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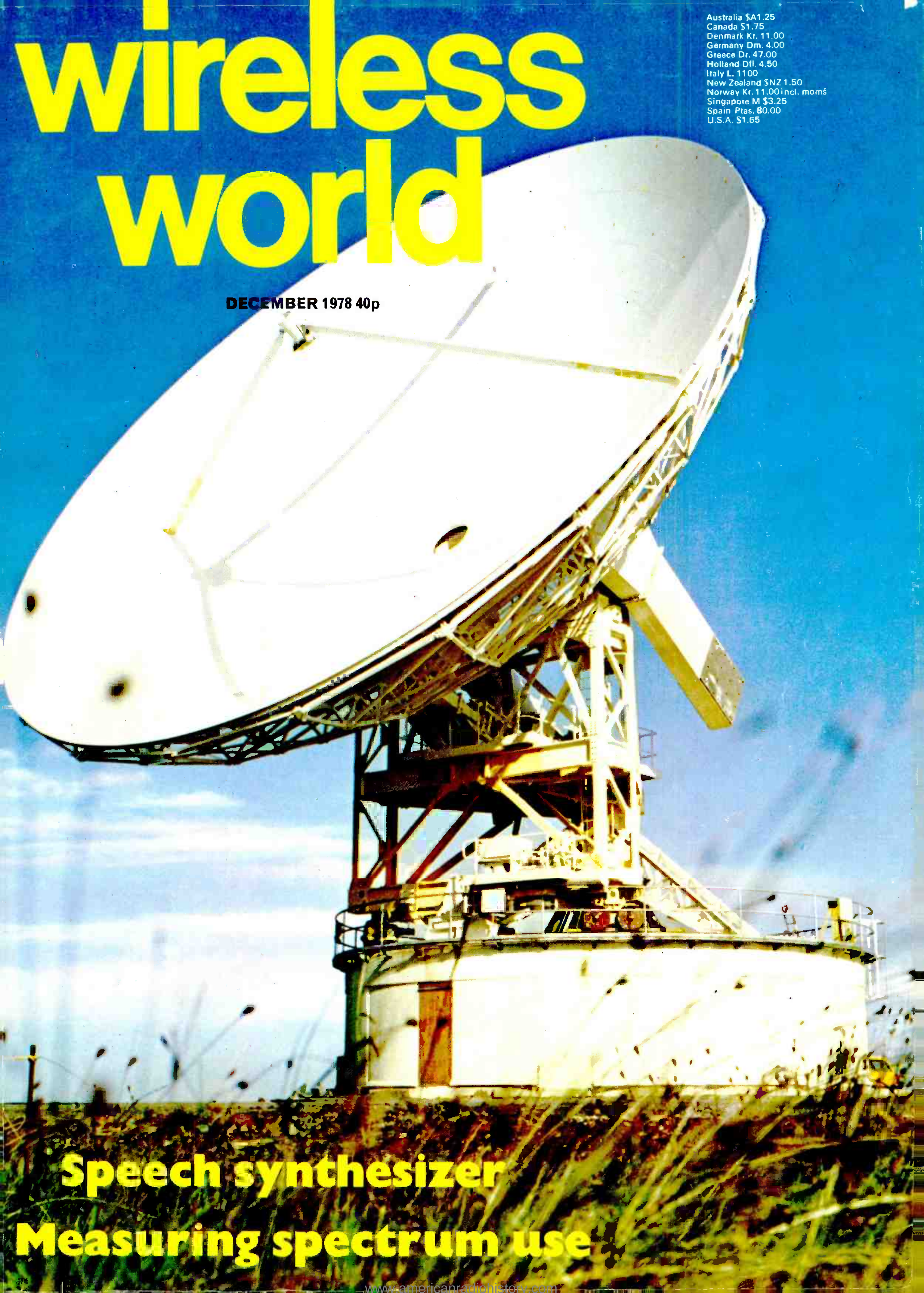
# wireless world

DECEMBER 1978 40p



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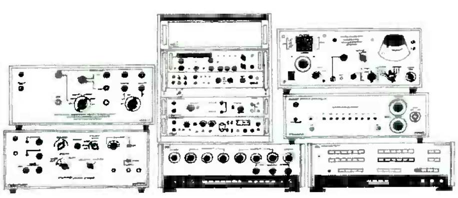

**Sine-squared Pulse and Bar Generators TF2905 series** each provide 4 switch-selected test waveforms which meet the CCIR Recommendations for accurate K-factor, luminance/chrominance gain and delay and other response measurements.

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If you'd like full information about any or all of these, we will of course be happy to fill in the picture.

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**WW—001 FOR FURTHER DETAILS**

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Front cover shows Goonhilly 4 earth terminal working with European OTS satellite. Details on p. 63. Photo by Marconi Communication Systems Ltd.

IN OUR NEXT ISSUE

***Digital frequency meter,*** **a low cost constructional design for "hands-off" operation, on a single p.c. board. Range: 1kHz to 200MHz with 5½ digit readout.**

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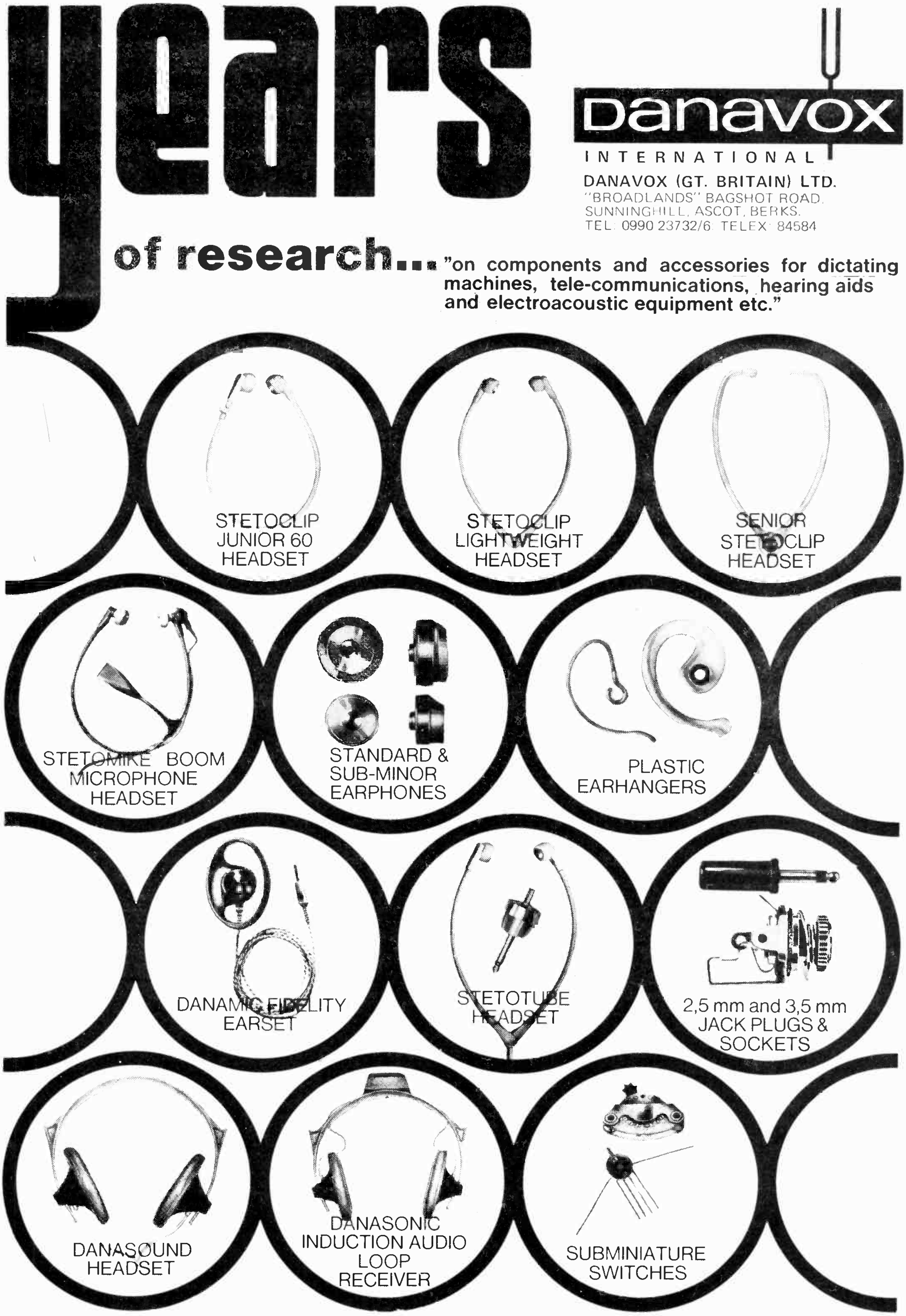
ISSN 0043 6062

# wireless world

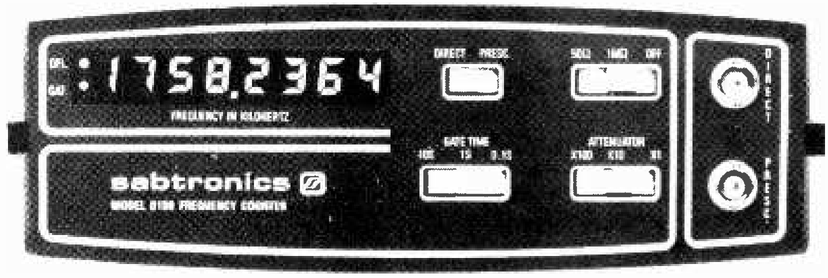
ELECTRONICS/TELEVISION/RADIO/AUDIO

DECEMBER 1978 vol 84 No 1516




WW—042 FOR FURTHER DETAILS

# We've made the impossible AGAIN. A superior frequency counter Kit for only £69.95

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**Also available assembled at £ 84.95.**

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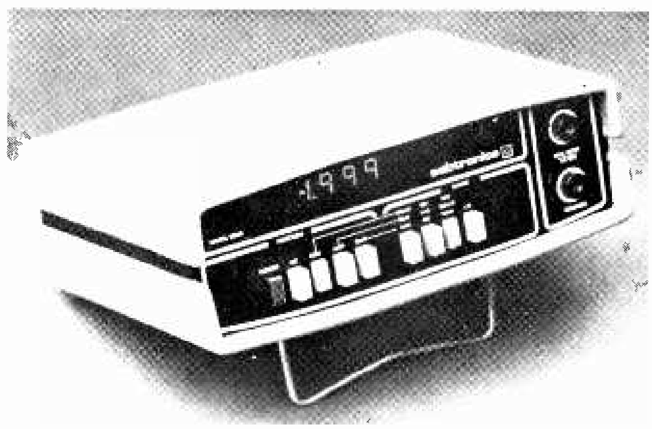


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# RA200/ADS1

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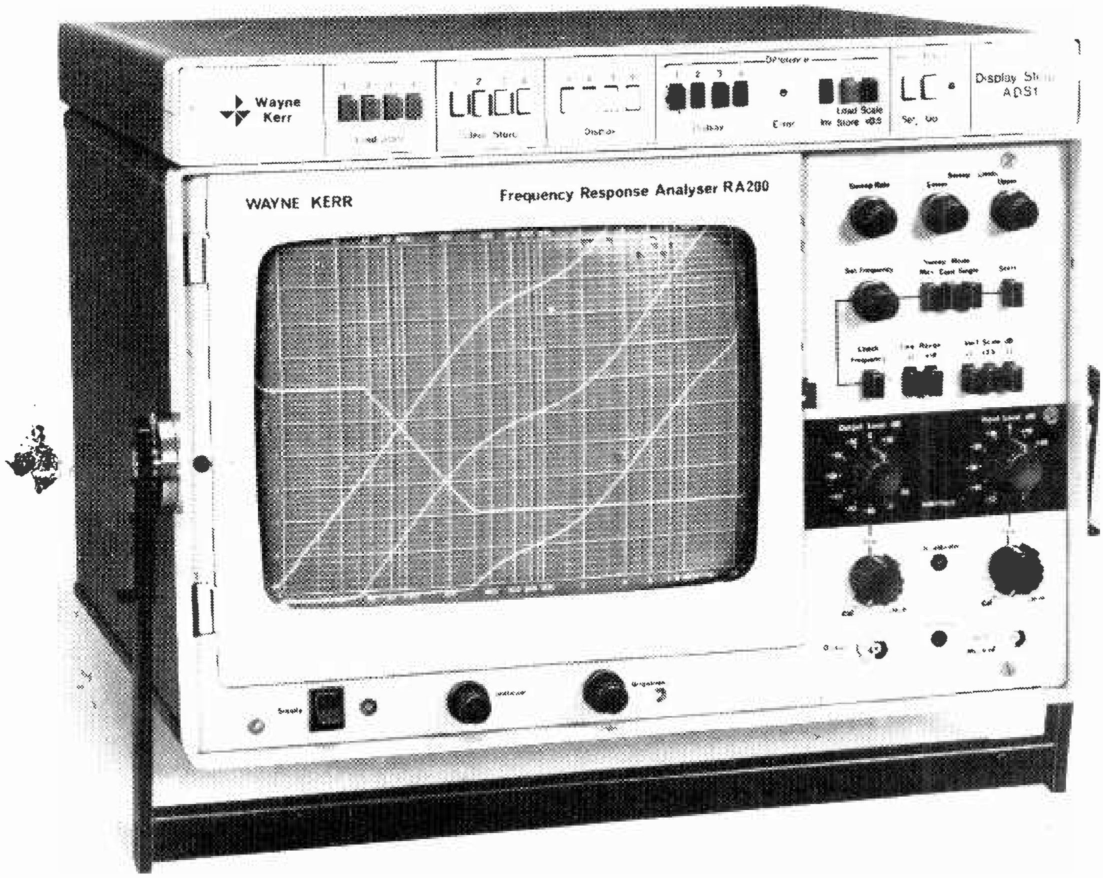


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**The RA200/ADS1**

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Please send me further information on the Wayne Kerr RA200 ADS1.

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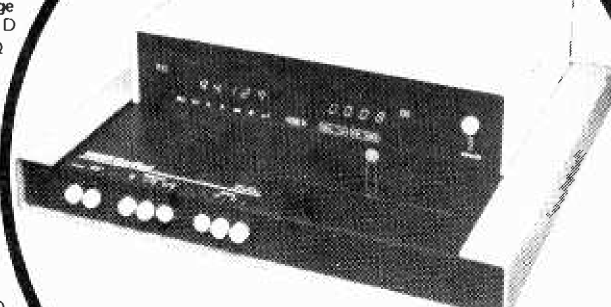
- Optional Kelvin test fixture tests radial and axial lead components



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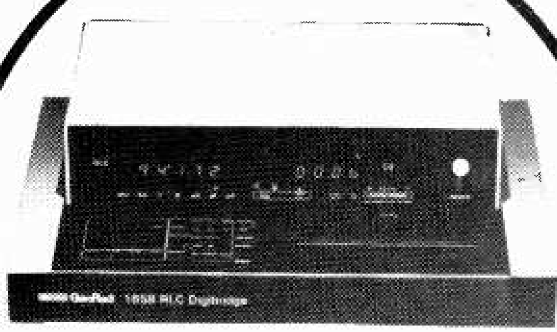

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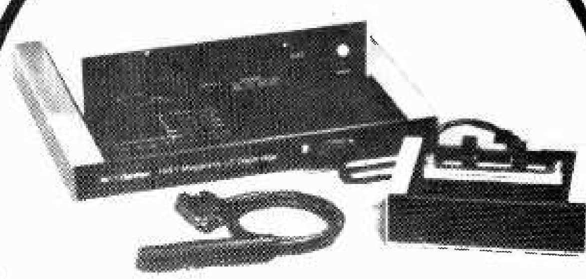

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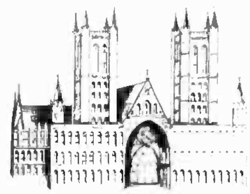

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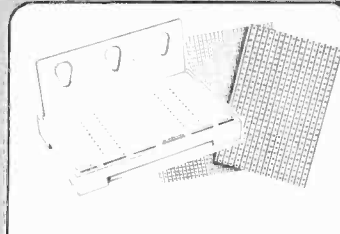

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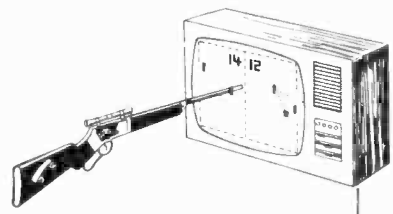

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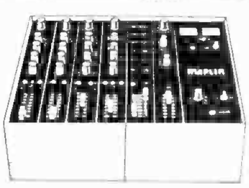

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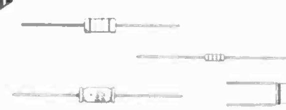

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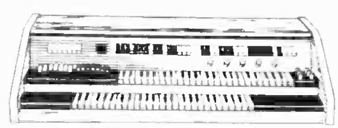

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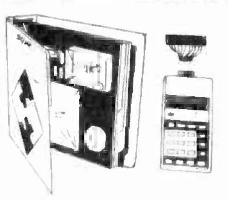

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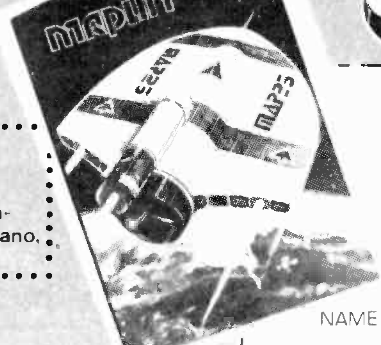


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Please send me details of the Wayne Kerr B424/CA4

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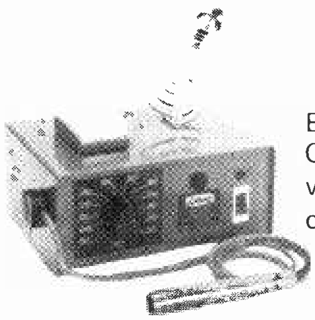

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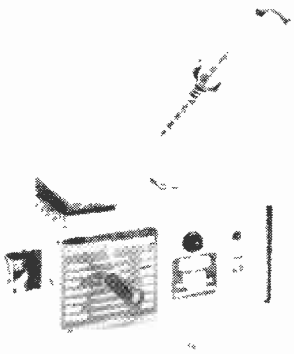

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- Grain size 200, thickness 55/100 mm., both faces diamonded. For quick cleaning of industrial relays and switching equipment, etc.
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- Grain size 400, thickness 25/100 mm., one face diamonded. For sensitive relays and tiny contacts. Two close contacts facing each other can be individually cleaned, because only one face of the spatula is abrasive.

