive manufacturer enables us to offer you last year’s model at a price in and ready to go SUPER LOW PRICE. Our own custom controller piggy backs directly into the 100 bus and we control 2 disk drives, offering a total storage of OVER 36 Mbs! and at data transfer rates in excess of 7 MB/sec seeing is believing! Fully assembled complete with all internal BIOS etc. Save a fortune, Limited quantity only.

**RECHARGEABLE NICADS**

SAFETY 12V 12 csize nicads 16 cells displayvary equipment packaging. Good condition — easily split to single cells £8.86 + £1.90 post and packing.

**SUPER DEAL? NO! SUPER STEAL!!!**

The FABULOUS 25CPS TEC Original start.

**DATA MODEMS**

**SEMICONDUCTOR 'GRAB BAGS’**

Mixed Semis amazing value contents include transistors, digital linear IC’s, diodes, bridge rectifiers, etc. All devices guaranteed brand new full spec with manufacturer’s markings, fully guaranteed.

**TELECOMMUNICATIONS**

**CALLING DEC USERS**

Brand New and boxed RXS 11M 32 Documentary kits, fill 3 days of your life. £3.50 + £1.00 p&p. At least one £10.00 + £1.00 car. £5.50 vat on all models. DEC 11/11 DD 32x2 16 bit RMAN £95.00
disable code on £1.60 = £24.00 + £1.00 123 456 789. We reserve the right to change prices and specifications without notice. Trade, Bulk and Export enquiries welcomed.

**DISPLAY ELECTRONICS**

32 Biggin Way, Upper Norwood, London SE13 3XF
Telephone: 01-679 4414 Telex 27924

**COMPUTER WAREHOUSE**

The ALADDIN’S CAGE OF COMPUTER AND ELECTRONIC EQUIPMENT

**COOLING MASTER**

Keep your hardware cool with our range of BRAND NEW professional fans. ETR 50x50 £1.60. 2B/C 62 x 22 + 25 mm. MARSHALL 3" fan complete with finger guard £9.95. MDL J.-B-3 at 25 x 25 compact very quiet running £20 operation. NEW £6.95. Bankers £5.00. Miniature reverse blower. Uses a brushless sub-assembly to ensure almost silent running and guaranteed 10,000 hour life. Ideal for good cooling. Current cost £23.00. OUR PRICE ONLY £15.00 with VAT.

**MUFFIN CENTAUR**

DE0420 / DC0011 20 x 10 at £26.95, or at £49.95 NEW DE0420 £0.95 110v/230v. Other fans EX STOCK, ask for Details. Post & Packing on all fans £1.50.

**DISTEF**

All in one quality computer cabinet with integrated switch. Designed for MILITARY and twin fan cooling. Originally made for the famous DEC PDP8 computer. Protects it from dust, heat and excess hours per day the PSU is fully screened and will deliver a massive +5v at 17 amps and -12v at 5 amps. The complete unit is fully enclosed with a good quality beaded grommet and internal fans. LEDS mounted on all front panel, rear cable entries, etc. Units are in good but vibrating condition for £240.00 on full complete with circuit and tech manual. £49.95 + Carr. Dim: 19” wide 18” deep 10.5” high £59.50. Also available LESS PSU, with FANS etc. Internal dim. 19” wide 16.5” deep 10.5” £49.50. Bargain and insurance price £39.50.

**VIDEO MONITORS**

12” Cased. Made by the British KGM Co. Designed for continuous use as a TV display terminal. BRASS LEAF attractive brushed aluminum case with ON/OFF switch. £175.00. 20” fibre glass PCB displays - which hinge out for ease of removal. Many controls for linearity etc. The monitor accepts standard 75 ohm composite video signal via 50233i socket on rear panel. Bandwidth of the unit is excellent and the screen image is of high end quality with most modern day monitors switched off. Although unguaranteed all monitors are tested prior to dispatch. Supplied with 20” fibreglass covers. Price approx. £14.1” wide by 11” deep. Supplied complete with all cables and manual. £129.95 + £20.00 VAT optional accessories:

- £49.95 screen cover
- £5.00 leads and £1.00 VAT

**Daisy Front load**

Transmission inc. tax £140.00

**SHOFTY 2.** The amazing SHOFTY 2. The complete: "Toolkit" for the open heart surgery surgeon. Copies, and ready to go.

**TELEPHONE**

From £119 + VAT + CAR.

**SUPER DISKING OFFER**

**SALES OFFER**

**10” TBERMO**

**SECURITY**

**3.5” WINBLO**

£130.00 Disk drive £52.00 with BIOS etc. Save £78.00 with order.