**Sole Distributors for the United Kingdom**
**SPECIAL PRODUCTS (DISTRIBUTORS) LTD**
**81 Piccadilly, London W1V 0HL. Phone: 01-629 9556**
**As supplied to the M.O.D., U.K.A.E.A., C.E.G.B. British Rail and other Public Authorities; also major industrial and electronic users throughout the United Kingdom.**

WW—028 FOR FURTHER DETAILS


## for all demagnetising problems

## LEEVERS-RICH have the answer

LR70 for tapes up to 8¼ Dia and 1" wide

LR71 for tapes up to 11½ Dia and 1" wide

LR72 Han-d-mag for demagnetising heads and tape path components

LEEVERS - RICH EQUIPMENT LTD 319 Trinity Road, Wandsworth, London SW18 3SL Tel: 01-874 9054 Telex: 92355

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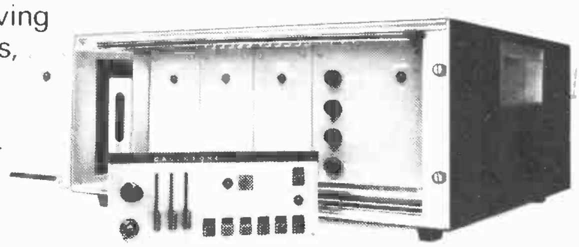


# NEW from Eddystone

## UHF receiver Model 1990S

This high-grade, professional UHF receiver is designed for use by –
Government Departments at home and overseas
Educational Establishments
Research Laboratories
Television Authorities
Satellite Ground Stations

470MHz

- AM: FM
- Modular c
- Wide/narro
- Tune frequen 1 kHz
- Panoramic displ available

Please ask for illustrated brochure

## Eddystone Radio Limited

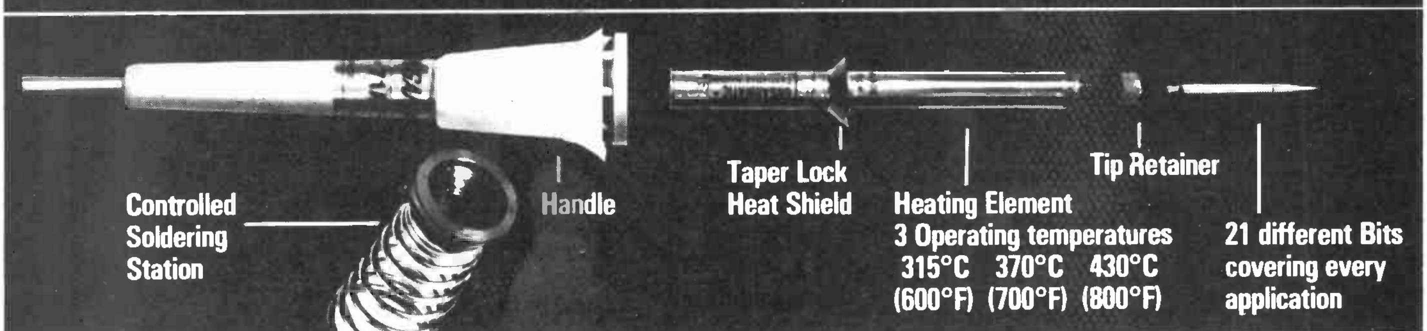
Member of Marconi Communication Systems Limited

Alvechurch Road, Birmingham B31 3PP, England
Telephone: 021-475 2231 Telex: 337081
A GEC-Marconi Electronics Company

Eddystone

WW—023 FOR FURTHER DETAILS

# UNGARmatic Soldering System





Available from HIRD-BROWN ELECTRONICS LIMITED

The UNGARmatic controlled soldering station is designed to protect sensitive components.

- Thread-in modular design for quick on line, heater or bit change
- Closed loop, non magnetic control
- Long life, low voltage system
- Compatible with any 24V/2A system
- Elimination of damaging transient spikes
- FULLY EARTHED SYSTEM

## Hird-Brown Electronics Limited

Head Office: Lever Street, Bolton BL3 6BJ.
Tel: Bolton (0204) 38631 Telex: 63478
Croydon: Norfolk House, Wellesley Road, Croydon CR0 0YF.
Tel: 01-681 1131/2 Telex: 8951036

CANNING
The W CANNING GROUP

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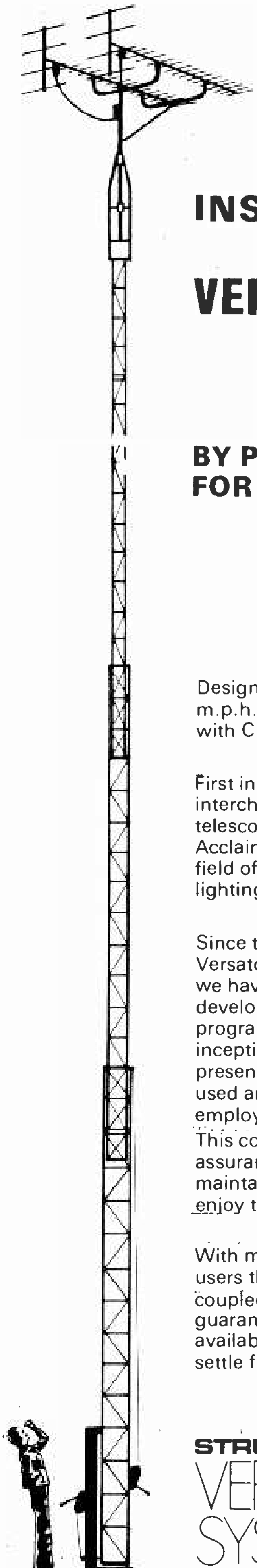


# INSIST ON

# VERSATOWER

## BY PROFESSIONALS— FOR PROFESSIONALS

Designed for Wind Speeds from 85 m.p.h. to 117 m.p.h., conforming with CP3 Chapter V, part II.

First in the field with a fully interchangeable (versatile) telescopic, tilt over, tower system. Acclaimed as the world leader in the field of communications and lighting, both static and mobile.

Since the launching of the Versatower system early in 1968 we have operated a continuous development and applications programme. Consequently from inception right through to the present day, detail design, materials used and production techniques employed are continually updated This coupled with our quality assurance scheme ensures that we maintain the leader position we enjoy today.

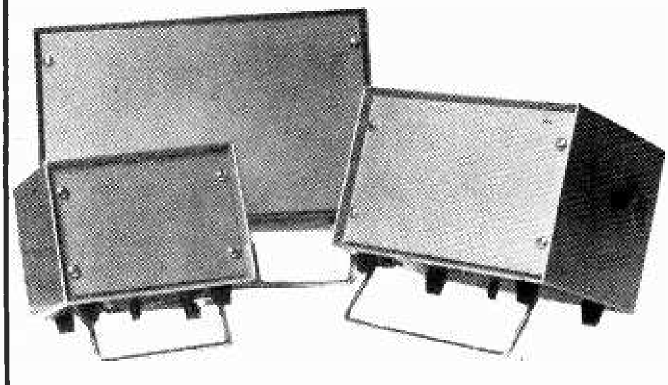
With many thousands of satisfied users throughout the world, coupled with our no nonsense guarantee and immediate spares availability, it makes little sense to settle for an alternative product.

**STRUMECH**
VERSATOWER SYSTEM

WW — 043 FOR FURTHER DETAILS

# OLSON

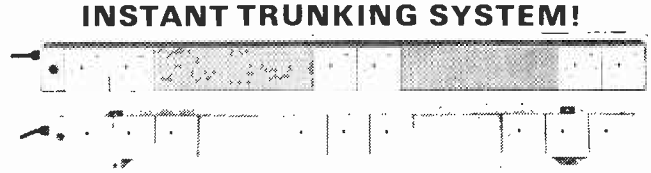
## MINICASES



| Type | Overall Dimension Width | Height | Depth | Case no vents | Case with vents | Chrome leg |
|---|---|---|---|---|---|---|
| 21 | 6½" | 4½" | 4½" | — | 5.35 | 1.10 |
| 22 | 8½" | 5½" | 5½" | — | 5.90 | 1.10 |
| 23 | 10½" | 6½" | 6½" | — | 7.00 | 1.20 |
| 24 | 12½" | 7½" | 7½" | — | 7.65 | 1.20 |
| 25A | 6½" | 4½" | 4½" | 5.10 | 5.70 | 1.20 |
| 25B | 6½" | 4½" | 6¼" | 5.45 | 6.05 | 1.20 |
| 26A | 8¾" | 5¾" | 6¼" | 7.15 | 7.75 | 1.20 |
| 26B | 8¾" | 5¾" | 8¼" | 7.50 | 8.10 | 1.20 |
| 27A | 12¼" | 7½" | 5½" | 7.85 | 8.55 | 1.20 |
| 27B | 12¼" | 7½" | 8" | 8.50 | 9.20 | 1.20 |
| 28A | 14" | 10½" | 6½" | 9.25 | 9.95 | — |
| 28B | 14" | 10½" | 8½" | 10.10 | 10.80 | — |
| 29A | 10" | 4" | 6" | 6.50 | 7.10 | 1.20 |
| 29B | 10" | 4" | 8" | 6.85 | 7.45 | 1.20 |
| 30A | 12" | 5" | 6" | 7.10 | 7.80 | 1.20 |
| 30B | 12" | 5" | 8" | 7.40 | 8.10 | 1.20 |
| 31A | 14" | 6" | 6" | 7.70 | 8.40 | 1.20 |
| 31B | 14" | 6" | 8" | 8.10 | 8.80 | 1.20 |
| 61 | 15½" | 7½" | 9½" | — | 11.75 | — |
| 62 | 17½" | 8½" | 9½" | — | 13.60 | — |
| 63 | 16½" | 9½" | 9½" | — | 13.60 | — |
| 64 | 15½" | 7½" | 12½" | — | 13.60 | — |
| 65 | 17½" | 8½" | 12½" | — | 15.50 | — |
| 66 | 16½" | 9½" | 12½" | — | 15.50 | — |

Postage & VAT extra

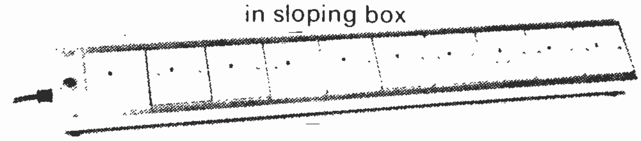
## INSTANT TRUNKING SYSTEM!



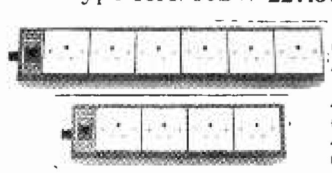
Ready to use. Internal wiring suitable for 30 amp
**TR6** — 6 sockets switched ............ **£21.50**
**TR9** — 9 sockets switched ............ **£25.50**
P&P £1.85 +VAT

## PORTABLE POWER DISTRIBUTION FOR INSTANT MAINS!

**NEW!** 10 sockets switched in sloping box



Type 13A/10SW **£27.50.** P&P £1.85 + VAT



COMPLETE WITH 6FT. CABLE AND 13 AMP FUSED PLUG

4 sockets 13A ...... **£12.15**
6 sockets 13A ...... **£14.30**
4 sockets 13A switched ...... **£13.75**
6 sockets 13A switched ...... **£15.95**

**ALL DISTRIBUTION PANELS ARE FITTED WITH MK SOCKETS & PLUG**
*Send for details of complete range + postage 85p each + 8% V A T*
**OLSON ELECTRONICS LTD., FACTORY NO. 8, 5-7 LONG ST., LONDON E2 8HJ**
**TEL: 01-739 2343**

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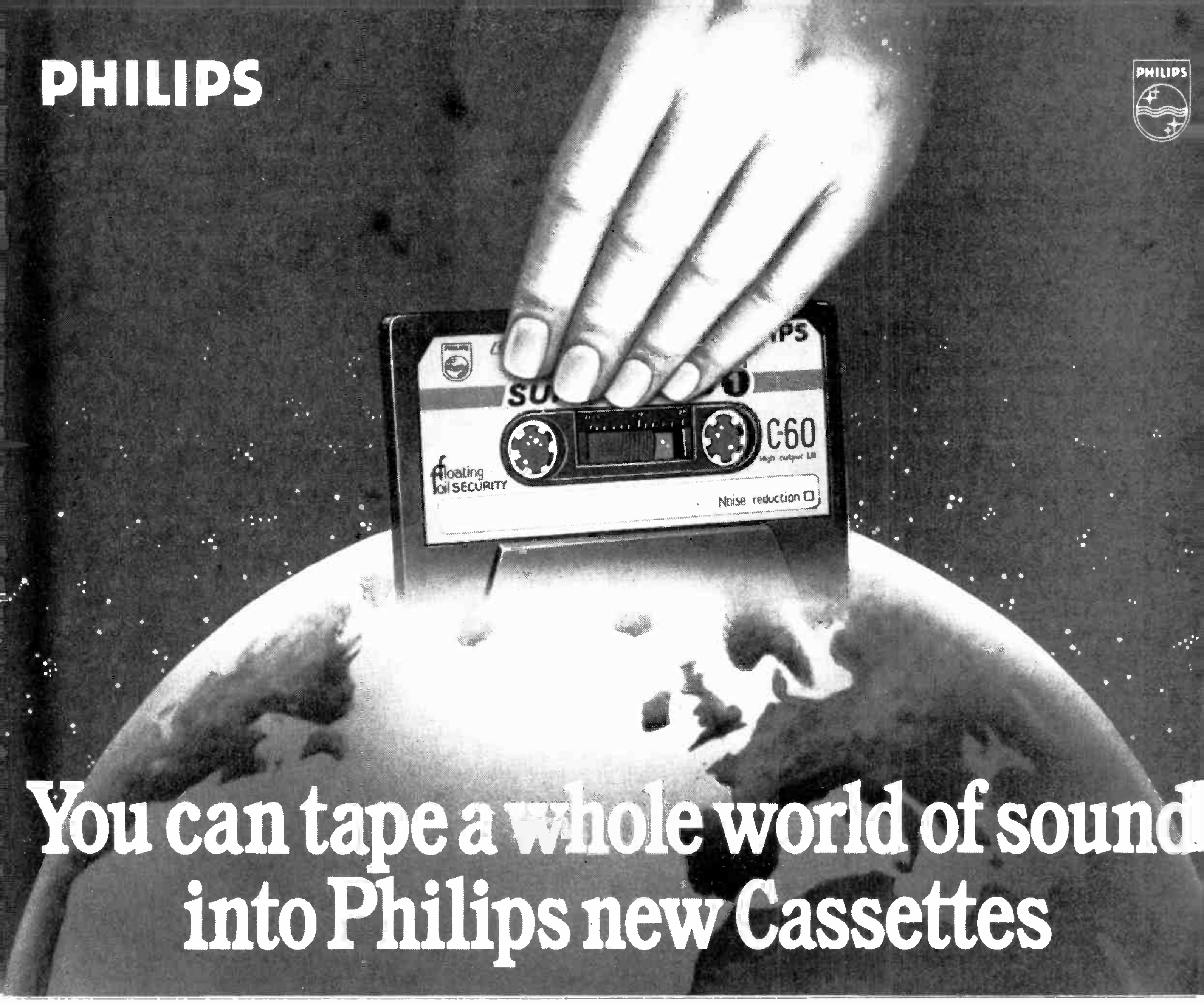


Here's a new generation of cassettes from Philips, inventors of the original compact cassette.

With five types of cassette in the range, from Ferro to hi-fi Chromium, there's one that matches almost any cassette machine you can name. From inexpensive Hipsters to the most costly systems.

We live in a world of sound. Whatever your taste, be it Punk Rock or Beethoven, these new Philips Cassettes give you a true reflection of the sound you want to hear. And they all have Philips' unique Floating Foil security to help put a stop to jamming and looping.

Look out for the Philips Select-a-Cassette chart in your local stockists. And ask for the free leaflet. Remember, when you explore the whole world of music, for the clearest sound from your equipment use Philips new Cassettes.

PHILIPS

Simply years ahead


The universal Cassette for all-round use. A low noise tape with balanced output and response. Suitable for use with most machines.

A Cassette specially developed for applications where high quality is required. The tape formulation guarantees high output and especially low distortion at low and middle frequencies.

For use with decks designed to give optimum performance using a higher bias tape. Super Ferro 1 works well with most modern machines, particularly those made in Japan. It gives well balanced reproduction and a higher output than normal Ferro.

Specially developed for hi-fi music, with particularly quiet background noise and brilliant high-frequency reproduction. The chromium dioxide coating gives a very smooth surface, ensuring good tape head contact.

For the most critical hi-fi fan, combining the excellent low-frequency reproduction of high density tape with the high frequency brilliance of chromium tape.

**Philips new Cassettes. For the whole world of sound.**

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". . . Shure guarantees a frequency response of 20 - 20,000 Hz within a tolerance field of 2 dB! Whoever promises something like this, certainly must have production under control!. . . . No wonder that its sound pattern was judged to be on the top end of the spectrum."

**Stereo**
Germany

"It is a smooth, neutral and analytical cartridge, and therefore best suited to an already neutral system."

"We doubt whether there is any commercially available record it is incapable of tracking."

**Records and Recordings**
United Kingdom

". . . a sound quality I cannot imagine to be bettered by any cartridge at any price. The art has reached a higher state!"

Cliff Coleman
**Honolulu Advertiser**
United States

"It seems that a curtain has been raised. . . . This increased definition seems to extend to the entire audible spectrum."

**Hi-Fi Conseils**
France

"It is, in fact, a superb-sounding and superb-measuring cartridge, which will set a new standard for the industry. . . . This is certainly the flattest response we have yet seen from a cartridge. . . . All in all, when Shure does it, they do it right."

**AudioScene Canada**
Canada

"In fact, the V15 Type IV wonderfully gets out of the most insidious traps, and, willingly tracks the most strongly modulated records. This, with a precision that no ear can miss, and comparatively better than all the other models tested up-to-date."

**Electronique Pour Vous —Hi-Fi Magazine**
France

"Its sound is smooth, flat, and clean to a degree that rivals anything on the market, at any price. . . . It should become the pickup of choice for a great many systems owners. It arguably represents the most significant (pickup) cartridge innovation in years."

CBS Technology Center
**High Fidelity**
United States

"The Super Track V15 Type IV is exactly that, a phenomenal performer that, with the proper associated gear, will provide gorgeous, undistorted sound from the most demanding records—for example the heavily cut direct-to-disk releases that many audiophiles are cultivating to show off their equipment. . . . In performance, it rivals or surpasses fancy, fragile, temperamental moving coil designs that may cost twice the price. . . ."

Robert C. Marsh
**Sun-Times**
United States


"The Type IV appears to be a cartridge that has the 'most' of every desirable quality and the 'least' of every undesirable quality. It is unsurpassed in the smoothness and flatness of its frequency response, low distortion, high trackability, and neutral sound character."

Hirsch-Houck Lab Report
**Popular Electronics**
United States

"The sound of the V15 Type IV can be described in much the same way as that of a good amplifier; there is really no particular sound at all that can be attributed to the cartridge. It is, after all, essentially flat, with distortions that seem to be below those inherent in even the best test records, and with far greater tracking ability over the entire audio band than any other cartridge we know of. . . . The Type IV is able to play records that other cartridges cannot."

**Stereo Review**
United States

"All in all, this is a quality cartridge that sweeps away one's fear of false advertising claims."

**Swing**
Japan

"It (the V15 Type IV) is superb on all types of music.
The remarkable points are:

—The extreme definition in low frequencies, which outclasses all the cartridges that were compared to it (moving magnet and moving coil).
—A clear mid-range.
—Accurate . . . . open sound.
—A radiant treble without any excess due to artificial addition.

The tonal balance is good without bias of any kind. On percussion instruments, the V15 Type IV reads only what is recorded, without any overbrightness."

**La Nouvelle Revue Du Son**
France

"This cartridge excels by genuine sound 'neutrality', without any tendency to sound 'shaping'. It is pure pleasure to play direct-cut records of pianos . . . absolutely clean play!"

**Radio-TV-Electronic**
Switzerland

"I do not intend to allow the Type IV to pass out of my hands. Its stability in the reproduced sound, the rich qualities and harmony of the vocals and strings, as well as the extension in the sound of pianos on direct-to-disc recordings, and others, are truly magnificent."

Masao Miyamoto
**Radio Techniques Antenna**
Japan

20-L
Please send me your leaflet describing the Shure V15 Type IV and other pickups in the Shure range.

Name ______________________

Address ______________________

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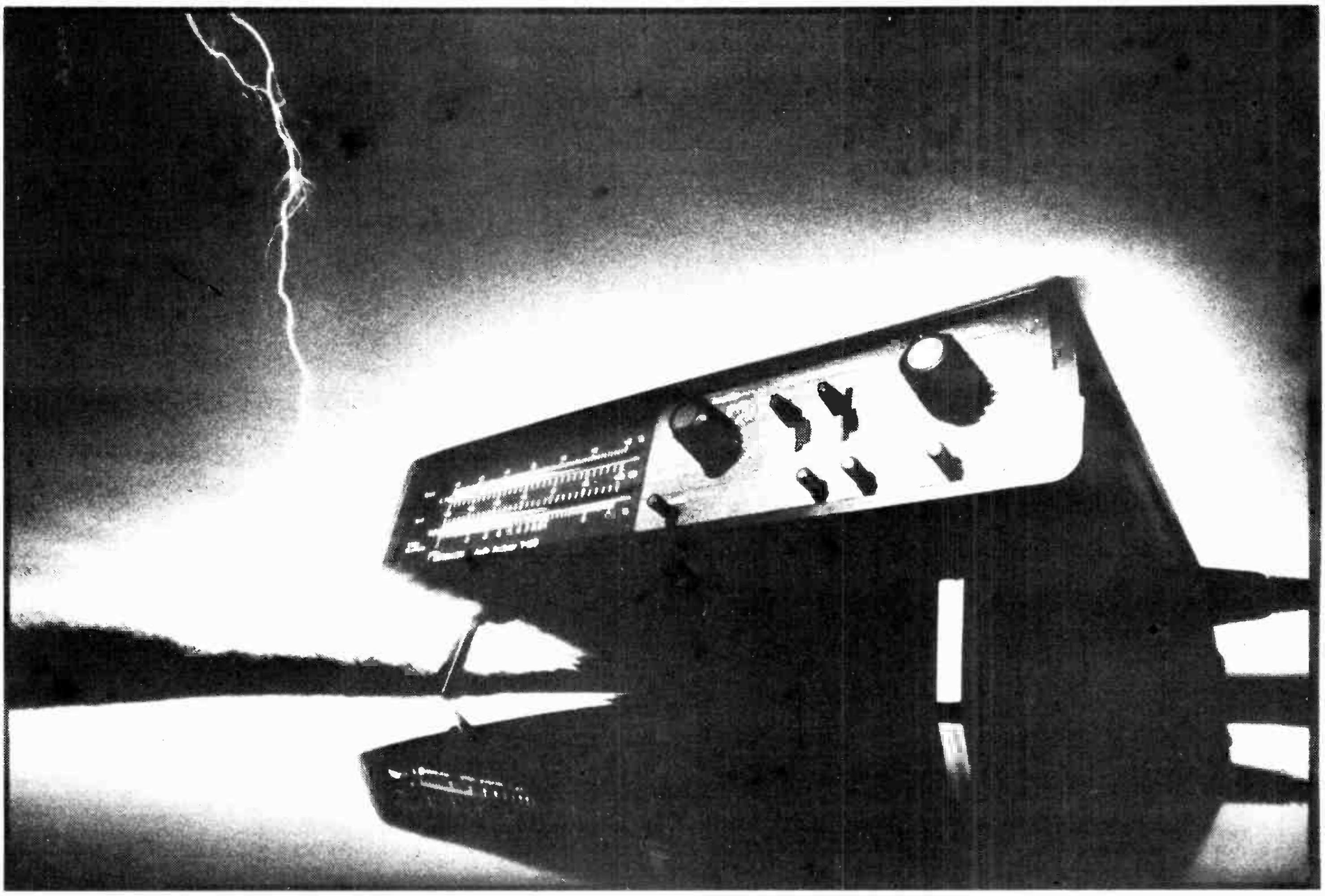
SHURE®

Shure Electronics Limited, Eccleston Road, Maidstone ME15 6AU, Telephone: (0622) 59881

**WW—094 FOR FURTHER DETAILS**

A flash of brilliance from Nakamichi illuminates audio analysis.



Smaller and lighter than a telephone directory. Yet the equal of a pile of test instruments many times its size and weight.

The Nakamichi T-100 is everything you've been wanting in an audio analyser.

And maybe a bit more.

It contains built-in oscillator with 21 frequencies from 20 to 20,000Hz; a pink-noise generator; a level meter featuring a lightening-fast dual plasma display with choice of "VU" or peak ballistics; a speed, wow and flutter meter with the option of unweighted or DIN peak weighted measurements; a fully automatic 400Hz distortion analyser; an A-weighting filter for noise measurements, a watt-scale graticule for power level indication.

It's rugged, versatile and accurate. An instrument that sustains infallible diagnosis.

Service and laboratory professionals, equipment reviewers, dealers, salespeople . . . and incurable audiophiles, the T-100 has arrived.

Enlightening audio analysis.

Write for more information to Natural Sound Systems Ltd, 10 Byron Road, Wealdstone, Harrow, Middlesex HA3 7TL.

Nakamichi

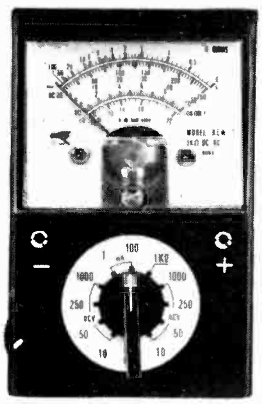
Products of unusual creativity and competence . . .

# NOT EVERY CABLE HAS A LABEL

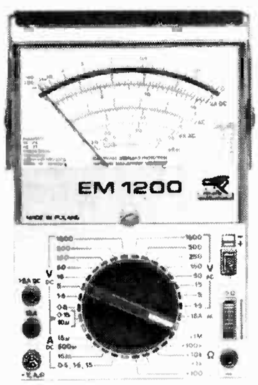

Everyone who works with electricity needs to know at some time or other what's going on inside the cable he's handling. What voltage. What current. What resistance. Not knowing the answers, or worse still having inaccurate answers, can make life difficult, even terminal.

**Eagle Test Equipment gives the right answers**

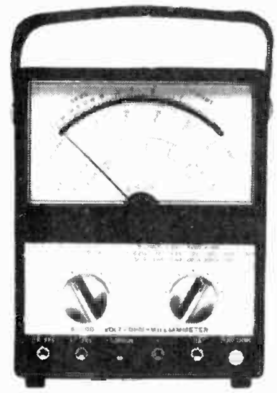
The range covers general multimeters, high voltage probes, clamp meters, insulation testers.
Here are just four. Send the coupon for details of all the rest.



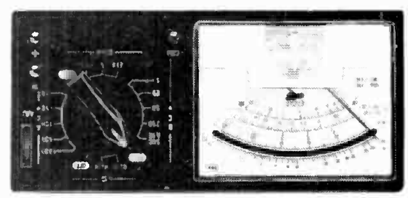
**KEW 7 Multimeter**
1000 OPV. DC volts up to 1000, DC amps up to 100 mA. AC volts up to 1000. Resistance up to 150 Kohms. Pocket size. "Off" damping. Complete with leads & battery. R.R.P. £6.95 ex. VAT.




**EM 1200 Multimeter**
100,000 OPV. Taut band movement. Overload protection. Reversible DC polarity. AC amps: 15, AC volts to 1500. DC amps up to 15, DC volts to 1500. Resistance up to 200 megohms. R.R.P. £49.95 ex. VAT.

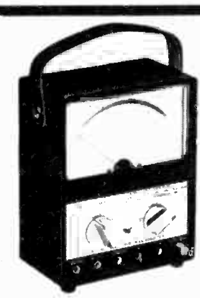


**K1400 Multimeter**
20,000 OPV. DC and AC volts up to 5000. DC and AC amps up to 10. Resistance up to 20 megohms. "Off" damping. Overload protection. R.R.P. £68.00 ex. VAT.



**EM10, 20 & 30 Multimeters**
10, 20 & 30,000 OPV. All with antiparallax mirror scale. DC volts to 1000 (1200 for EM30). DC amps to 250 mA (600 for EM30). AC volts to 1000 (1200 for EM30). Resistance up to 6,5 and 60 megohms respectively. R.R.P.'s EM10 £12.40 EM20 £16.40 EM30 £18.95 ex. VAT.

## Test Equipment: EAGLE



Please send me details of your complete range of Test Equipment.

Name ______________________ Company ______________________

Address ______________________________________________

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EAGLE INTERNATIONAL Precision Centre, Heather Park Drive, Wembley, Middlesex HA0 1SU.

WW2

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# Telegraph testing simplified

# TCT10


## Lightweight, portable, Telegdata TCT10 makes light work of on-site circuits and machines.

This new Plessey instrument combines signal generator and analyser in a single briefcase-size unit enabling on-site testing of telegraph circuits and machines to be carried out speedily and with a high degree of accuracy.

Powered from the a.c. mains supply, the TCT10 gives a choice of output levels and test signals in CCITT No 2 and No 5 alphabets including the full 96 character 'fox' message, Q9S and any single character on demand.

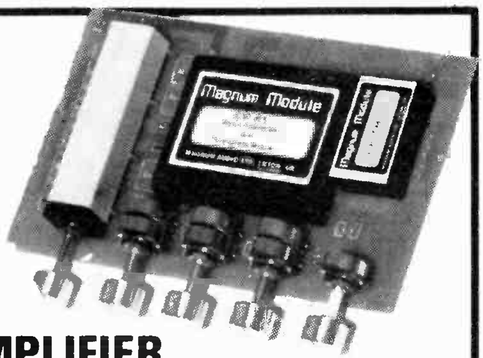
Accurate readout (to 1%) is given unambiguously on an LED scale registering up to 40% distortion early/mark bias and late/space bias.

Full specification is available in a colour-illustrated brochure. See how your telegraph test operations can be improved — telex or write to: Telegdata Department, Plessey Controls Limited, Sopers Lane, Poole, Dorset, United Kingdom BH17 7ER. Telex: 41272.

**PLESSEY CONTROLS**

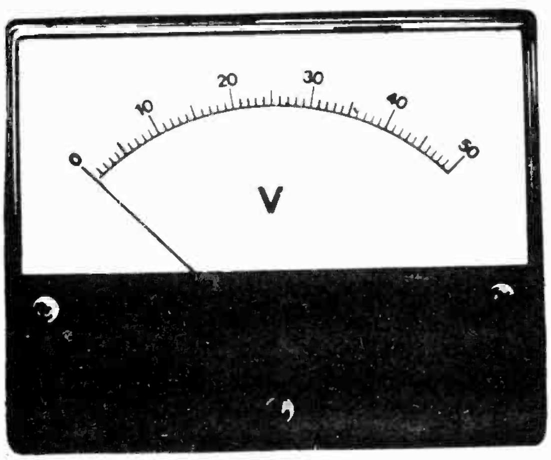
WW—019 FOR FURTHER DETAILS

RP 600-2-224









0
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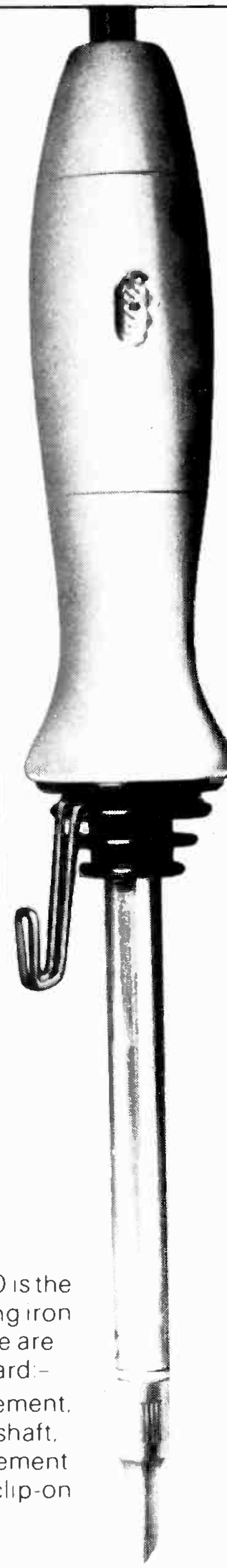


# YOUR COMPLETE RANGE OF ELECTRONIC HARDWARE....

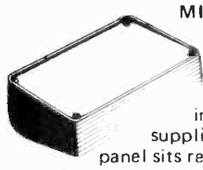
## BIMENCLOSURES

### ALL METAL BIMCASES

Red, Grey or Orange 14swg Aluminium removable top and bottom covers. 18 swg black mild steel chassis with fixing support brackets.

BIM 3000
(250x167.5x68.5mm)
£14.58

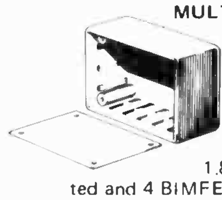
### MINI DESK BIMCONSOLES



Orange, Blue, Black or Grey ABS body incorporates 1.8mm pcb guides, stand-off bosses in base with 4 BIMFEET supplied. 1mm Grey Aluminium panel sits recessed with fixing screws into integral brass bushes.

BIM 1005 (161 x 96 x 58mm) £2.18
BIM 1006 (215 x 130 x 75mm) £3.05

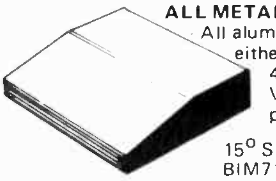
### MULTI PURPOSE BIMBOXES



Orange, Blue, Black or Grey ABS with 1mm Grey Aluminium recessed front cover held by screws into integral brass bushes. 1.8mm pcb guides incorporated and 4 BIMFEET supplied.

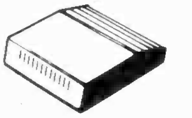
BIM 4003 (85x56x28.5mm) £1.18
BIM 4004 (111x71x41.5mm) £1.62
BIM 4005 (161x96x52.5mm) £2.19

### ALL METAL BIMCONSOLES



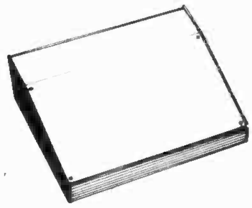
All aluminium, 2 piece desk consoles with either 15° or 30° sloping fronts, sit on 4 self-adhesive non-slip rubber feet. Ventilation slots in base and rear panel for excellent cooling.

| Colour Code | Top Panel | Base |
|---|---|---|
| A | Off White | Blue |
| B | Sand | Green |
| C | Satin Black | Gold |



| 15° Sloping Panel | 30° Sloping Panel | |
|---|---|---|
| BIM7151 (102x140x51[28] mm) | BIM7301 (102x140x76[28] mm) | £10.67 |
| BIM7152 (165x140x51[28] mm) | BIM7302 (165x140x76[28] mm) | £11.44 |
| BIM7153 (165x216x51[28] mm) | BIM7303 (165x183x102[28] mm) | £12.61 |
| BIM7154 (165x211x76[33] mm) | BIM7304 (254x140x76[28] mm) | £13.82 |
| BIM7155 (254x211x76[33] mm) | BIM7305 (254x183x102[28] mm) | £15.36 |
| BIM7156 (254x287x76[33] mm) | BIM7306 (254x259x102[28] mm) | £16.67 |
| BIM7157 (356x211x76[33] mm) | BIM7307 (356x183x102[28] mm) | £17.58 |
| BIM7158 (356x287x76[33] mm) | BIM7308 (356x259x102[28] mm) | £18.55 |

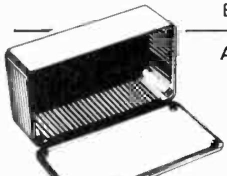
### LOW PROFILE BIMCONSOLES



Orange, Blue, Black or Grey ABS body has ventilation slots as well as 1.8mm pcb guides and stand-off bosses in base. Double angle recessed front panel with 4 fixing screws into integral brass bushes. 4 BIMFEET supplied.