**WINCH C/A**

£130.00 Windows C/A £35.00

**10” MEGA 85**

£175.00

**8” MEGA 85**

£95.00

**10” MEGA 85**

£67.00

**10” MEGA 85**

£49.00

**10” MEGA 85**

£49.00

**3.5” WINBLO**

£149.00

**ALL PRICES PLUS VAT**

**Display Telecommunications**

32 Biggin Way, Upper Norwood, London SE13 3XF
Telephone: 01-679 4414 Telex 27924

**WIRELESS WORLD OCTOBER 1993**

99

www.americanradiohistory.com
WIRELESS WORLD OCTOBER 1983

Advertisements accepted up to 12 noon Thursday, October 4th, for November issue, subject to space available.

DISPLAYED APPOINTMENTS VACANT: £17 per single col. centimetre (min. 3cm).
LINE advertisements (run on): £3.50 per line, minimum £25 (prepayable).
BOX NUMBERS: £5 extra. ( Replies should be addressed to the Box Number in the advertisement, c/o Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS).
PHONE: JAN FAUX, 01-661 3033 (DIRECT LINE)
Cheques and Postal Orders payable to BUSINESS PRESS INTERNATIONAL LTD. and crossed.

ALWAYS AHEAD WITH THE BEST!
£7,000-£20,000
★ Where does your interest lie: Communications; Computers; Weapons; Radar; Sonar; Data-Comms; Signal Processing; Medical; Telemetry; Simulation; Satcom; Local Area Nets; ATE?
★ Experienced in: Microprocessor Hardware or Software; Digital and analogue circuity; RF and Microwave techniques?
★ There are hundreds of opportunities in: Design; Test; Sales and Service for Engineers and Managers
★ Act now: Just dial 100 and ask for FREEPHONE JOBLINE or send your C.V. (no stamp needed) to:
ELECTRONIC COMPUTER AND MANAGEMENT APPOINTMENTS LIMITED
Freepost, Barkway, Royston, Herts SG8 8BR

THE UNIVERSITY OF SHEFFIELD
Audio Visual & Television Centre
SENIOR TELEVISION ENGINEER
Applications are invited for the above post. The successful applicant will take charge of all engineering aspects of the Centre's work, including planning and development, studio and mobile operations and supervision of the technical staff. Applicants should preferably be graduates or have comparable qualifications in electronic engineering and wide experience in broadcasting, industrial or educational television. Initial salary on Grade II for Other Related Staff £11,160; £14,125 a year according to qualifications and experience. Tenable for two years in the first instance. Particulars from the Registrar and Secretary (Staffing), the University, Sheffield S10 2TN to whom applications (15 copies), including the names of three referees, should be sent by 30 September 1983. Quote ref. R096/SH.

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
01-637 5551 or 01-636 9659
(24 hours)
Or if you prefer send a FULL CV to:
CAPITAL APPOINTMENTS LTD
29-30 WINDMILL STREET, LONDON W1P 1HG

SURREY COUNTY COUNCIL
Guildford County College of Technology
invite applications for the following vacancy:
Department of Science and Electrotechnology
SENIOR TECHNICIAN in COMPUTER TECHNOLOGY
£6,264-£7,005/£7,191-£7,896
plus £270 Surrey Allowance
Suitably qualified person required to service computer equipment, with an emphasis on microprocessor development.
Application forms and further details from the Committee Clerk, Guildford County College of Technology, Stoke Park, Guildford, Surrey GU1 1EZ, on receipt of SAE. (Tel: Guildford 31251)
Closing date: Friday 14th October 1983
(Re-advertisement)

SENIOR DEVELOPMENT ENGINEER
Location. West London
An appointment exists within a long established electronic data capture company for a senior development engineer.
The main duties associated with this appointment are:
★ Development of microprocessor based data capture equipment.
★ Development of customised interfaces.
★ Customer liaison.
The successful applicant would probably be qualified to HNC level, and have at least three years’ experience in the electronic industry, preferably in data processor type equipment, and have experience of microprocessors and data communications interfaces.
Normal large-company benefits + company car.
Salary commensurate with experience.
Apply to Box No. 2282

PHOTOSTAFF
The Photography, A.V. Film and Video Agency has vacancies for:
VIDEO ENGINEERS: To service, repair and maintain domestic, industrial and broadcast equipment. Salaries from £5,000 to £10,000+ U.K. and overseas.
RESEARCH & DEVELOPMENT: Experienced Data or HNC level Engineers. Opportunities exist for project leaders, technical assistants, etc. in electronics, electrotechnics and computing.
PHOTOSTAFF: 133 Oxford Street, London W1 Tel: 01-430 1821

WIRELESS WORLD OCTOBER 1983
Appointments

CUT THIS OUT!
Clip this advert and you can stop hunting for your next appointment. We have a wide selection of the best appointments in Digital, Analogue, HF, Microwave, Microprocessor, Computer, Data Comms and Medical Electronics and we’re here to serve your interests.
Call us now for posts in Design, Sales, Applications or Field Service, at all levels from £6,000–£16,000.