BIM 6005 (143 x 105 x 55.5 [31.5] mm) £2.37
BIM 6006 (143 x 170 x 55.5 [31.5] mm) £3.08
BIM 6007 (214 x 170 x 82.0 [31.5] mm) £4.12

### ABS & DIECAST BIMBOXES

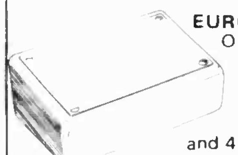


6 sizes in ABS or Diecast Aluminium. ABS moulded in Orange, Blue, Black or Grey. Diecast Aluminium in Grey Hammertone or Natural. All boxes incorporate 1.8mm pcb guides, stand-off supports in base and have close fitting flanged lids held by screws into integral brass bushes (ABS) or tapped holes (Diecast).

| | ABS | | Diecast | Hammertone | Natural |
|---|---|---|---|---|---|
| (50x60x31mm) | N/A | | BIM5001/11 | TBA | TBA |
| (100x50x25mm) | BIM2002/12 | £0.96 | BIM5002/12 | £1.46 | £1.19 |
| (112x62x31mm) | BIM2003/13 | £1.13 | BIM5003/13 | £1.78 | £1.46 |
| (120x65x40mm) | BIM2004/14 | £1.35 | BIM5004/14 | £2.24 | £1.82 |
| (150x80x50mm) | BIM2005/15 | £1.52 | BIM5005/15 | £2.84 | £2.28 |
| (190x110x60mm) | BIM2006/16 | £2.37 | BIM5006/16 | £3.94 | £3.33 |

Also available in Grey Polystyrene with no slots and self-tapping screws
BIM 2007/17 (112x61x31mm) £1.00

### EUROCARD BIMCONSOLES

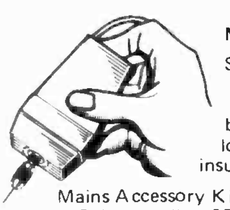


Orange, Blue, Black or Grey ABS body accepts full or ½ size Eurocards, with bosses in the base for direct fixing. 1.8mm wide pcb guides incorporated and 4 BIMFEET supplied. 1mm Grey aluminium lid sits flush with body top and held by 4 screws into integral brass bushes.

BIM 8005 (169x127x70[45] mm) £4.12
BIM 8007 (to be announced shortly)

## BIMTOOLS

### MAINS BIMDRILLS

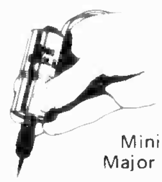


Small, powerful 240V hand drill complete with 2 metres of cable and 2 pin DIN plug. Accepts all tools with 1mm, 2mm or .125" dia. shanks. Drills brass, steel, aluminium and pcb's. Under 250g, off load speed 7500 rpm. Orange ABS, high impact, fully insulated body with spring return on/off switch £10.53

Mains Accessory Kit 1 includes 1mm, 2mm, .125" twist drills, 5 burrs and 2.4mm collet £2.48

Mains Kit 2 includes Mains BIMDRILL as above, 20 assorted drills, mops, burrs, grinding wheels and mounted points, 1mm, 2mm, 2.4mm and .125" collets. Complete in transparent case measuring 230x130x58mm £22.14

### 12 VOLT BIMDRILLS



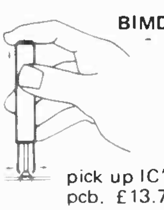
2 small, powerful drills easily hand held or used with lathe/stand adaptor. Integral on/off switch and 1 metre cable.

Mini BIMDRILL with 3 collets up to 2.4mm dia £ 8.10
Major BIMDRILL with 4 collets up to 3mm dia £13.60

Accessory Kits 1 have appropriate drills and collets as above plus 20 assorted tools. Mini Kit 1 – £15.12, Major Kit 1 – £19.44.
Accessory Kits 2 have appropriate drills, collets plus 40 tools and mains 12V dc adaptor. Mini Kit 2 – £34.02, Major Kit 2 – £39.42.

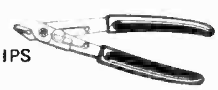
Accessory Kits 3 as appropriate Kits 2 plus stand/lathe unit. Mini Kit 3 – £45.36, Major Kit 3 – £50.76.

### BIMDIPS



Rapidly inserts and withdraws any 4-18 pin, .3" pitch DIL package without beding the legs. Adjustable metal jaws for MOS type devices grip the bottom of the leg for minimum strain. Will pick up IC's from a bench, a carrier or a pcb. £13.77.

### BIMSNIPS



Precision made side cutters, spring action, ground steel fine pointed blades for intricate work.

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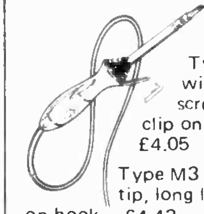
### BIMIRONS



Type 30 General Purpose 27 watt iron with long life, rapid change element, screw on tip, stainless steel shaft and clip on hook. Styled handle with neon. £4.05

Type M3 Precision 17 watt iron, quick change tip, long life element, styled handle with clip on hook £4.43

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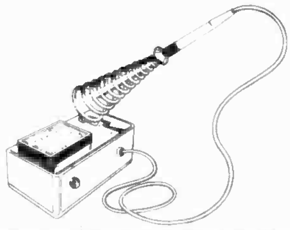

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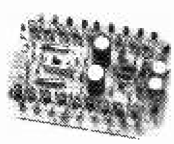

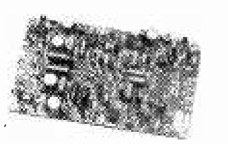

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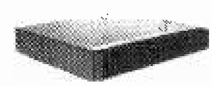

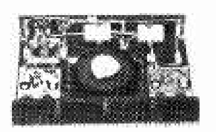

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| MC1 | £18.50 |
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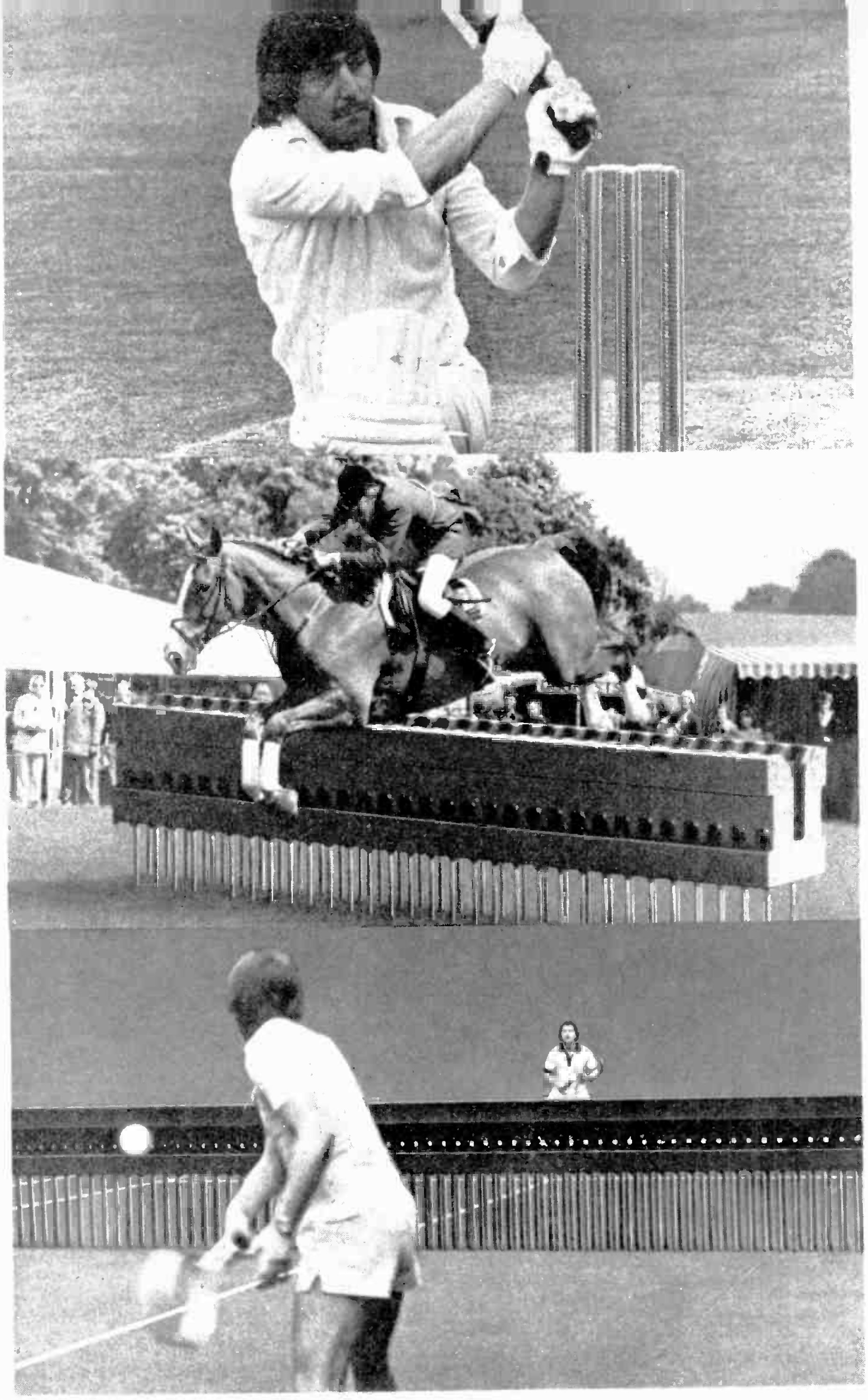



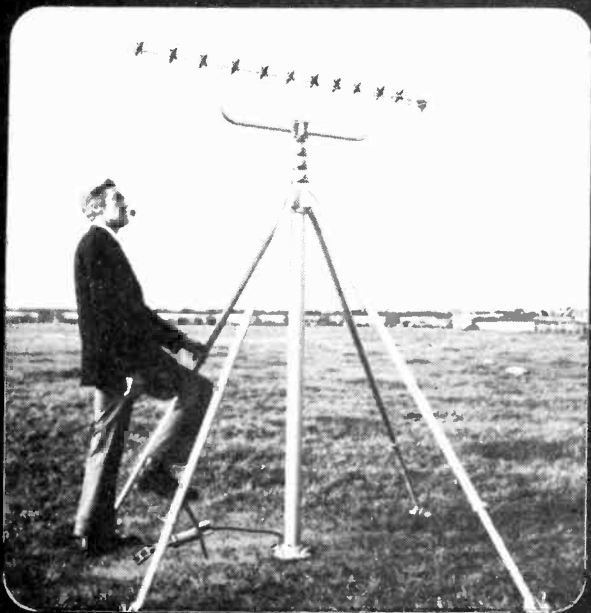

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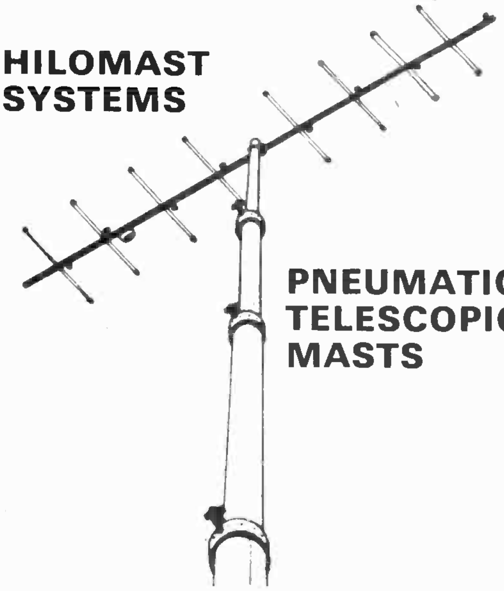

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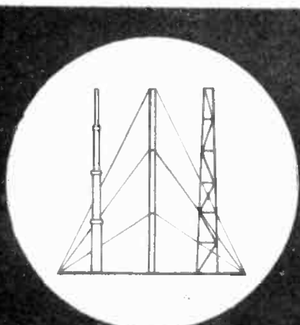

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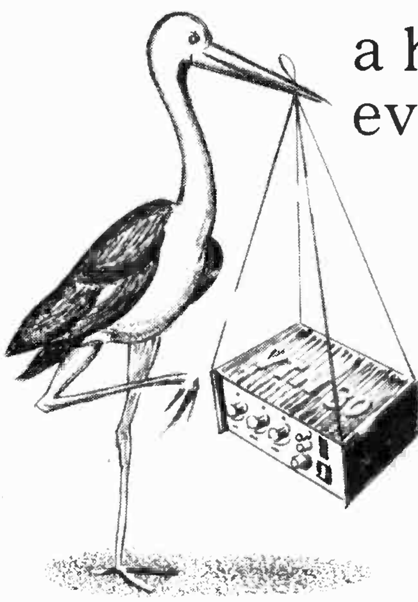

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From Bell & Howell, exclusive distributors of JVC video products to the educational, industrial and institutional markets.

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Weight including lens and viewfinder is only 9.6Kg. For location work the well respected JVC CR4400LE U format portable recorder is an ideal companion. Up to 12 metres away the whole system operates from internal batteries or external power.

Used alone, the new CR8500E 3/4" U format video cassette recorder is designed to make editing simple and fast. Automatic variable speed playback in forward and reverse ensures accurate access to the exact edit point. Fully framed edits with an accuracy of ±2 frames and the proven JVC colour dub system, ensure successful copies every time.

Together with the RM85E two CR8500E's form a first class edit suite for off-line or 3/4" master editing. All transport and edit functions are remoted to the control console. From pressing the play button, video and audio head contact with the tape is maintained to enable any mode to be instantly selected. Location on the tape is constantly monitored by counting control track pulses and assures accurate tape position and time determination. Edit in and out times can be programmed and memorised for automatic assemble or insert editing and the precise position can be adjusted in single frame steps in the preview mode before a commitment to record is made. The video and audio tracks may be separately or simultaneously edited in any combination.

**The CR8500E brings a new degree of flexibility to the 3/4" format; the CY8800E brings it to portable cameras. If you would like further information on JVC equipment use the reader enquiry service or write direct to Bell & Howell A-V Ltd., Alperton House, Bridgewater Road, Wembley, Middlesex HA0 1EG.**

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# Give the customer what he wants

In October the British Standards Institution held its fourth regional consumer campaign in the West Country and included two public meetings for consumers, one with the theme title "British goods. British Standards. Best Value." One wonders if this theme title was the result of wishful thinking, or a real belief that buying British, regardless, really is a good idea. In contrast to this one frequently sees in the daily newspapers letters from consumers complaining about British goods and saying such things as "Why should we buy inferior goods (for a given price) when we can get better foreign goods with greater choice, and far better deliveries and after-sales service." Why indeed? As we pointed out in a survey some time ago (Amateur radio equipment, Aug./Sept., 1977), foreign companies are not only providing better deliveries despite periods of time consumed by transportation and customs compounding, they are also keeping prices low despite normal mark-ups, heavy freight costs and insurances, and import duties — on electronic equipment import duty is more often than not between 11 and 14% of all costs up to the point where the goods pass through customs. When making comparisons UK companies conveniently forget that they already have this considerable price advantage.

Too often one hears facile remarks like "Oh, you've got one of those cheap Japanese imitations." It may or may not be true that at one time certain Japanese products were cheap imitations, and it may or may not be true that at one time "dumping" was practised (it is doubtful, however, whether this could ever be proved or disproved in the case of electronic products) but today the goods are seen to have been produced to a high standard of workmanship, employing the latest design developments — often custom-designed and certainly not copied — with a sensible choice of materials, and an after sales service which is second to none. Perhaps most important of all are the Japanese abilities to provide good deliveries and to "give the customer what he wants." British manufacturers like Rank acknowledge these facts by happily selling Japanese products and going into partnership with Japanese firms.

The UK's inability to compete with the Japanese lies just as much with its insensitivity to customer requirements as with anything else. All too often one hears said of British-made goods—especially cars—"Oh yes, well, this fault is quite common on a . . ." That fault, on a foreign product, would more often than not be put right forthwith, not temporarily corrected, but designed-out of the next batch with no questions asked.

In some professional electronics fields the view of UK manufacturers seems to be that they will rely on their good names and their many years of experience and skill and ignore the threats of future competition from the newcomers, the Japanese. They believe their products are so good that deliveries and other factors will not affect the potential customer's choice. What they appear not to recognise is that the Japanese have shown that they require only a relatively short apprenticeship and can quickly overtake the teacher. Where professional communications are concerned, the Japanese will almost certainly prove that they too can produce the required type-approved goods, and for far less. UK prices for these goods at present "reflect what the market can stand" and are grossly inflated.

In its October issue the consumer magazine, *Which?* gave reasons why the UK would not be helped back on its feet if consumers always made a point of "buying British." They believed that Britain's industries should tackle their lack of competitiveness by improving the design and/or reliability of their products, by producing them on time and in the quantities needed, and by marketing them more effectively and at more competitive prices. Unquestionably *Which?* is right. Britain should design-out that fault, provide those extras, meet that delivery, give the customer what he wants!

# The Chatterbox

## A simple speech synthesizer for demonstration and amusement

by **Ian H. Witten,** M.A., M.Sc., Ph.D., M.I.E.E. and **Peter H. C. Madams,** B.Sc., M.Sc.

Department of Electrical Engineering Science, University of Essex.

The device described is a hand-controlled, electronic model of the acoustic properties of the vocal tract, and was built to illustrate the physiological and acoustic nature of speech. Although designed as a portable demonstration and lecturing tool it makes a fascinating toy for adults and children alike, and has been used as a stimulus for retarded and autistic children. After discussing the nature of speech and the mechanism of electronic speech synthesis, the authors explain the design principles of the Chatterbox and in a later article will give further circuit details and instructions on how to make it talk.

PEOPLE SPEAK by using their vocal chords as a sound source, and making rapid gestures of the articulatory organs (lips, tongue, mouth, etc.). The resulting changes in shape of the vocal tract allow the production of the different sounds that we know as the vowels and consonants of ordinary language. For several years it has been possible to simulate the action of the vocal tract electrically, using a device similar to an electronic organ to produce sounds with the same character as those of human speech. The first of these "speech synthesizers," built in the early 1950s, comprised many racks of equipment, consumed a lot of power, and cost a great deal of money. Now, however, with the advent of cheap integrated circuits, it has become possible to build simple, compact, and quite inexpensive synthesizers, without sacrificing the ability to produce the full range of speech sounds.

Of course, to make the ever-changing patterns of speech, a synthesizer needs some form of continuously varying control, and just as there are many vocal tract organs involved simultaneously in speaking, so it is necessary to control several parameters of the synthesizer at once. Most speech research laboratories nowadays use a digital computer to manipulate the control signals for their synthesizers. However, for the purposes of informal experiments with speech or just to learn about the sounds we make, a pair of hands will suffice – with the added advantage that the operator can use his long-standing experience with real speech to mould the sounds into voice-like ones.

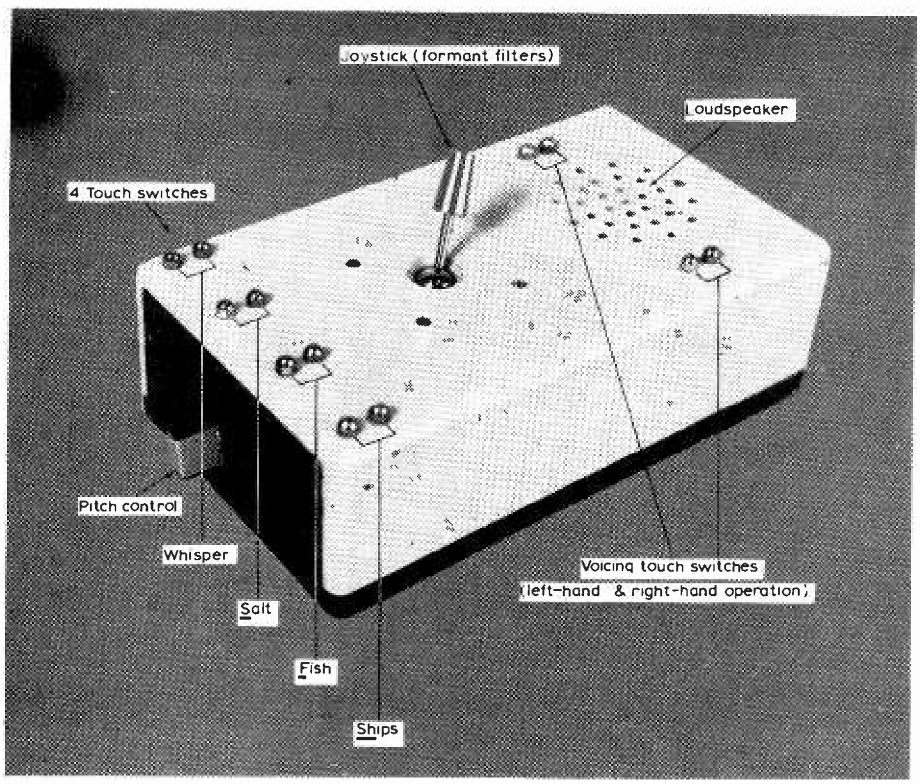



**Fig. 1.** *The Chatterbox, showing the controls for hand operation.*

By way of illustration of these points, we have built a small, manually controlled speech synthesizer, suitable for home construction – the "Chatterbox" (Fig. 1). In experienced hands it can be encouraged to utter recognizable words and phrases ("hello," "how are you," etc.), while even a complete novice can make it generate a great variety of astonishingly different noises, all of which are immediately recognizable as speech-like. The Chatterbox was originally designed as a portable demonstration and lecturing tool for illustrating the different sounds of speech and how they can be synthesized, but we quickly found that the fascination of artificial speech makes it a successful and compelling toy for adults and children alike. As a hand-controlled, electronic model of the acoustic properties of the vocal tract, it provides a natural feel for the growing science of phonetics — the study of what people do when they are talking and when they are listening to speech.

This first article discusses the nature of speech and the mechanisms of electronic synthesis. The Chatterbox design is described later, with some circuit details, as a concrete example of the implementation of a speech synthesis system.

### The anatomy of speech

The so-called "voiced" sounds of speech – like the sound you make when you say "aaah" – are produced by passing air up from the lungs through the larynx or voicebox, which is situated just behind the Adam's apple. The vocal tract from the larynx to the lips acts as a resonant cavity, amplifying certain frequencies and attenuating others.

The waveform generated by the larynx, however, is not simply sinusoidal. (If it were, the effect of the vocal tract resonances would merely be to give a sine wave of the same frequency but amplified or attenuated according to how close it was to the nearest resonance.) The larynx contains two folds of skin – the vocal cords – which blow apart and flap together again in each cycle of the pitch period. The pitch of a male voice in speech varies from as low as 20Hz to perhaps 250Hz, with a typical median value of 100Hz. For a female voice, of course, the range is correspondingly higher. The flapping action of the vocal cords gives a waveform which can be approximated by the triangular pulse of Fig. 2. This has a rich spectrum of harmonics, decaying at around 12dB/octave, and each harmonic is affected by the vocal tract resonances.

A simple model of the vocal tract is an organ-pipe-like cylindrical tube with a sound source at one end (the larynx) and open at the other (the lips), as shown in Fig. 3. This has resonances at wavelenghts $4L$, $4L/3$, $4L/5$, . . . , where $L$ is the length of the tube; and these correspond to frequencies $c/4L$, $3c/4L$, $5c/4L$, . . . Hz, where $c$ is the speed of sound in air. Calculating these frequencies, using a typical figure for the distance between larynx and lips of 17cm, and $c = 340$ m/sec for the speed of sound, leads to resonances at approximately 500Hz, 1500Hz, 2500Hz, . . .

When excited by the harmonic-rich waveform of the larynx, the vocal tract resonances produce peaks known as *formants* in the energy spectrum of the speech wave (Fig. 4). The lowest formant, called formant 1, varies from around 200Hz to 1000Hz during speech, the exact range depending on the size of the vocal tract. Formant 2 varies from around 500 to 2500Hz, and formant 3 from around 1500 to 3500Hz.

Of course, speech is not a static phenomenon. The organ-pipe model describes the speech spectrum during a continuously held vowel with the mouth in a neutral postion such as for "aaah." But in real speech the tongue and lips are in continuous motion, altering the shape of the vocal tract and hence the positions of the resonances. It is as if the organ-pipe were being squeezed and expanded in different places all the time. Say "ee" as in "heed" and notice how close your tongue is to the roof of your mouth, causing a constriction near the front of the vocal cavity.

Linguists and speech engineers use a frequency analyser called a sound spectrograph to make a three-parameter plot of the variation of the speech energy spectrum with time. Fig. 5 shows a spectrogram of the utterance "go away." Frequency is given on the vertical axis, and bands are shown at the beginning to indicate the scale. Time is plotted horizontally, and energy is given by the darkness of any particular area. The lower few formants can be seen as dark bands extending horizontally, and they are in continuous motion. Notice that in the neutral first vowel of "away," the formant frequencies approximate the 500Hz, 1500Hz and 2500Hz that we calculated earlier. (In fact, formant 2 is around 1250Hz and formant 3 around 2300Hz.) The fine vertical striations in the spectrogram correspond to single openings of the vocal chords. Of course, the pitch is continuously changing throughout an utterance, and this can be seen on the spectrogram by the differences in spacing of the striations. Pitch change, or *intonation*, is singularly important in lending naturalness to speech.

On a spectrogran, a continuously held vowel shows up as a static energy spectrum. But beware – what we call a vowel in everyday language is not the same thing as a "vowel" in phonetic terms. Say "I" and feel how the tongue moves continuously while you're speaking. Technically, this is a *diphthong* or slide between two vowel positions, and not a single vowel. And there are many more phonetically different vowel sounds than the a, e, i, o and u that we normally think of. The words "hood" and "mood" have different vowels, for example, as do "head" and "mead." The principal acoustic difference between the various vowel sounds is in the frequencies of the first two formants. Table 1 gives a list of the English vowels, with a one- or two-character name for each, an example

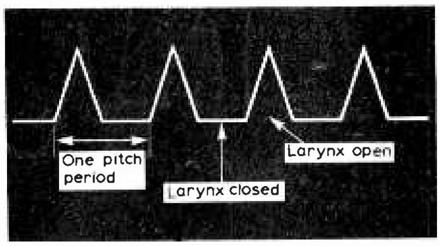



**Fig. 2.** *Approximate waveform produced by the larynx.*

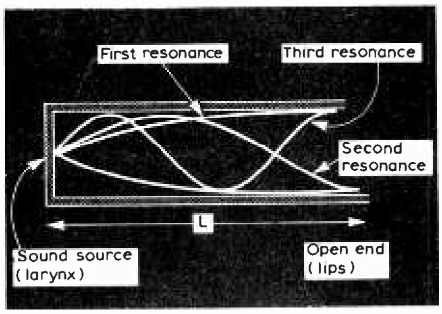



**Fig. 3.** *Resonances in the organ-pipe model of the vocal tract.*

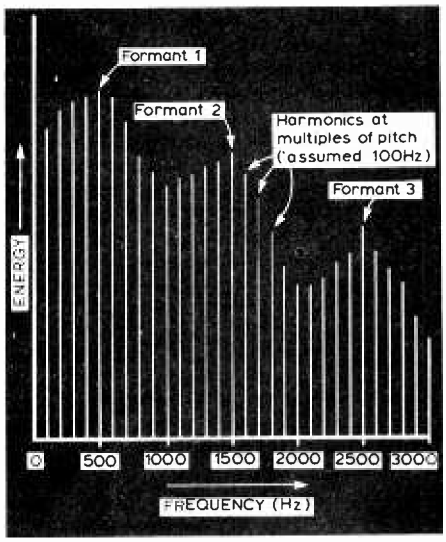
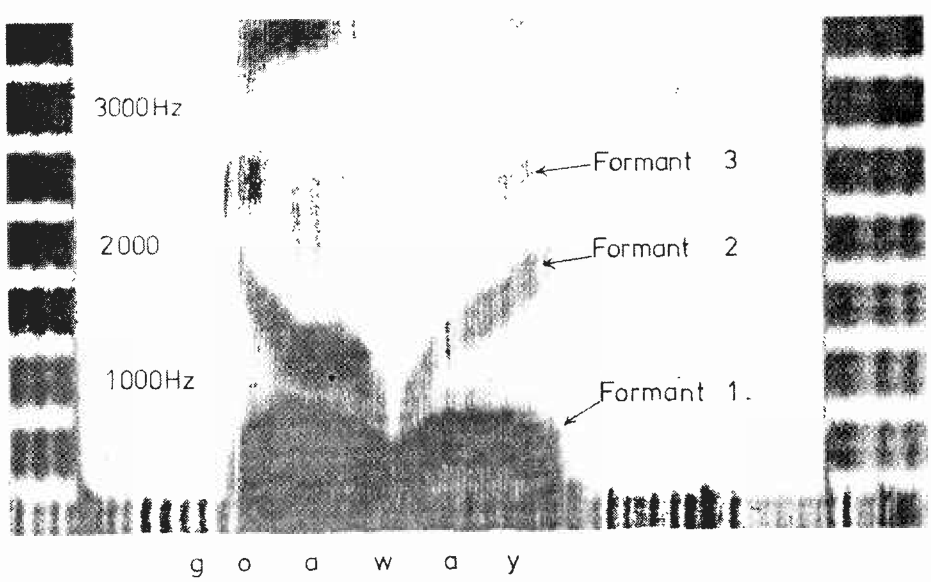



**Fig. 4.** *The energy spectrum of speech, showing three formants.*

**Table 1. The vowels and their formant frequencies**

| Vowel name | Example of use | F1 (Hz) | F2 (Hz) |
|---|---|---|---|
| UH | ab(ove) | 500 | 1500 |
| A | bud | 700 | 1250 |
| E | bed | 550 | 1950 |
| I | bid | 350 | 2100 |
| O | bod | 600 | 900 |
| U | good | 400 | 950 |
| AA | bad | 750 | 1750 |
| EE | bead | 300 | 2250 |
| ER | bird | 600 | 1400 |
| UU | brood | 300 | 950 |
| AR | bard | 700 | 1100 |
| AW | board | 450 | 750 |

**Fig 5.** *Spectrogram of the utterance "go away."*



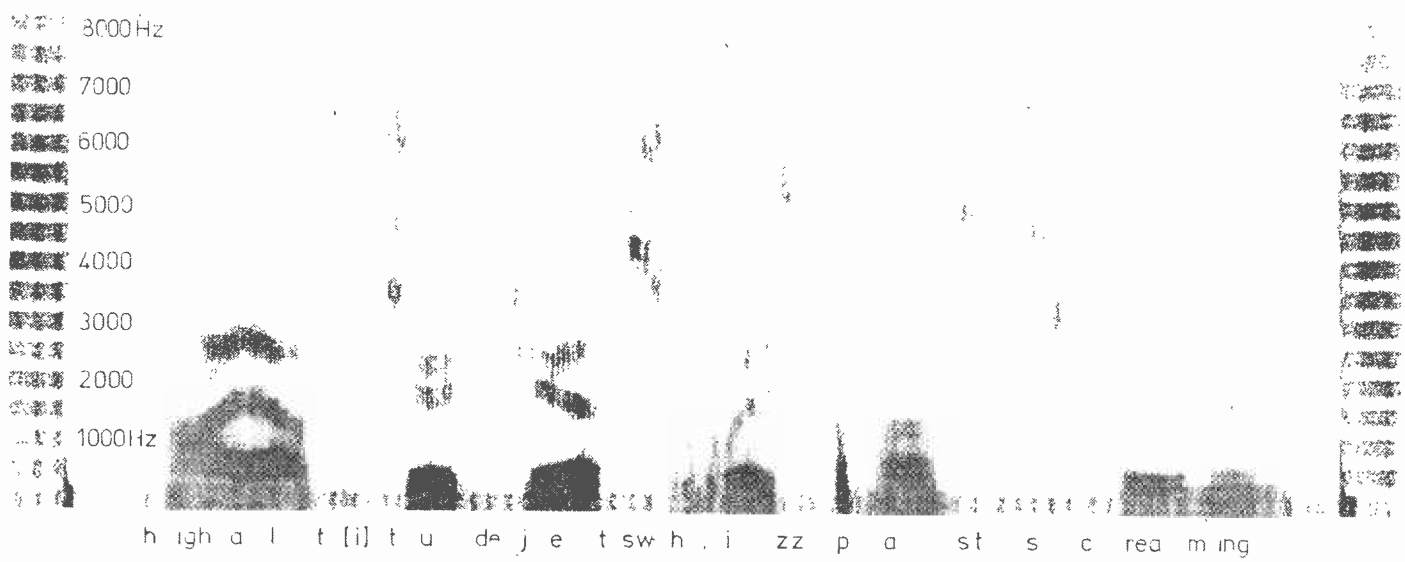



**Fig. 6.** *Spectrogram of "high altitude jets whizz past screaming."*

word, and the two formant frequencies which characterize the sound.

Speech involves other sounds, different from the voiced ones that we have been discussing so far. When you whisper, the folds of the larynx are held slightly apart so that the air passing between them becomes turbulent, causing a noisy excitation of the resonant cavity. The formant peaks are still present, superimposed on the noise. Such "aspirated" sounds occur in the "h" of "hello," and for a very short time after the lips are opened at the beginning of "pit."

Constrictions made in the mouth produce hissy noises such as "ss," "sh," and "f." For example, in "ss" the tip of the tongue is high up, very close to the roof of the mouth. Turbulent air passing through this constriction causes a random noise excitation. For "sh," the tongue is flattened close to the roof of the mouth, in a position rather similar to that for "ee" but with a slightly narrower constriction, while "f" is produced with the upper teeth and lower lip. If the larynx is vibrating as well we get the corresponding voiced sounds "z," the "zh" in "azure," and "v." Because they are made near the front of the mouth, the resonances of the vocal tract have little effect on these hissy sounds. The complicated acoustic effects of noisy excitations in speech can be seen in the spectrogram Fig. 6 of "high altitude jets whizz past screaming."

## Speech synthesis and synthesizers

The idea of artificial speech has always fascinated man. The first genuine talking machine appears to have been demonstrated in 1791 by one Baron von Kempelen, who used bellows to inject sound into a leather tube which modelled the vocal tract, and was deformable with the hands to imitate the different vowel sounds. Progress continued sporadically (one notable achievement being Alexander Graham Bell's encouraging his pet dog to talk by manipulating its vocal tract by hand while the dog growled), until the need for bandwidth reduction for efficient use of communication channels in the 1940s and 1950s stimulated serious research on the acoustic nature of the speech signal. Since then, the advent of widely-available real-time computing power has encouraged work on speech synthesis under computer control, and the difficult problems of pronunciation, speech rhythms, and intonation are currently being tackled to exploit this novel and effective computer output medium.

In order to simulate electrically the resonating action of the vocal tract on the sound generated by the larynx, a waveform generator and several resonant filters in cascade are needed. Varying the frequency and amplitude of the sound source simulates changes in the pitch and loudness of the speech, and different vowels can be made by adjusting the positions of the resonances appropriately.

Further analysis of the organ-pipe model reveals that simple second-order resonators with unity d.c. gain are appropriate filters, with the slightly unusual requirement that the bandwidths should remain constant as the resonant frequencies are altered, producing sharper resonances at higher frequencies (Fig. 7). The phase response of the filters is not important. Such resonators can be achieved with simple active filter circuits.

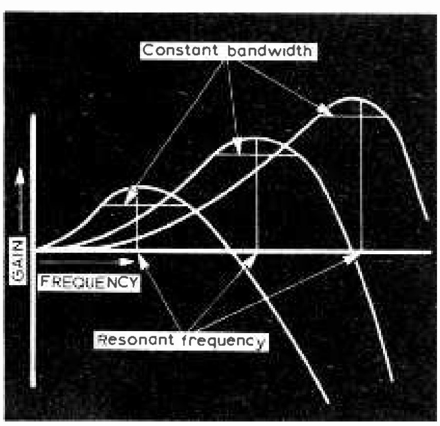



**Fig. 7.** *Amplitude profiles of the resonant filter.*

Although vocal tracts, like organ pipes, have an indefinite number of resonances, in practice only a few filters are employed in the chain (Fig. 8). Most existing synthesizers simulate four or five formants, of which typically only the first three have controllable resonance positions. In fact, two formant filters are sufficient to generate most vowel-like speech sounds: a third is especially useful in distinguishing the "r" in "rice" from the "l" in "lice." Omitting the higher resonances means that some compensation filter needs to be introduced to give spectral lift at higher frequencies.

Whispery sounds can be synthesized by injecting noise into the chain of formant filters, instead of the harmonic-rich pulse of the waveform generator. For the sibilant sounds made at the front of the mouth, the noise should not be injected into the formant chain, but instead passed through a separate high-pass resonance whose centre frequency can be controlled to give the sounds "f," "sh," and "ss."

These considerations lead to the block diagram of Fig. 9. A synthesis system similar to this was invented in 1951 by Walter Lawrence, and he called it PAT – Parametric Artificial Talker. The eight circled numbers represent parameters of the system, and if they are varied appropriately, it can be persuaded to give a respectable imitation of almost any speech utterance. For example, the parameter tracks for "six" are shown in Fig. 10 as a set of eight graphs. You can see the onset of the hissy sound at the beginning and end (parameter 5), and the amplitude of voicing (parameter 1) come on for the "i" and go off again before the "x." The pitch (parameter 0) is falling slowly throughout the utterance.

Naturally, storage of the parameter tracks presents some problems. In the earliest version of PAT, eight parameter-versus-time graphs were painted on a glass slide, which was scanned photo-electrically to read off the parameter values. Lawrence was fond of disconnecting the pitch parameter and controlling it directly with a potentiometer. One of the utterances for which he had prepared a glass slide was "What did you say before that?" and he could manipulate the pitch by hand to change the emphasis, getting "What did you *say* before that?", "What did you say *before* that?" and so on. Even artificial singing proved possible! In fact, the earliest computer conversation on record was between PAT and a Swedish synthesizer, called "Ove." The inventors, Gunnar Fant and Walter Lawrence, stood by their machines on a stage at an international acoustics meeting, Fant with a small transistorized table-top box, and Lawrence with several great racks of valve-based equipment. The conversation went

Ove: "How *are* you?"
PAT: "What did you say before *that*?"