Technomark
Engineering & Technical Recruitment
11 Westbourne Grove, London W2 Tel: 01 229 9239

PLYMOUTH HEALTH AUTHORITY
Department of Medical Physics and Biomedical Engineering

ELECTRONICS TECHNICIAN
required for interesting post in medical electronics. The person appointed will be a member of a team of nine in a well-equipped and expanding Department. He/she will be responsible to a graduate electronics engineer for maintenance and development of a wide range of patient-oriented equipment situated in Hospitals and Health Centres throughout the Plymouth Health District.

Hospital experience is not essential, as further training will be given. HNC, ONC, City and Guilds Final Certificate or equivalent qualification is required. The work involves occasional travel and necessitates a current driving licence. There is a requirement to participate in a scheme to provide out of hours emergency cover. The current salary scale is £5,171 rising to £6,798.

Further information is available from Mr A. C. Dawson, Chief Technician, telephone Plymouth (0752) 834276.

Application forms are available from the Personnel Officer, Unit Personnel Dept. PGH No. 1, Belvedere, Greenbank Road, Plymouth PL4 7JN. Please enclose a stamped addressed envelope.

Closing date for return of application forms: 21st October, 1983.

Proposal Support Manager
£10,000 + generous bonus
Surrey

Granger Associates are a leading company in the design, manufacture and marketing of communications equipment for overseas markets. Our products are marketed extensively to both major industrial nations and to developing countries and we are now looking to strengthen further our commercial expertise by appointing a Proposal Support Manager.

Based at our Sales Headquarters in Weybridge, Surrey, you’ll provide vital support to the international sales team in the preparation of systems and proposal documentation for all our communications products marketed to Europe, Africa and the Middle East, with particular emphasis being placed upon HF systems.

In addition to sound relevant experience gained within an electronics engineering environment, you will need to be a good communicator at all levels with the ability to interpret Government, Military and commercial specifications, work effectively under pressure. Knowledge of a foreign language would be a distinct advantage.

Please write in the first instance with full c.v. to Mrs L. Tabb, Granger Associates Ltd., 1 Brooklands Road, Weybridge, Surrey KT13 0SD.

LABORATORY TECHNICIANS
We have vacancies for Laboratory Technicians at senior and junior level at our Equipment Department, based at Chiswick. Duties include the testing of newly manufactured broadcast equipment and involve work on sound, television, radio-frequency and digital equipment.

Technicians should possess, or be studying for a TEC or HTEC certificate in electronics, and have at least one year’s relevant experience. Salary is in the range £6346 to £7615.

Applicants with less experience may be considered for junior posts at a lower salary.

Requests for application forms to Engineering Recruitment, BBC, P.O. Box No. 2BL, London W1A 2BL. Quote reference 83.E.4099/WW.

BBC
We are an equal opportunities employer
Hanslope in Buckinghamshire is, we admit, an unlikely backdrop for high technology research and development.

Yet a mere stone's throw away from this delightful rural village the men and women at HM Government Communications Centre are applying the very latest ideas in electronics to the development of sophisticated communications systems and installations, designed to meet special Government needs both at home and overseas.

For graduates and near graduates with real ability and a genuine passion for creative electronics design (the kind of enthusiasm that may already have prompted you to design and build your own communications equipment), this is a superb career environment.

Technically challenging projects cover a wide range of interests including radio (HF to microwave, advanced modulation, propagation studies and micro-circuitry applications); acoustics; magnetics; signal analysis; systems engineering.

The majority of these projects are directed towards specific ends, and we have our own production facility. So, unlike many other R&D establishments, HMGCC offers you the satisfaction of seeing your work right through from conception to manufacture.

With such a broad spectrum of work and training facilities at your disposal, HMGCC is an ideal environment in which to develop the potential you've gained by studying an electronics-based course. What's more, we think you'll find the working conditions and location very much to your liking.

Please write to us for further details on the work and the remunerations offered at the Centre. As our careful selection process takes some time, it would be particularly helpful if you could detail your qualifications, your personal fields of interest and practical experience, and describe the type of working environment most suited to your career plans.

Dr. D. Orr, Recruitment Officer, HMGCC, Hanslope Park, Hanslope, Buckinghamshire MK19 7BH.

HER MAJESTY'S GOVERNMENT COMMUNICATIONS CENTRE
HANSLOPE PARK
Appointments

Test & Calibration Engineers

Having introduced an extended new product range, many of which are microprocessor based, Marconi Instruments has once again confirmed itself as Europe’s leading manufacturer of sophisticated test and measurement systems. Our products are selling throughout the world and we are naturally developing further new and innovative designs.

A key role in our organisation is that of our Luton based Service Division, where a group of Technicians satisfy a very wide range of customer needs in the repair and calibration of test equipment.