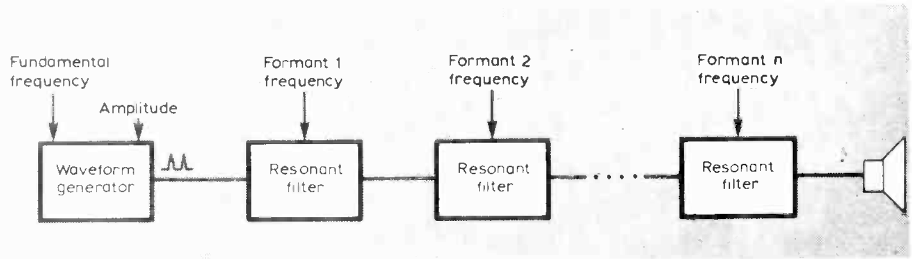



**Fig. 8.** *Simulating the resonance action of the vocal tract.*

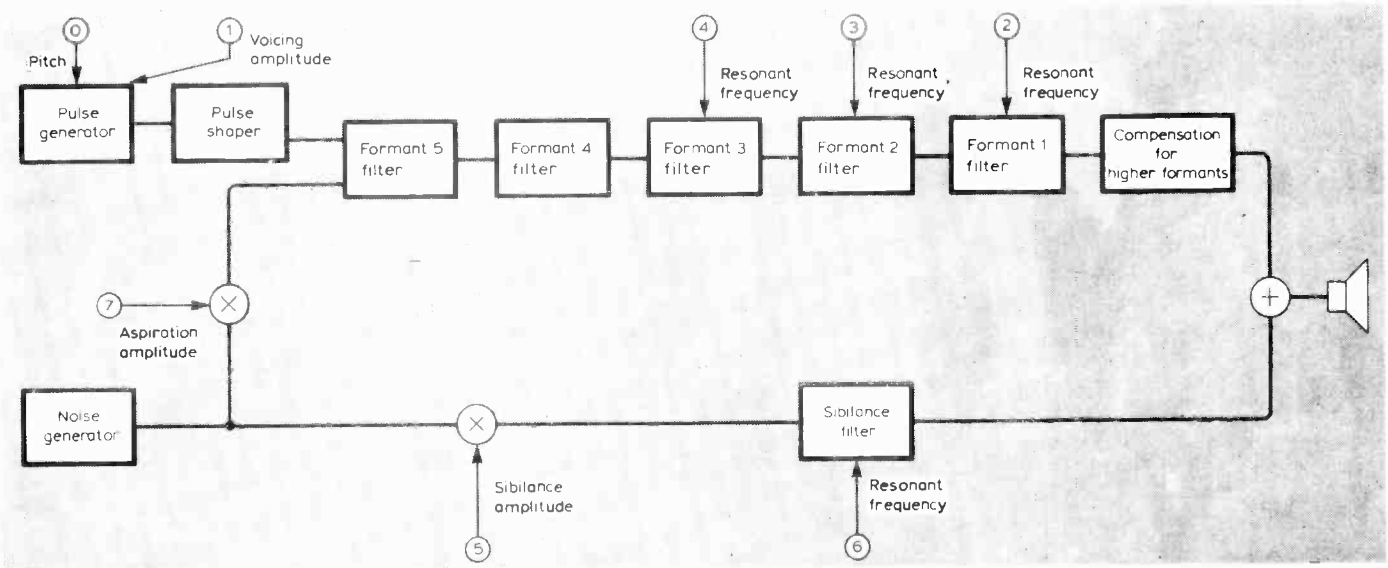
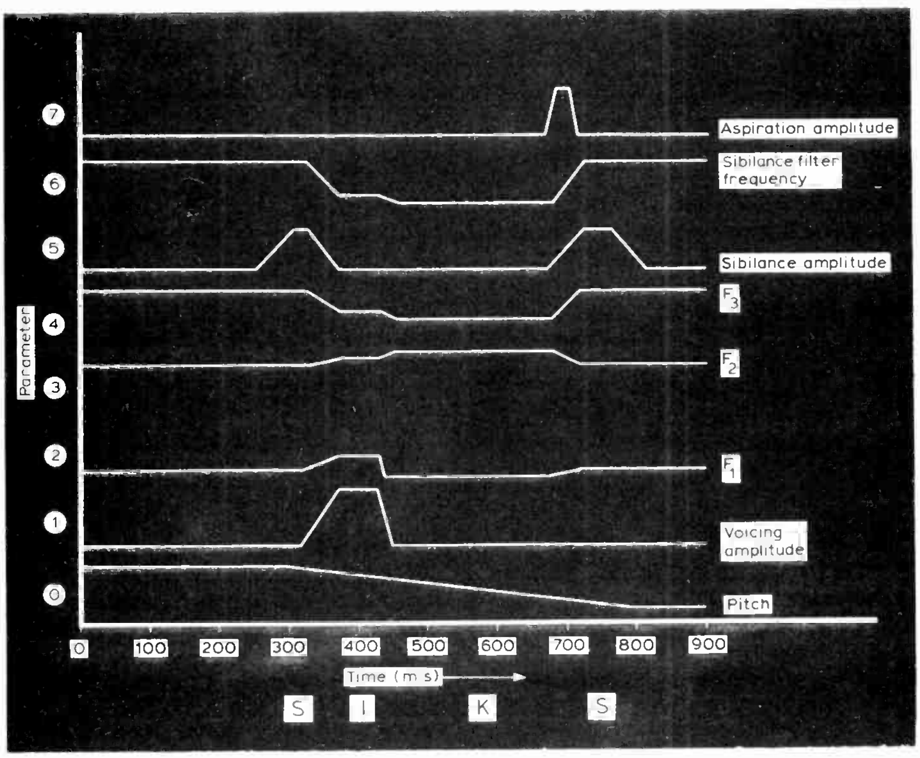



**Fig. 9.** *Block diagram of PAT, the Parametric Artificial Talker.*

**Fig. 10.** *Parameter tracks for "six" with the Parametric Artificial Talker.*




Ove: "I love *you*."
PAT: "What did you say *before* that?"
Ove: "I love *you*."

At which point, PAT burst into song (no prizes for guessing the words!).

To obtain good speech, the best way of getting parameter tracks is to derive them from spectrograms of human utterances. Although this is a tiresome and time-consuming process, it gives the synthesizer a chance to reproduce the precise acoustic quality of the original speech. However, the parameter tracks of Fig. 10 are stylized: they don't come from a human utterance. In fact they were generated by a computer programme from the input "S I K S", a phonetic transcription of the word. This programme has direct control over the parameters of a hardware synthesizer through a computer interface, and will attempt to speak any utterance that is entered in phonetic format. In practice, the most difficult parameter to control in a convincing way is pitch. The intonation of speech is subtle, and evades classification into a form that a computer programme can handle.

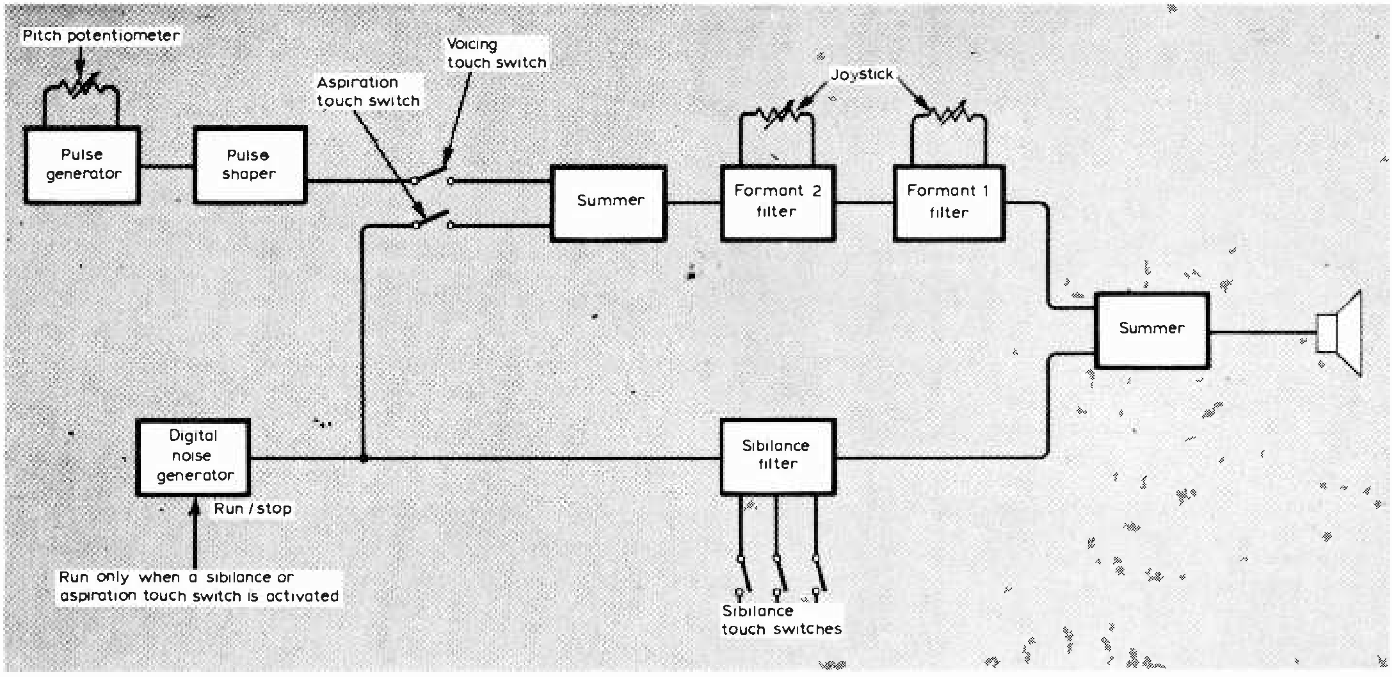



Fig. 11. *Chatterbox block diagram.*

The Chatterbox, however, avoids these difficulties of computer control by using a person to manipulate the parameters. Generating natural-sounding intonation is easy for people, and this turns out to be true even if they have to use their hands rather than their vocal tracts to control the pitch.

## System design of Chatterbox

**The manual controls.** Hands were never intended to speak! In your vocal tract, separate muscles control a multitude of parameters of the system simultaneously in order to produce speech sounds. Pitch is controlled by the vocal cord tension, amplitude by the lung pressure, and vowel quality by the many dimensions of movement of the tongue, teeth and lips. The greatest challenge of the Chatterbox design was the engineering of the man-machine interface: it is difficult physically to find enough degrees of freedom to control it with the hands. In fact, we even considered using arm and leg movements in addition to hands, but felt that these detracted from the neatness and compactness of the toy.

A single X-Y control is used to vary the two formant filter frequencies. Two models of Chatterbox have been designed and constructed, one with a joystick control and the other with a stylus and resistive plastic pad instead. Fortunately, the recent popularity of quadraphonic audio systems means that it is quite easy to get hold of a compact joystick assembly designed as a quad balance control. Ours had two tracking potentiometers for each direction of motion, and we took advantage of this in designing the formant filters. The alternative stylus arrangement gives a two-dimensional position indication by injecting a current from the stylus tip into a uniformly resistive plastic sheet, and monitoring the current from the sides of the sheet. Since it is fairly difficult to lay hands on a suitable resistive sheet for the stylus model, and the circuitry to take advantage of this is more complex anyway, we will describe only the joystick version here.

The pitch is varied by a potentiometer. We decided, after some experimentation, that linear rather than rotary control feels more natural, so a slider potentiometer is used. This is operated with one hand while the other directs the joystick.

Turning to control of the volume of the sound, it transpires that contrary to intuitive expectations, it is not important to provide variation of the amplitude of the voice source, apart from the obvious necessity to switch it on and off. Different vowel sounds do have different amplitudes, of course, because of different degrees of mouth opening (compare the vowels in "mad" and "mood", for example). However, this is taken care of by the formant filters: resonances for "mood" will naturally produce a weaker sound than in "mad" because they occur at lower frequencies, and the constant bandwidth property of the filters gives them less amplification (that is, lower Q) at lower resonance frequencies. The amplitude of the sound produced by the vocal cords corresponds more to vocal effort than to loudness, and this is more or less constant for the great majority of speech sounds. Hence we use a simple switch to turn the voicing on and off.

The hissy sounds pose the most difficult control problem. Aspiration (whispering) can be treated just like the voicing amplitude: we need only be able to turn it on and off. The joystick formant control can then be used to whisper different vowel sounds. However, constrictions in the front of the mouth must be treated separately, for here the sound type ("ss", "sh" and "f") needs to be controlled independently of the voicing, so that the counterparts "z", "zh" and "v" can be produced simply by superimposing a normal vowel-like sound. We opted for separate switches for these three noises, instead of an analogue control which would simulate the tongue positions more accurately. These are operated by the same hand that manipulates the pitch potentiometer, as is the aspiration switch. This arrangement is not parti-

### Further reading

**The anatomy of speech**

The "source-filter model of speech production," which separates the sound source (larynx) from the filtering operations of the vocal tract, was treated most comprehensively by Gunnar Fant in *Acoustic theory of speech production*, 1960.

The sound spectrograph was developed in 1946 by Koenig, Dunn, and Lacey ("The sound spectrograph," *Journal of the Acoustical Society of America*, vol. 18, pp. 19-49) and is described, with hundreds of spectrograms, by Potter, Kopp and Green (*Visible Speech*, 1947).

**Speech synthesis and synthesizers**

A classic book is *Speech analysis, synthesis and perception*, by James Flanagan of Bell Laboratories in the USA (1965, revised 1972). There is a book of collected papers on speech synthesis by Flanagan and Larry Rabiner called *Speech synthesis* (1973). A British contribution is *Speech synthesis* by John Holmes of the Government Joint Speech Research Unit (1972). Walter Lawrence wrote "The synthesis of speech from signals which have a low information rate" (in *Communication theory*, edited by W. Jackson, pp. 460-469) when he invented PAT in 1953 in the Government Signals Research and Development Establishment.

cularly easy to use, but since pitch control is unimportant during hissy sounds, it is possible to share the pitch hand satisfactorily between all these functions.

It is essential, however, that the voicing on/off switch is easy to operate while complicated pitch movements are being made, because the moment of onset and offset must be timed precisely, without disrupting the smooth flow of intonation. In the pad-and-stylus Chatterbox, it is possible to detect electrically when the stylus is in contact with the pad, and this is used to turn on the voice. A similar arrangement could be made in the joystick model if the act of grasping the joystick were detected, but this would involve modification of the joystick assembly. We opted instead to site a switch contact where it could easily be reached with the heel of the hand that operates the joystick.

All switches on the Chatterbox are touch switches, and work by detecting the skin resistance when two adjacent contacts are touched together. These are much easier to use – and cheaper to build! – than, say, pressure operated microswitches.

**The overall system.** The Chatterbox is essentially a simplified version of Lawrence's original PAT. As shown in Fig. 11, it consists of two parallel signal paths, a voicing/aspiration path (top of diagram) and a sibilance path (bottom). Two formant filters form the upper path, each controlled by one direction of the joystick. These can be excited by a simulated larynx pulse, produced by a variable-frequency impulse generator, or by a noise source (for aspiration). We use a digital pseudo-random generator implemented by a feedback shift register with exclusive-OR feedback. The same noise source drives the lower sibilance path, which includes a high-pass resonance to give the noise an appropriate colouration. The position of the resonance is controllable to three places by touch-switches. A full circuit diagram of the system is shown in Fig. 12, and the various sections of this will be explained here and next month.

**Source for voiced sounds, and mixer.** A simple circuit using c.m.o.s. gates forms the basis of the voicing waveform generator. This circuit is used because of its simplicity and low cost. The 100kΩ potentiometer varies the frequency of the oscillation. The output from the oscillator is inverted, delayed, and "ANDed" with itself. This produces a train of spikes which is the required harmonic-rich voicing waveform. The circuit is turned on and off by a logic signal from one of the touch switches shown in Fig. 12. The period can be adjusted from a very low value, 20Hz (good for sound effects and "creaky voice"), up to 200Hz. The harmonic content of the spiky waveform is very high and provides a suitable excitation for the formant filters. The 741 amplifier that follows this circuit is used both to add a signal from the noise generator to produce aspirated sounds and to adjust the amplitude of both sources.