When you join our team you will quickly become individually responsible for work assignments involving many different kinds of propriety products.

Prospects are excellent. The Division is part of a large company with its main Instrument Design/Manufacturing Base at St. Albans, a Microwave Plant at Stevenage and a further substantial Design Manufacturing Group at Donibristle in Scotland. The Company is proud of its policy of promoting men and women from within, as future Salesmen, Managers and Engineers.

Salaries, which are dependent upon experience and ability are excellent and regular overtime is normally available. Progress for competent engineers and technicians can be rapid. Relocation assistance is available in approved cases. Special consideration is given to ‘ex-forces’ personnel.

We would like to hear from you. Cut out the coupon and send it to John Proctor, Recruitment Manager, Marconi Instruments Limited, FREEPOST, St. Albans AL4 0BR. Tel: (0727) 59292.

Name
Address
Tel. No.
Years Experience
Present Salary: £6,000 £7,000 £8,000 £9,000 £10,000
Qualifications
Present Job

ELECTRONIC MAINTENANCE ENGINEER

Yorkshire Television, one of the five major Independent Television companies, has established a worldwide reputation for producing quality award-winning programmes. Each week, over 100 hours of programmes are transmitted to 6 million viewers in Yorkshire, Lincolnshire and Derbyshire.

The Industry Code of Practice sets exacting quality standards for broadcast television. To meet these stringent performance parameters, the Electronic Maintenance team follows a comprehensive policy of routine maintenance, inspection, examination and measurement of the complex electronic systems in the Leeds studio facility.

Through internal promotion, an opportunity has arisen to join the Electronic Maintenance team. Applicants should be qualified to a minimum of HNC level or equivalent in Electronic Engineering. Experience of working, using advanced test equipment, on broadcast electronic systems, either with a television company or an equipment manufacturer is essential.

Starting salary will be in a range up to £12,500 depending on qualifications and experience, plus overtime payments.

Applications in writing to:
The Personnel Officer (Recruitment)
Yorkshire Television Limited
The Television Centre, Leeds LS3 1JS

Yorkshire Television

Sartorius Instruments is a world leader in electronic weighing in the analytical, research, quality assurance and allied industries. The product range is expanding further into the industrial systems market and personnel are required to supplement our already established Field Service team.

Successful applications will service and install our computerised systems nationwide. Primary responsibilities will be problem solving of Sartorius equipment and liaison production and the customer.

Education to a suitable allied qualification i.e. C&G/TEC - Electronics is preferred. A successful trouble shooting ability in electronics is essential with a knowledge of basic computer programming.

On appointment you will spend three weeks training in our workshop in Belmont followed by suitable training at our parent company factory in West Germany, when available. Initially the job will require a large proportion of time to be spent at our in-house service centre at Belmont, Surrey.

Candidates must be in possession of a current driving licence and be prepared for nationwide travel. A company car is provided.

In addition to the above vacancies technicians are required for certain areas on general electronic and mechanical balance maintenance.

If you would like to receive more information or apply for a position, please write giving brief career details to the Service Co-ordinator, Sartorius Instruments Limited, 18 Avenue Road, Belmont, Surrey.

WIRELESS WORLD OCTOBER 1983
Television Recording requires Electronics Engineers to train in Broadcast Engineering, to support an expanding Video Tape and Telecine Operation, which includes complex digital and analogue equipment.

Applicants need not initially possess an in-depth knowledge of Television Engineering, as full training will be given, but previous academic training must be supported by enthusiasm for practical engineering.

After training, applicants will progress to work involving all aspects of Television Recording, including in-depth servicing, acceptance of equipment, design of modifications, and technical investigations.

These challenging posts offer excellent promotional prospects for the self-motivated and committed engineer capable of working at the forefront of today's technology.

Salaries range from £8,129 to £9,200—this includes an allowance for shift working. A higher salary will be considered in exceptional circumstances.

Qualifications required are, a Degree in Engineering, HND, HNC, Full C & G.

For further information please write, with details of your academic and work experience, to Bob Neal, BBC, P.O. Box 2 BL, London W1A 2BL.

Please quote ref: 83.E.4055.

We are an equal opportunities employer.
In "Survivability" technology MEL, the Electronic Systems Development Division of the Philips U.K. Group of Companies, have been pioneers for over 30 years. Since the earliest days of Electronic Warfare, we have been applying our technical expertise and in-depth understanding of military and naval needs to the development of systems which detect, analyse and counter enemy threats. Systems which include ESM, ECM and ECCM that are more than a match for the growing sophistication of land-based, airborne or shipborne radar and air or surface launched homing missiles.

A key in-house consultancy and design service is that of the Antennae Design Group who ensure the application of the most advanced technology in the design, production and utilisation of antennae systems for many of our projects.