*To be continued*

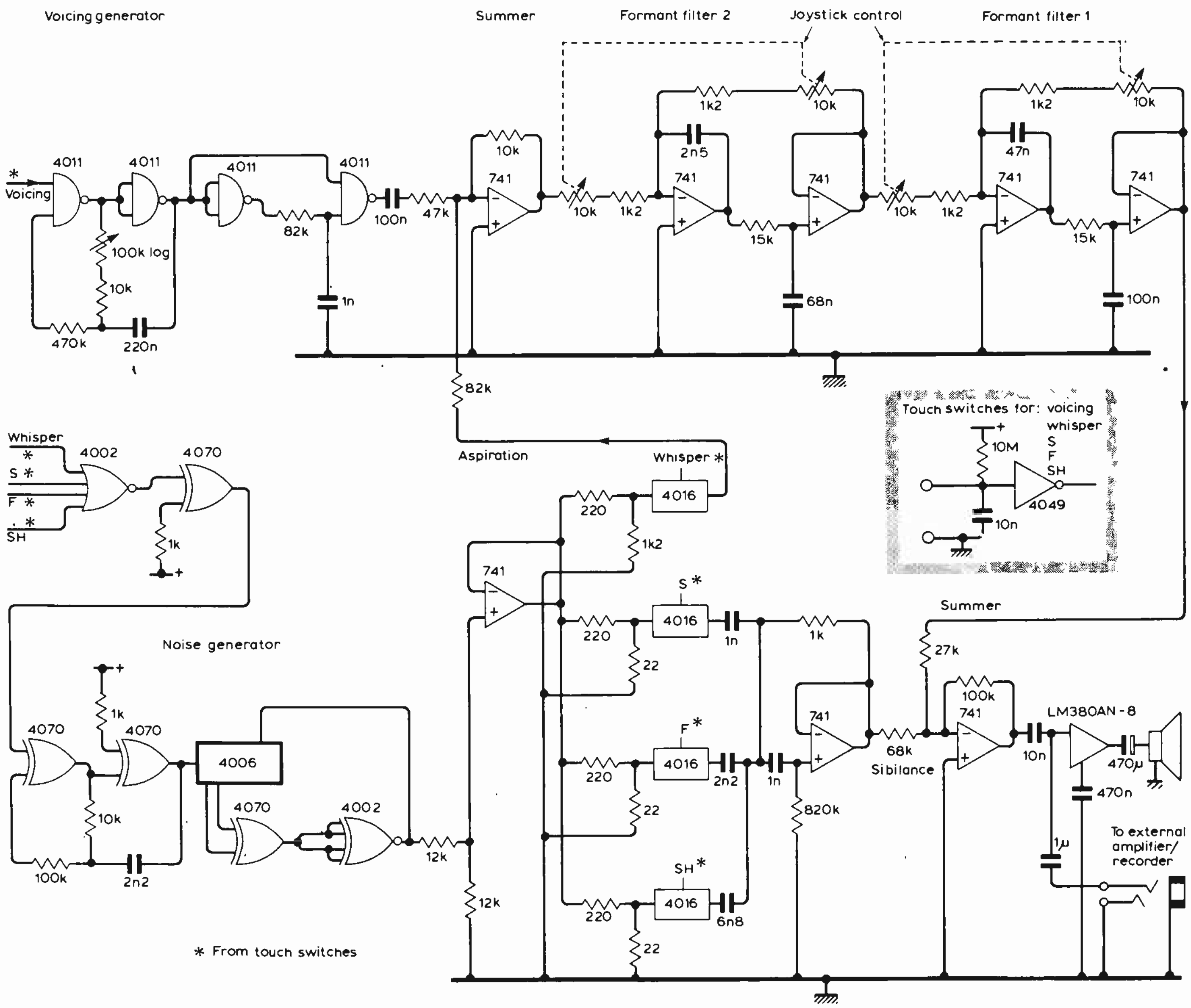



*Fig. 12. Full circuit diagram of the Chatterbox.*

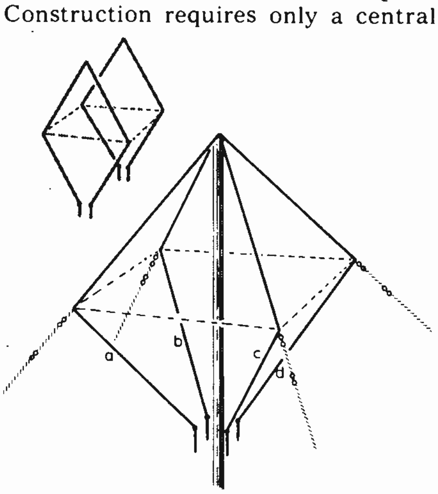
# WORLD OF AMATEUR RADIO

## Rotary or switched?

THE MECHANICALLY rotatable h.f. beam aerial was developed in the 1930s and 1940s, mainly by radio amateurs. It provided the high power gains and good front-to-back ratios associated with Yagi and Quad arrays in gardens far too small to accommodate the rhombic farms or multiple sloping-V aerials used in professional communications. Today, of course, rotatable aerials are used professionally, including large log-periodic arrays favoured by some h.f. broadcasters. Amateur rotatable arrays however are still mechanically complex, do not always survive winter gales and can be operationally inconvenient in the time taken to swing them round to another direction.

Increasingly a good deal of effort is being directed away from mechanically rotatable arrays towards arrays which can instantly be switched to radiate in a number of different directions. Such arrays can of course be formed fairly simply from two or more monopoles by incorporation of phase delay sections in the feed lines, for example by switching in additional lengths of coaxial cable. But while such arrays can provide useful "nulls" the forward gain, at least with limited space, is low and results are also greatly influenced by earthing radials and ground conductivity. Reversible uni-directional fixed arrays such as the "G8PO" and "ZL-Special" have been used and the rotary Quad can be made instantly reversible by bringing two open-wire lines into the shack.

A novel approach to this problem, providing an array that can readily be switched to fire towards the four quadrants has been described by the Russian amateur L. Vsevolzhskii, UA3IAR in *Radio* (Moscow) No. 6, 1978, and is based on a modified form of fixed Quad. Construction requires only a central supporting pole with no large framework or tubular elements. The array is formed by appropriate selection (by relays) from four half-loops so that four different configurations, each comprising a radiator and driven active phase-adjusted reflector, are available.




*The UA3IAR switchable quad aerial, showing its development from a conventional array. The four half-loops abcd are electrically joined at the top, and pairs of half-loops are used to form the full-wave loops which function either as radiator or, with the additional phasing extensions, as driven reflectors.*

While the Russian amateur has been using the system since 1973, he makes no claim as to forward gain. Les Moxon, G6XN, an authority on Quad aerials, while recognising that the Russian idea is "too good to be turned down" is convinced that it is capable of further improvement and that the array as described is unlikely to have a forward gain exceeding about 3.5dB compared with perhaps 5-6dB for a conventional Quad.

It will be interesting to see who will be the first to come up with a low-cost switch-rotatable beam with a forward gain exceeding say 5dB. Such a system represents an important technical challenge. UA3IAR has clearly shown the possibilities by providing a simple, rugged system – and 3.5dB forward gain with useful side nulls is not to be scoffed at!

## Band scan

During September problems arose in the Oscar 7 satellite (launched November 1974) affecting the operation of the "Mode B" tansponder (432 to 145 MHz) and amateurs have been asked to confine working through the satellite to Mode A (145 to 29 MHz).

A new Norwegian beacon station LA6ER operates from batteries kept charged by solar panels.

An international group "SMIRK" is dedicated to keeping 50MHz active and used by amateurs in those countries where it is available. It has some 2,630 members in 27 countries. British amateurs cannot use the band but are watching carefully to see what happens after the closing down of 405-line television.

Amateurs continue to report "pirating" of their callsigns by unlicensed station (I once replied to a "CQ DE G3VA" call and gave the pirate such a shock that he promptly closed down). However, according to Dr John Allaway, G3FKM, a mean new illegal practice has been noticed recently: stations using other people's callsigns while causing deliberate interference. Also to be heard increasingly on some bands is deliberate rudeness to foreign amateurs, especially when these are inexperienced operators. There are times when it seems that British amateurs are losing their responsible attitudes to amateur activities.

## A prefix is a prefix

At one time the international prefix (initiated in the late 1920s) was a useful device that immediately denoted the location of the station. This can hardly be said always to be the case today where special prefixes are eagerly sought in order, it often seems, to mystify the listeners. Surprisingly the American regulatory body, the FCC, seems to have become one of the worst offenders. I continue to find it annoying when stations with such prefixes as AC4 and KA2 turn out to be in Florida or New York. And one wonders why the United Nations HQ in New York (4U1UN) or the ITU station in Geneva (4U1ITU) should be classified as "countries". But at least the American Radio Relay League is reported to have considered the possibility of denying future DXCC requests for demilitarised neutral zones, embassies, consulates, or "extraterritorial monuments" to count as separate countries. Why does the hobby seem so keen to insist on such absurdities?

## In brief

John Bazley, G3HCT, has been elected RSGB president for 1979 . . The RSGB is to make available to its members a personal identity card to help deal with official enquiries when operating portable radio equipment . . . The deaths have been reported of two amateurs closely concerned with national amateur radio exhibitions: Phil Thorogood, G4KD, for many years associated with the London exhibitions; and Tom Darn, G3FGY, organiser of the Leicester exhibitions in recent years . . . FCC has rejected petitions seeking to expand the US phone allocations as being unwise just before WARC 1979 and for other reasons . . . Violators of CB rules in the USA are losing not only their CB licences but also their right to obtain amateur licences while a number of amateur licences have been revoked for operation just below 28MHz . . . A regular bulletin of news is broadcast in r.t.t.y. from VK2TTY on Sunday mornings on 7 and 14MHz . . . The use of 1800-1810kHz by amateur stations in Hawaii has been extended indefinitely following a year's check on possible interference to navigational aids.

**PAT HAWKER, G3VA**

# Measuring spectrum use

## CCIR spectrum efficiency definition could affect all radio systems

By **Leslie A. Berry,** M.A. National Telecommunications and Information Administration, Institute for Telecommunication Sciences, USA.

This article puts forward a way of measuring the efficiency with which radio services use the electromagnetic spectrum. The subject is significant because the CCIR is likely to adopt a formal definition of spectrum efficiency soon, and the resulting changes in international regulations could affect all radio systems planners, designers and operators. The measure proposed here, a ratio of communications output to spectrum-space input, is easier to compute than another candidate based on an ideal system, claims the author, and gives the same relative result. Examples of the application of the proposed efficiency measure are included.

SPECTRUM efficiency is widely advocated. With many countries and services expected to press for larger frequency allocations at the 1979 WARC, efficient use of allocated spectrum will be an important consideration. But there is no generally accepted definition of spectrum efficiency or even a measure of spectrum use. The International Radio Consultative Committee (CCIR) has called for such a definition[1], and it is likely that one will be adopted at the next Plenary Assembly. If a definition is adopted, present CCIR recommendations and international radio regulations may be changed to call for "maximum spectrum efficiency," rather than for minimum necessary bandwidth as they now do. Within nations, the relative spectrum efficiency of services competing for allocations (for example, broadcasting and land mobile radio) may influence regulatory decisions. It is therefore important that the definition be realistic and computable.

Several definitions have been proposed[2-8]. Some of these are for specific services; others are generally applicable; but all can be cast in one of two general forms. One form is the ratio of the communications output to the spectrum space used to produce the output, which will be called the output/input efficiency. The other form is the ratio of the spectrum space used by an "ideal" system to the spectrum space actually used, which will be called the ideal/input efficiency.

Later I will show that the two forms always give the same relative result and that the output/input measure is easier to compute. However, a measure of the spectrum-space input must be defined first.

### Components of spectrum space

Efficient spectrum use comes from geographic re-use or time sharing of radio frequencies. So, it is generally, but not universally, agreed that the components of spectrum space should be radio-frequency bandwidth, physical space (such as area or volume), and time[2-12]. There have been suggestions that other quantities, such as polarization and modulation, are also dimensions of spectrum space because systems using values of the parameters that are "orthogonal" or nearly orthogonal do not interfere with each other[13]. However, these proposed quantities do not have the characteristics of a dimension of a metric space, and so they will not be included in the measure of spectrum space use. They will influence the value of spectrum efficiency.

The dimensions of the physical space depend on the service that is involved. For terrestrial services such as broadcasting and land mobile radio, area is used as a factor, as proposed by Gifford[2] and Powers[3], for example. The critical physical space for geostationary satellites is a line — the geostationary orbit. So measures of spectrum space for this service usually include degrees of arc (a linear metric)[4,5]. In some cases the relevant physical space is volume[7], and for point-to-point services it may be angle around a pivotal point.

The importance of the time dimension varies with the service. Many services operate continuously with analogue modulation (for example, point-to-point microwave, some broadcasting, navigation services); so the time factor is a constant. In other services, such as land-mobile radio, time sharing is of vital importance to efficient spectrum use.

**The author** Leslie A. Berry has been studying technical trade-offs for efficient use of the radio spectrum since 1971. He received the M.A. degree in mathematics from the University of Kansas in 1960 and joined the Central Radio Propagation Laboratory in Boulder, Colorado. He contributed to the theory of l.f. and v.l.f. radio propagation and to the theory of propagation over irregular, inhomogeneous terrain. Through government reorganization, he is now on the staff of the National Telecommunications and Information Administration, Institute for Telecommunication Sciences. He has twice been a US delegate to CCIR Study Group 1 (spectrum utilization) meetings.

### "Used" means "denied to others"

The area around a transmitter in which a reliably usable signal can be received is almost always smaller than the area in which the same transmitter can cause unacceptable interference. For purposes of spectrum management and efficiency, it is clearly the area that is denied to other potential users that is important. This is the area that is related to spectrum saturation. Similarly, it is the bandwidth and time that are denied to other users that is critical in frequency assignment.

It is proposed that the unit of measurement of spectrum-space use be defined as the product

(bandwidth) × (relevant physical space) × (time)

that is denied to other potential users.

There are two ways in which spectrum space can be denied. The space is physically denied if it is filled with sufficient power to interfere with other proposed operations. This is the denial of interest to spectrum engineering. Definitions of a spectrum measure based on physical denial are developed in the appendix.

Frequently the spectrum space is administratively denied. That is, frequency managers make rules or frequency assignments denying space to other users even if that space is not filled with interfering radiation. Administrative denial is sometimes a practical upper bound to physical denial imposed to account for the statistical variability of radio system performance and to make management of the spectrum simpler. In other cases, administrative denial is related to the spectrum space used by the receiver.

### Spectrum-space use by receivers and transmitters

Traditionally radio transmitters have been considered to be the users of the spectrum resource. They use the spectrum space by filling some portion of it with radio power — so much power that receivers of other systems cannot operate in certain locations, times, and frequencies because of unacceptable interference. Notice that the transmitter denies the space to receivers only. Power in a space in no way prevents another transmitter from emitting power into the same location; that is, the transmitter does not deny operation of another transmitter.

On the other hand, receivers use spectrum space because they deny it to transmitters. Operation of the receiver interferes with no one (except as it inadvertently acts as a transmitter or power source — even then the space used physically is small). However, in an attempt to guarantee interference-free reception, the authorities deny licences to transmitters. The protection may be in space (separation distance, co-ordination distance), in frequency (guard bands), or even in time (in the United States some m.f. broadcasting stations are limited to daylight operation). This denial constitutes "use" of the space by the receiver. The radio astronomy bands are a familiar example of the recognition of receiver use of the spectrum space.

Thus receiver and transmitter usage of the spectrum resource results in complementary denial: transmitters deny use of a time-frequency-geographic region to receivers wishing to receive another signal, and a protected receiver denies a time-frequency-geographic region to transmitters whose operation would interfere with it. An obvious way to incorporate these facts into a unit of measurement of spectrum space is to partition the resource into two spaces — the transmitter space and the receiver space — and define dual units to measure the usage of each space.

For administrative simplicity, the two units can be recombined into a single measure of system use. Similarly, the spectrum space used by all systems in a particular service can be defined as the space denied to other services.

## A measure of spectrum efficiency

The concept of quantifying efficiency by the ratio of desired output to valued input is familiar to people in all walks of life. A measure of personal transportation efficiency, miles/gallon, illustrates several features of generally accepted measures of efficiency. The numerator is the desired output of interest — even though it may not represent the entire output or system function. The denominator is a measure of the critical input required to produce the output. Notice that the numerator and denominator need not be the same kind of quantity, and that the units of the resultant ratio may not make "sense" — the units of miles/gallon turn out to be inverse area!

This measure of efficiency does not include all of the technical detail that an engineer might want, but it communicates significant information to the non-engineer — the consumer, the policy maker, and the government regulator. To be valuable and accepted, a measure of spectrum efficiency also should be understood and usable by non-engineers — the lawyers, economists, and nonspecialists who make final decisions about spectrum use in the International Telecommunication Union and national regulatory agencies.

Therefore, the measure of spectrum efficiency should have the general form

$$\frac{\text{communications achieved}}{\text{spectrum space used}}$$

or more generally (to accommodate radar, navigation systems, radio control, etc.)

$$\frac{\text{information delivered}}{\text{spectrum space used}}$$

The nature and units of the numerator will depend on the type of service provided. The quantity of information in the signal (measured, for example, in bits), the distance over which it is transmitted, and the number of people who receive the message should be included in the numerator.

The spectrum efficiency of an entire service, such as tv broadcasting, can be computed by aggregating the total communications achieved and divided by the total spectrum space denied to other users.

## Examples of input/output measure

Engineers addressing practical problems of interest to them have defined input/output ratios naturally. A notable example is the measure of "orbit utilization efficiency," defined by CCIR Study Group 4 in 1974, for the geostationary satellite service[4], and still under study[5]. For digital modulation, they defined efficiency as

$$\frac{\text{bit rate}}{\text{(r.f. bandwidth)(orbit arc in degrees)}}$$

Since bit rate is bits/s, this can be written

$$\frac{\text{bits}}{\text{(r.f. bandwidth)(orbit arc)(time)}}$$

This is precisely the form recommended for the output/input efficiency measure. The numerator is the amount of information transferred (measured in bits), and the denominator is the product of bandwidth, time, and geometric space. In this case, the critical geometric space is the geostationary orbital arc — a line.

For analogue communications satellites, the orbit utilization was defined to be

$$\frac{\text{information bandwidth}}{\text{(bandwidth)(orbit arc)}}$$

In this case, the information delivered is not quantified. Instead, the surrogate quantity (information bandwidth) is used because it is proportional to the potential rate of information transfer. This example illustrates one of the practical compromises that can be made in implementing the general form of the definition.

Hatfield[8] reviewed measures of spectral efficiency proposed for comparing land mobile radio systems and concluded that the most useful definition of spectral efficiency is

$$\text{erlangs/MHz/mi}^2$$

Since an erlang is a measure of traffic per unit time, this ratio can be rewritten

$$\frac{\text{traffic}}{\text{(bandwidth)(area)(time)}}$$

which is precisely the output/input ratio for spectrum efficiency.

Starting with the general form, but not including time as a factor, Vinogradov[3] developed an explicit formula for the spectrum efficiency for a point-to-point radio link. Considerations used to derive the formula include the antenna gains and sidelobe power, the transmitter power and emission bandwidth, polarization, receiver sensitivity, and path length.

## Another candidate

One proposed definition of "spectrum efficiency" has the form[2,14]

$$\frac{\text{spectrum space used by "ideal" system}}{\text{spectrum space used by the system being evaluated}}$$

The denominator of this ratio is intended to be the same as the denominator of the output/input ratio; namely, the product of bandwidth, geometric space, and time denied to other users. The numerator is the product of the same three factors that an "ideal" or "perfect" system performing the same function would deny to other users.

The ideal/input measure conforms to the traditional engineering concept of efficiency — a dimensionless number between 0 and 1. However, to non-specialists it may have a parochial flavour — a preoccupation with conserving spectrum space as an end in itself. Returning to the miles/gallon analogy, would consumers want to replace the miles/gallon measure with one which compared the amount of fuel used by an "ideal" automobile with the amount used by a particular model? Such a measure does allow ranking of different systems, but gives no guidance as to what the customer gets for his input of petrol. Since many decisions about spectrum use are made by non-specialists, it is advantageous to have a measure of spectrum efficiency that they intuitively grasp.

Technical advantages of the output/input ratio are that it is less subjective, takes fewer steps to compute, and gives the same relative answer as the ideal/input measure of spectrum efficiency.

For example, suppose that the spectrum efficiency of a point-to-point microwave link must be computed. The link must carry a fixed number of telephone circuits $m$ miles a given percentage of the time. This is the "output" which is the numerator of the output/input efficiency ratio: $x$ circuit miles for $p$ percent of the time. To complete the calculation of the efficiency, the spectrum space (bandwidth × area × time) the link denies to other users must be computed. Although this calculation is not trivial, it is not necessary for the present comparison because both measures of spectrum efficiency have the same denominator.