Applicants for the position of Head of this key activity must offer an appropriate professional engineering background and proven ability in technical leadership at least to the level of 2 i/c within a similar activity. The successful candidate will report directly to the Technical Manager and will carry "bottom line" responsibility for the performance of the Group.

Salary and other conditions will be attractive. Assistance with relocation is available, if required. Please write, in full confidence, quoting reference WW9 to:
Mr. L. B. Staunton, Personnel Manager, MEL, Manor Royal, Crawley, Sussex.
CUSTOMER ENGINEER
North London-based to £9,100 + car + extensive benefits

Do you have at least a couple of years' electronics field service experience backed by a relevant HNC (or equivalent)? If so, you could be just the person we seek to service our sophisticated range of medical electronic equipment in the North London area.

As the dominant leader in the UK instrumentation market, we can offer you a comprehensive programme of induction and on-going training. There are outstanding career development prospects in this very successful high-technology company. An attractive salary is backed by profit-sharing and a share-purchase scheme amongst the wide range of company benefits.

Aged at least in your mid-20s, and preferably living on or within reach of the territory, you must have the strong personal presence to succeed in a demanding customer-contact environment in addition to a high level of technical capability. Previous experience of hospital markets and equipment, whilst an advantage, is not essential.

Move up to a more satisfying - and more rewarding - field service challenge with the top name in electronic measurement systems. Call Andrew Webb for more information and an application form on 0544 773100. Or write to him enclosing your full personal and career details at Hewlett-Packard Limited, Nine Mile Ride, Easthampstead, Wokingham, Berkshire RG11 3LL.

World Leading Telecoms Products
RF ENGINEERING

£12,000 to £15,000 Home Counties

Our client has precipitated many firsts in the history of communications technology and currently offers the most advanced business communications systems available in the market. The need to stay ahead in a fast moving technological world demands the highest calibre of engineers available, coupled with extensive use of the latest design aids. The current design of the next generation system has created the opportunity for a Project Engineer and a Senior Engineer to control the complete engineering aspect of this project.

The ideal candidates will be:
- qualified to degree or equivalent in electronics or telecommunications
- experienced in analog design up to and including VHF
- currently employed within radio or communications related industries

The responsibilities range from involvement in the initial design of specifications, through all the trouble-shooting and problem solving aspects of the concept to prototype building and successful quantity production.

These opportunities offer a dedicated professional environment with an unrivalled range of support resources throughout the group. Career development is excellent within one of the Company’s most successful and fastest expanding departments. The complete package, which will include relocation expenses where appropriate, is highly attractive to the successful candidate.

For an initial and confidential discussion please call Bob Archibold on Newbury (0635) 33445 quoting reference D/111 or write in strict confidence to:

ARCHIBOLD RAE CONSULTANTS LIMITED,
(High Technology Search & Selection),
7, London Road, Newbury, Berkshire RG13 1JL.
Tel: Newbury (0635) 33445.
THE HUNT IS ON FOR ELECTRONICS ENGINEERS WHO HAVE SET THEIR SIGHTS HIGH

The current Jaguar cars represent the epitome of mechanical engineering excellence, but to maintain this lead through the remainder of this century will require a complementary standard in vehicle electronics. We are therefore seeking to recruit a specialist electronics team whose brief will be to identify and solve problems in the application of microprocessors and computers to cars from system design through to manufacture and service.

The formal qualifications sought will be a degree in electronics or related subject, with both hardware and software experience. Applications from multi-disciplinary engineers who have experience in other relevant areas such as engines, instrumentation, transducers, CAD, reliability engineering or computer modelling will be viewed with particular favour.

The salary and benefits package including relocation where appropriate, reflects the key nature of these positions.

To put your career on target write in confidence giving full career details and current salary to:

A. R. Chapman
Manager, Organisation & Personnel Planning
Jaguar Cars Limited
Browns Lane, Allesley, Coventry CV5 9DT
We are an equal opportunity employer

THE POLYTECHNIC OF NORTH LONDON

Department of Electronic and Communications Engineering

LABORATORY TECHNICIAN Grade III (Electronics)

Applications are invited for the above post, to assist senior staff in the day-to-day running of the Department's busy laboratories.

The duties involve the construction, modification and repair of experimental chassis working from precise instructions, together with the preparation and setting-up of equipment for class practicals. Some experience with the use and maintenance of oscilloscopes, signal generators and power supplies would also be an advantage.

Qualifications:
OND, ONC, two A levels or Ordinary City and Guilds or equivalent, with three to five years' relevant experience (including training period).

Salary scale: £5,151-£6,036 plus £1,220 London Weighting.

Application forms and further details from Mr. E. W. Bowman, Departmental Superintendent, Department of Electronic and Communications Engineering, The Polytechnic of North London, Holloway Road N7 8DB.

Closing date for receipt of applications: October 7, 1983.

INSTALLATION ENGINEER

Electronics engineer required to pre-assemble and install complex sound and lighting systems worldwide. Good electronics knowledge and common sense vital. Applicants should be single, in twenties, and be prepared to travel extensively. Salary up to £10,000 depending on experience.

Ring or write:
Linda Johns 01-741 7241
Bacchus International Discotheque Services
64/66 Glenthorn Road
London SW13 9JJ

GRAND OPPORTUNITY FOR LIGHTING BOFFIN

A rare, company-minded, self-motivated individual interested in working with a team of people shaping the future.

Duties will include DA of Lighting and Audio Musical Products for the music, theatre and rock 'n' roll industry, with some opportunities for design and update work.

A good working knowledge of both analogue and digital techniques is essential, particularly in lighting control applications.

PRIMA DONNAS NEED NOT APPLY

Apply in writing with c.v. and current salary directly to:

THE MANAGING DIRECTOR
ROLAND (U.K.) LIMITED
997-1001 WEST ROAD
BRENTFORD
MIDDLESEX

ELECTRONICS TECHNICIAN (Grade V)

required for Department of Biochemistry to be responsible for a wide range of equipment used in teaching and research. Good knowledge of fault finding, together with the ability to design, construct and service apparatus essential. Salary in range £6,279-£7,332 plus £1,220 per annum London Weighting.

Application form from Personnel Officer (Technical Staff FC7), University College London, Gower Street, London WC1E 6BT.

INDUSTRIAL VIDEO ENGINEER

With experience in high quality black and white video needed.

Telephone 01-900 0487

WIRELESS WORLD OCTOBER 1983
Recently awarded contracts have created a need for immediate expansion of on-site facilities and the design team. Some senior appointments have been filled from within, but there are still opportunities for Engineering Managers and Group Leaders to head up additional teams now being formed.

At Senior Engineer/Engineer levels there are several vacancies in each of the above work areas. Qualifications required are Degree/R&D/HNC in a relevant discipline, plus experience. Excellent salaries and comprehensive range of benefits are offered, together with relocation assistance if required. Please complete the coupon below and send it to:

**Jack Burnie, Marconi Space and Defence Systems, Browns Gate, The Airport, Portsmouth, Hants. Tel. Portsmouth 674019.**

(All posts are open to both male and female applicants.)

**Marconi**

**Space & Defence Systems**

---

**Classified**

**Radio & TV Electronic Servicing Instructor**

Have you thought of teaching your skill? We have a vacancy for a Radio and TV Electronic Servicing Instructor at Deptford Skills Centre.

To apply you should have a full trade training, be at least 25 years of age, and have five years' practical experience behind you.

The promotion opportunities, pensionable security and self-respect are what only a teaching training organization like ours can offer.

There is a starting salary of £7,063 rising by two annual increments to £8,510 plus £500 Outer London Weighting.

If you think you've got what it takes telephone Thirza Mathieson on 01-836 1213, ext. 443. Marconi Services Commission, Saiikirk House, 106 High Holborn, London WC1V 6PF.

---

**Electronics Engineer**

**committed to Third World Development**

To develop simple solar electric products and assist in establishing small scale manufacturing units in Batamwe.

Practical experience in design and construction of electronic devices essential.

2 year contracts including modest living allowance and flights.

**Required to work as an expatriate.**

Write for details including how c.v. and s.a.e. to International Volunteer Service, E20, 5 Nagat Road, Leicester LE1 6BL.

---

**Brighton Polytechnic**

**Learning Resources**

**Technician/Projectologist**

**£2.976-£6.135**

Technician required to assist in the audio-visual college equipment loan service to support teaching at the Moulsecoomb site. Equipment includes colour cameras, video recorders and high-quality sound and film equipment. Applicants should be familiar with audio-visual equipment of this kind, and able to work with a wide range of academic, production and engineering staff. Work will include some first line maintenance.

Further details and application forms are available from the Personnel Officer, Brighton Polytechnic, Moulsecoomb, Brighton BN2 4AT. Tel: Brighton 693665, Ext. 2536. Closing date: September 30, 1983.

---

**THE SCIENTIFIC WIRE COMPANY**

411 Lower W. London, E.17 Tel: PI 305846

---

**ILVER PLATED COPPER WIRE**

(14 & 30)

<table>
<thead>
<tr>
<th>Size</th>
<th>Awg</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.06</td>
<td>£1.75</td>
</tr>
<tr>
<td>16</td>
<td>0.075</td>
<td>£1.75</td>
</tr>
<tr>
<td>18</td>
<td>0.12</td>
<td>£1.95</td>
</tr>
<tr>
<td>20</td>
<td>0.15</td>
<td>£2.00</td>
</tr>
<tr>
<td>22</td>
<td>0.20</td>
<td>£2.30</td>
</tr>
<tr>
<td>24</td>
<td>0.25</td>
<td>£2.60</td>
</tr>
<tr>
<td>26</td>
<td>0.30</td>
<td>£2.80</td>
</tr>
<tr>
<td>28</td>
<td>0.35</td>
<td>£3.10</td>
</tr>
<tr>
<td>30</td>
<td>0.40</td>
<td>£3.40</td>
</tr>
<tr>
<td>32</td>
<td>0.45</td>
<td>£3.80</td>
</tr>
</tbody>
</table>

---

**ENAMELLED COPPER WIRE**

(14 & 30)

<table>
<thead>
<tr>
<th>Size</th>
<th>Awg</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.06</td>
<td>£1.80</td>
</tr>
<tr>
<td>16</td>
<td>0.075</td>
<td>£1.80</td>
</tr>
<tr>
<td>18</td>
<td>0.12</td>
<td>£2.10</td>
</tr>
<tr>
<td>20</td>
<td>0.15</td>
<td>£2.30</td>
</tr>
<tr>
<td>22</td>
<td>0.20</td>
<td>£2.50</td>
</tr>
<tr>
<td>24</td>
<td>0.25</td>
<td>£2.80</td>
</tr>
<tr>
<td>26</td>
<td>0.30</td>
<td>£3.10</td>
</tr>
<tr>
<td>28</td>
<td>0.35</td>
<td>£3.40</td>
</tr>
<tr>
<td>30</td>
<td>0.40</td>
<td>£3.70</td>
</tr>
<tr>
<td>32</td>
<td>0.45</td>
<td>£4.00</td>
</tr>
</tbody>
</table>

---

**COPPER WIRE**

<table>
<thead>
<tr>
<th>Size</th>
<th>Awg</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.06</td>
<td>£1.90</td>
</tr>
<tr>
<td>16</td>
<td>0.075</td>
<td>£2.00</td>
</tr>
<tr>
<td>18</td>
<td>0.12</td>
<td>£2.20</td>
</tr>
<tr>
<td>20</td>
<td>0.15</td>
<td>£2.40</td>
</tr>
<tr>
<td>22</td>
<td>0.20</td>
<td>£2.50</td>
</tr>
<tr>
<td>24</td>
<td>0.25</td>
<td>£2.80</td>
</tr>
<tr>
<td>26</td>
<td>0.30</td>
<td>£3.00</td>
</tr>
<tr>
<td>28</td>
<td>0.35</td>
<td>£3.20</td>
</tr>
<tr>
<td>30</td>
<td>0.40</td>
<td>£3.50</td>
</tr>
<tr>
<td>32</td>
<td>0.45</td>
<td>£3.80</td>
</tr>
</tbody>
</table>

---

For further details contact:

Benwick Electronics
9 Dodington Road, Benwick near March, Cambs. PE15 0UX

Telephone: Benwick (035477) 471

---

**ARTICLES FOR SALE**

**24 COLUMN PRINTER ONLY £99 EACH (Inclusive)**

Standard 4 inch 3U mounting. Inverted 4 double sized print; single 9V AC or 9V DC power supply, standard centronics interface or serial data, extends only 40mm behind panel.

For further details contact:

Benwick Electronics
9 Dodington Road, Benwick near March, Cambs. PE15 0UX

Telephone: Benwick (035477) 471

---

**BBC MICROCOMPUTER "GENLICH" BOARD**

This card enables the video outputs of the computer to be synchronised to an external video or sync pulse.

**BBC MICROCOMPUTER EQUIPMENT**

**ENCAPSULATING EQUIPMENT FOR ICs, TRANSISTORS, CAPACITORS, DECAPSULATING RELAYS, RESISTORS, ETC.**

**Wireless World October 1983**
**UNIVERSITY OF CAMBRIDGE**

School of Clinical Medicine

**SENIOR ELECTRONICS ENGINEER**

The successful candidate will be in charge of a small Electronic Workshop providing design, maintenance and repair of equipment for all departments of the Clinical School.

Applicants should have HNC/HTEC or a Degree in Electronics with several years of experience in both analogue and digital electronics. Salary on scale £7,232-£8,722. For further information contact Dr R. Hanka at 0223-358217.

Applications naming two referees should be sent by 30 September, 1983, to the Secretary of the Clinical School, Addenbrooke’s Hospital, Hills Road, Cambridge CB2 2QD.

---

**ARTICLES FOR SALE**

**QUARTZ CRYSTALS IN 24 HOURS**

ANY FREQUENCY 2-50 MHz FOR £5 inc

New fast service for C.W.O. only (state holder style).

Clock oscillators for microprocessors in stock from £9.30.

McKnight Crystal Co Ltd, Hardley Industrial Estate
Mythe, Southampton SO4 6ZY
Tel: 0703 849619

---

**TO MANUFACTURERS, WHOLESALERS, BULK BUYERS, ETC.**

**LARGE QUANTITIES OF RADIO, TV AND ELECTRONIC COMPONENTS FOR DISPOSAL**

SEMI-CONDUCTORS, all types, INTEGRATED CIRCUITS, TRANSISTORS, WINDERS & BUNDLES, RESISTORS, etc., CAPACITORS, SILICA MICA, POLYSTYRENE, C280, C296, DISC CERAMICS, PLATE CERAMICS, ELECTROLYTIC CAPACITORS, SPEAKERS, CONNECTING WIRE, CABLES, SCREENED WIRE, SCREWS, NUTS, CHOKES, TRANSFORMERS, etc. ALL AT KNOCKOUT PRICES – come and pay us a visit at ALADDIN’S CAVES. TELEPHONE: 4475 4495 2713.

BROADFORDS & SONS

21 Lodge Lane, North Finchley, London, N.12

(5 minutes from Tally Ho Corner)

---

**RAILWAY COMMUNICATION RECEIVERS**

**AT RAILWAY PLATFORMS, HOTEHS, ETC.**

FOR USE IN ALL PARTS OF THE UK. SPECIMENS AVAILABLE.

MICROMETERS, INDICATORS, ETC.

D. A. HINSON, 713, MERTON COVE, S.W.19.

---

**RACAL COMMUNICATION RECEIVERS**

**FOR USE IN ALL PARTS OF THE UK.**

SPECIMENS AVAILABLE.

D. A. HINSON, 713, MERTON COVE, S.W.19.
New Course in Telecommunications

A new three year BSc(Eng) Degree course is being launched in September 1984 by the Department of Electrical and Electronic Engineering at Queen Mary College. This course covers all important aspects of communications from microwave and optical systems to the design and use of large scale communication networks. It provides a firm foundation for a student wishing to enter any part of the telecommunications industry.

Further information from: Dr E. M. Scharf
Department of Electrical and Electronic Engineering
Queen Mary College, University of London
Mile End Road, London E1 4NS
INDEX TO ADVERTISERS

Appointments Vacant Advertisements appear on pages 101-111
THE NEW ANTEX TCSU-D
At last—a digital soldering unit
for £67.50
THE NEW ANTEX TCSU-D gives you total control
over production soldering temperatures

Again Antex research and development pays off—with this new high-value high-performance unit. It's simple design incorporates an LED display and a unique ULA integrated circuit, specially designed and produced for Antex by Ferranti. Tight temperature control can be maintained by setting the station—then removing the knob, preventing any further alteration.

For laboratory, for workshop, for production-line—TCSU-D is the station. Let it figure in your soldering specifications.

- Temperature range—ambient to 495°C.
- Working temperature reached in under 1 minute.
- Detachable sponge-tray—no drips or spillage.
- Includes the world-famous Antex iron.
- Bit temperature maintained to ±5°C.
- Conforms to BS 3456 and CEE 11.
- Zero crossing switching.

Look into the future of soldering technology—send for the TCSU-D fact-pack now.

ANTEX (Electronics) Ltd.,
Mayflower House, Plymouth, Devon. Telephone: 0752 667377 Telex: 45296

WWW.002 FOR FURTHER DETAILS
If you’re the sensitive type, check out the new ZN451 DVM.

Measuring microvolt signal levels is easy with the new ZN451 DVM 1C. It’s the first DVM that auto-zeroes external signal conditioning circuits to give full-scale readings as low as ±1.999 mV with no zero adjustment.

Two logic outputs are provided to control external analogue switches, allowing op-amps and other circuits to be put inside the auto-zero loop and have their offsets cancelled by the ZN451's digital auto-zero system.

Use the ZN451 with pressure transducers, thermocouples, strain gauges or any low output transducer.

To make it even easier there’s the ZN451 Evaluation Kit, which contains everything you need to make a 2mV DVM, available from your Ferranti distributor price £29.50 inc. VAT.

Distributors:
Celdis, Reading, Tel: 0734 585171
Farnell Electronic Comps., Leeds, Tel: 0532 636311
Intel Electronics, Henlow, Tel: 0462 812505
STC Electronic Services, Harlow, Tel: 0279 26777
Midwich Computer Co., Bickinghah, Tel: 0379 898751
Semicomps, Keighley, Tel: 0535 65191
Semicomps, Kelso, Tel: 0573 24356
Swift-Sasco, Crawley, Tel: 0293 28700

Ferranti Electronics Limited, Fields New Road, Chadderton, Oldham OL9 8NP, England. Tel: 061-624 0515 and 061-624 6661 Telex: 668038

FERRANTI Semiconductors

*VAT is not included.