Now consider the calculation of the ideal/input efficiency measure. The calculation of the denominator is the same as before. Also the output ($x$ circuit miles with reliability $p$) must still be specified else how can the ideal system be determined? And what is the amount of spectrum space used by the "ideal system"? The transmission could be via coaxial cable or by waveguide which would use almost zero spectrum space – implying a spectrum efficiency of zero for any practical microwave system.

Or the system could use antennas with very narrow main beams and very low sidelobes. What is the pattern of the "ideal" antenna? Other parameters which would minimize the required spectrum space would have to be specified; e.g., receiver noise figure, modulation index, and modulation type. The necessity of answering these questions makes the ideal/input measure of spectrum efficiency difficult to compute and somewhat subjective. In practice, the ideal system is usually replaced by some reference system[14].

If the purpose of a measure of spectrum efficiency is to compare systems, then nothing is gained from the additional difficulty of computing the ideal/input measure, because both measures give the same relative result. Let C stand for the output specified in the example above ($x$ circuit miles with reliability $p$). Suppose system A uses $S_A$ spectrum space to provide the output, system B uses $S_B$ spectrum space to do it, and an ideal system uses $S_I$ spectrum space. The ideal/input efficiency measure for system A is $S_I/S_A$ and for system B it is $S_I/S_B$. Using this measure

$$\frac{S_I/S_A}{S_I/S_B} = S_B/S_A$$

times more efficient than system B. Using the output/input measure, the efficiency for system A is $C/S_A$ and for system B is $C/S_B$. Using this measure system, A is

$$\frac{C/S_A}{C/S_B} = S_B/S_A$$

times better than system B, which is the same result obtained before.

In conclusion, I recommend a spectrum efficiency measure of the form (communications achieved)/(spectrum space used) because

- it will be understood by nonspecialists who make or influence decisions about use of the spectrum resource;
- it is easier to calculate and less subjective than another candidate, the ideal/input measure.

The practicality of the definition should be tested by converting the general form into specific definitions for services such as broadcasting, point-to-point microwave links, and radar. This should not be considered to be merely an academic exercise because the CCIR will probably adopt some definition of spectrum efficiency soon. The resulting change in international regulations will affect radio system planners, designers, and operators.

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## Appendix

### Calculation of physical denial

For the purpose of calculating its spectrum use, a transmitter can be characterized by its location in geography and frequency and by its emission power density function $\epsilon(\phi,f;\ f_T)$. This function shows the spectral power density at frequency $f$ radiated in the azimuthal direction $\phi$ when the transmitter is tuned to frequency $f_T$. (Area will be used as the physical space in this development.) The function includes all power emitted, including spurious emissions and transmitter noise.

Similarly, a receiver can be characterized by its location and its admission function $\alpha(\phi',f;\ f_R)$, which is the fraction of the power density at frequency $f$ arriving from direction $\phi$ that will reach the demodulator of a receiver tuned to frequency $f_R$.

Much of the power emitted by the transmitter does not reach the receiver. The ratio of received power to emitted power is the basic transmission loss – defined to be the loss between isotropic antennas and denoted by $L(f,d)$, where $d$ is the distance between the transmitter and receiver[1]. It is assumed here that $L(f,d)$ represents the basic transmission loss for average conditions for the frequency of interest.

A general expression for the power coupling between a transmitter $T$, which is a distance $d$ from a receiver $R$, is

$$P = \int_0^\infty \left[\frac{\epsilon(\Phi,f;fT)}{L(f,d)}\right][\alpha(\phi',f;f_R)]df \qquad (1)$$

In this equation, $\phi$ is the azimuth angle from $T$ to $R$, and $\phi'$ is the azimuth angle from $R$ to $T$. On a flat surface, $\phi' = \phi + \pi$. The first factor in brackets is the spectral power density arriving at the receiver, having suffered basic transmision loss $L(f,d)$. The second factor in brackets is the fraction of that power density admitted by the receiver, so that the product is the spectral power density received. Integration over all frequencies with nonzero power density yields the total received power, $P$.

### Situation-specific denial measure

Suppose now that transmitter $T$ and receiver $R$ are not in the same system, so that there is a potential for interference. For any receiver there is some threshold amount of power in an unwanted signal that will interfere with acceptable reception of the wanted signal. Denote this threshold power level of receiver $R$ by $P_R$.

By setting $P = P_R$, and assuming that all characteristics of the transmitter and receiver are fixed, (1) can be solved for $L(f,d)$ interms of the fixed characteristics. This relationship can be inverted to find the minimum non-interfering separation $d = d(\phi,f_R)$ of $T$ and $R$.

Fig. 1 is a plot of $d(\phi,f_R)$ for an illustrative transmitter with a directional antenna. It can be seen from Fig. 1 that the geographical area that $T$ denies $R$ is given by

$$A(f_R) = \int_0^{2\pi} 1/2d^2(\phi,f_R)d\phi \qquad (2)$$

The spectrum-space "volume" used at frequency $f_R$ is $A(f_R)df_R$ (see Fig. 1). The denied areas for each frequency $f_R$ can be computed, and the resulting incremental volumes are summed. The result multiplied by $\tau_T$ (the time the transmitter operates) is the situation-

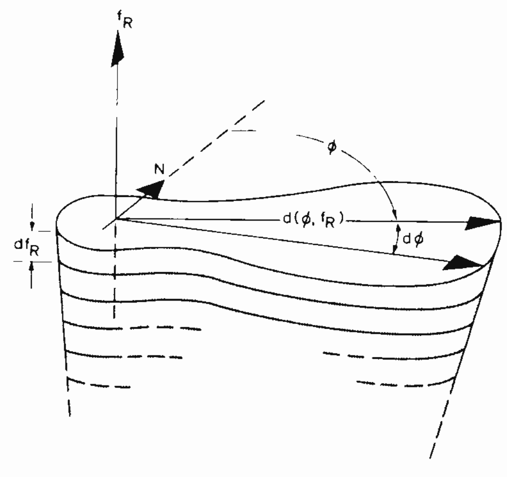


**Fig. 1.** *Representation of the (bandwidth × area) volume denied to a receiver by a transmitter with a directional antenna.*

specific measure $M_T$ for the spectrum space used by transmitter $T$

$$M_T = \tau_T \int_0^\infty A(f_R)df_R$$

$$= \tau_T \int_0^\infty \int_0^{2\pi} 1/2d^2(\phi,f_R)d\phi df_R \qquad (3)$$

Similarly, the spectrum space denied to a transmitter by a receiver R operating $\tau_R$ h/day is

$$M_R = \tau_R \int_0^\infty \int_0^{2\pi} 1/2d^2(\phi',f_T)d\phi'df_T \qquad (4)$$

where $d = d(\phi',f_T)$ must satisfy (1) for the admission function of the evaluated receiver and the emission function of the denied transmitter.

Formally, the only difference between the measures $M_R$ and $M_T$ is the interchange of admission and emission functions, but it is likely that the numerical values are different. At any rate, the space measured is different; receiver space is denied to transmitters and transmitter space is denied to receivers.

### Uniform denial measure

The numerical value of the situation-specific measure depends on the relative locations and specific emission and admission characteristics of the competing systems. Thus the value for a fixed system could be changed by the introduction of a new system in the same band or area. The uniform measure avoids this undesirable feature by using idealized reference transmitters and/or receivers. Spectrum space used is now considered to be the spectrum space denied to such reference receivers and transmitters. Equations (3) and (4) are still used to define the uniform measures; however, (1) now has simplified forms.

For the transmitter measure, define an idealized "probe" receiver which has an isotropic loss-free antenna and a perfect narrow selectivity function, so that $\alpha(\phi',f;f_R) = 0$ if $f_R - b/2 \leq f \leq f_R + b/2$ and $\alpha(\phi',f;f_R) = 1$ otherwise. The bandwidth of the reference receiver $b$ is chosen small enough that the emission function of the transmitter is essentially constant over it.

With these assumptions on the referenced receiver, the power coupling (3) becomes

$$P_R = \epsilon(\phi,f_R,f_R,f_T)b/L(f_R,d) \qquad (5)$$

where $P_R$ is the interference power threshold of the reference receiver. Recall that (5) must be solved for $d = d(\phi,f_R)$ to evaluate (3) for the transmitter measure.

The power threshold $P_R$ of the reference receiver in (5) is somewhat arbitrary. However, it may logically be related to the average ambient noise power density since this is the power that would "use" the space in the absence of any system. Specifically, choose $P_R/b$ to be the average ambient noise power density [2,3].

An analogous definition can be made of the space denied to a reference transmitter by a particular receiver R. In this case, assume that the reference transmitter has an isotropic antenna and a perfect narrow spectral density function. Specifically, $\epsilon(\phi,f;f_T) = 0$ unless $f_T - B/2 \leq f \leq f_T + b/2$, and in this interval $\epsilon(\phi f;'f_T) = P_T/b$, where $P_T$ is the emitted power of the reference transmitter.

With these assumptions, (1) becomes

$$P_R = \frac{P_T\alpha(\phi',f_T;f_R)}{b\ L(f_T,d)\ b} \qquad (6)$$

where $P_R$ is the interference threshold of the evaluated receiver. Again, (6) must be solved for $d = d(\phi',f_T)$ to evaluate (4) for the uniform measure for receiver R.

Equation (6) shows, explicitly, what is intuitively obvious – that the space denied by a receiver to a transmitter depends on the power $P_T$ emitted by the reference transmitter. In this case there is no "natural" reference level to use as there was in the case of a reference receiver, so the choice will have to be arbitrary. Once a choice has been made, however, this measure of spectrum-space use depends only on the characteristics of the evaluated receiver, including its power threshold.

### Simple measure for idealized transmitters and receivers

The uniform metric for a transmitter assumes that the reference receiver has a rectangular bandpass (i.e., selectively function). Similarly, the uniform metric for a receiver assumes that the reference transmitter has a rectangular power spectral density function. In both cases, the emission (or admission) function of the evaluated equipment (transmitter or receiver) is arbitrary; it does not need to be "rectangular."

Suppose, on the other hand, that a transmitter has a perfect power spectral density function of bandwidth $B$. Then, the uniform measure $M_T = \tau_T BA(f_T)$ where $A(f_T)$ is the area (2) denied to a competing receiver with tuned frequency $f_R = f_T$. Analogously, if we want to evaluate the measure for a receiver with a perfect rectangular bandpass of bandwidth $B$, then the uniform measure is $M_R = BA(f_R)$, where $A(f_R)$ is the area denied to a competing transmitter. That is, the uniform measure reduces to a simple (time) × (area) × (bandwidth) product for "perfect" equipment characteristics.

The expressions above measure the amount of spectrum space denied by individual transmitters and receivers. If a system has multiple receivers and the spectrum-space volumes denied by these receivers overlap, then the amount of spectrum used by the system is not simply the sum of use by its component parts. Rather, it should be the union of spectrum-space volume denied, and the measure of system use should be less than the sum of the use of component receivers. An analogous situation may occur with a system having transmitters.

Ewing and Berry[4] discuss these definitions in more detail and give sample calculations.

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## Guide to hi-fi equipment

Over 450 pages of detailed information and photographs of all major categories of high fidelity equipment, including aerials, construction kits, hi-fi cabinets, magnetic tape, tape accessories, and unit audio systems, as well as speakers, cassette decks, music centres, record decks and amplifiers are offered in *The Hi-Fi Year Book 1979*, just issued by our publishers IPC Electrical-Electronic Press Ltd. A brief description of each item is given, together with specifications and price. A directory section lists brand names, dealers and manufacturers and suppliers in alphabetical order for easy reference. The book is available from main bookshops at £3 or direct from the publishers at £3.50 inclusive. Cheques should be made payable to IPC Business Press Ltd., and sent to General Sales Department, CP34 Dorset House, Stamford Street, London SE1 9LU.

## Oscilloscope waveform store

As readers will perhaps have discovered, no sooner was the design of the "Add-on oscilloscope waveform store" published (October and November) than we were informed that the MC1407 integrated circuit was no longer to be made. All is not lost, however. We hope to publish in the January issue a replacement circuit for which the printed board will need only a small modification. At the same time, we will print the circuit diagram of the power supply. Components for this design were obtained by the author from C.P. Development, 16 Hughenden Road, High Wycombe, Bucks. See also p.64 for the correct version of Fig. 7.

# NEWS OF THE MONTH

## EBU discusses technical details for WARC '79

The EBU has published a document "Study of technical questions of interest to the WARC 1979" which provides the complementary technical basis for the requirements given in an earlier report on the guiding principles for the WARC 1979 (see p75, August 1978 issue). Most of the studies were carried out within the EBU in preparation for the CCIR's autumn '78 Special Preparatory Meeting (SPM). Although contributions have been made by the EBU to the SPM on most of the subjects in the document, in other cases only preliminary results were available and it was therefore planned to up-date the information according to the progress made by the EBU Technical Committee during 1979.

### H.f. broadcasting

The 56-page document, SPB66, is in three parts; terrestrial sound broadcasting, terrestrial television broadcasting and satellite broadcasting. In the first part the questions are related exclusively to h.f. broadcasting (band 7). A proposal is made for a specification for a possible future single-sideband (s.s.b.) system for h.f. broadcasting as this has many advantages not possessed by any compatible s.s.b. (c.s.s.b.) system (subject of CCIR report 299-3).

The proposal suggests that the introduction of such a s.s.b. modulation technique be in such a way that the transition from double sideband (d.s.b.) to s.s.b. can be well organised in advance in order to avoid incompatibilities with existing receivers. The EBU also consider that an s.s.b. system would be more effective than a c.s.s.b. system in increasing the efficiency of the l.f./m.f. bands (bands 5 and 6).

A conclusion in the document says that, because most of the h.f. broadcast frequencies are in constant use, it would not be possible for broadcasting services to change their operation from one band to another in an organised way to comply with the sunspot cycle, even if all allocated broadcast bands were of equal width.

In view of the number of services competing for the allocation of appropriate portions of spectrum space for communication by ionospheric propagation, suggestions were made that some of the additional frequency ranges which are to be allocated to broadcasting, be shared by other services. The EBU consider that this would lead to difficulties and would not satisfy either party. The 7MHz bands where radio amateurs in region 2 share with broadcasters in other regions is used as an example. It is the view of the EBU that frequency allocations for h.f. broadcasting should be exclusive and identical in all three regions.

Increased congestion in the h.f. broadcasting bands, drew attention to the fact that the deviations in carrier frequency from broadcasting transmitters complying with CCIR recommendations are not likely to ensure the optimum use of the available frequency spectrum. It was suggested that to meet the proposed requirements of a maximum difference between carrier frequencies of 0.2Hz, the stability of emissions needs to be 1 part in $10^8$ (based on a carrier frequency of 10MHz). It is the EBU's view that this standard should be proposed for adoption at the WARC '79 by the SPM and that all new transmitters should conform to the standard. Transmitters currently in use should all be converted by the end of 1984.

### Terrestrial television broadcasting

The possibilities of television broadcasting frequency sharing with the land mobile services below 1GHz was one subject raised in the document and the three main ways of doing it were discussed. These were sharing by using separate hours of operation, sharing by the use of separate frequencies, and sharing in separate geographical areas. In terms of its effect on television broadcasting it was found that, although sharing might be technically feasible in particular cases (see Spread spectrum comm. p50, August 1978), it would always be very difficult from an organisational point of view and might even be impossible in certain circumstances. The effects of sharing on the mobile radio service were not studied because this was believed to be outside the competence of the broadcasters. However, the EBU felt that because of the low interference tolerances in the mobile service the mobile radio users may experience even more serious difficulties than the broadcasting service. The EBU therefore advise that frequency sharing, as suggested, should be avoided.

One question concerned the possibilities of reducing the channel bandwidth of a tv signal by incorporating the sound information in the video signal. The EBU came to the conclusion that there were three basic requirements to be fulfilled. The first was that the inserted digital sound signal should not interfere with the performance of existing receivers. The second was that the system should be capable of the transmission of stereophonic sound or of two independent sound signals, if possible with full quality. Lastly, they concluded that the service area of a transmitter should be limited by the degradation of the picture and not by that of the sound. The EBU have decided to pursue the development of a new transmission system which meets these requirements and will keep in close collaboration with the relevant industries. However, because of the time that will elapse before a new standard could be made effective, it was concluded that the WARC '79 will most probably not be in a position to take a decision on the introduction of such a transmission system.

### Satellite broadcasting

Under the heading 'satellite broadcasting' one study dealt with the feasibility of satellite sound broadcasting on the 26MHz range. Although it indicated that this was feasible, some EBU members were in favour of the future utilization of the band for an international service, while others thought that the proposal was inopportune, in view of decisions made at the WARC '71 conference. Another study considered a satellite sound-broadcasting system for a national service using portable receivers in the 1GHz range. It was decided that between sixty and sixty-five channels, each of 150kHz bandwidth, would probably be needed for each of the countries in region 1 and the corresponding bandwidth would therefore be about 9MHz.

A number of studies dealt with questions resulting from the 1977 Geneva Conference, where a frequency plan for the 12GHz range within regions 1 and 3 were drawn up. The major problem here was related to the frequency spectrum that would be required in order to provide all the satellites in the Geneva Plan with programme links in the up-links. The EBU study contributes to the general objective of making the optimum use of the frequency spectrum but to achieve such an aim it would be necessary for the WARC 1979 to lay down certain regulations that would enable the realisation of these up-links under the recognised constraints. Some additional problems relating to the use of the 12GHz range are also discussed, as are the dangers of interference to future 12GHz broadcasting receivers that could be caused by spectrum users outside this range. These show that caution is required in the use of certain frequency bands, when decisions are to be made with regard to future allocations to other services. The WARC will also be required to decide on the introduction of additional broadcasting services. In the 12GHz range only domestic radio receivers could be used, which would restrict the utility of this band to specialised sound broadcasting services. The studies described in the document give all the system characteristics required to enable the appropriate decisions to be made at the WARC.

Finally, some consideration is given in the document to future developments in television, and the system characteristics for high-definition television systems for reproduction on large screens. An evaluation is also made of the frequency-spectrum requirements for the realisation of such systems in ranges above 12GHz. The document also includes six Appendices giving information complementary to the subjects discussed in the main parts.

## Mobile radio aids show

The first Motor Show at the National Exhibition Centre in Birmingham was a triumph for mobile radio communications, according to Pye Telecommunications Limited. There were over 900,000 visitors to the show and Pye takes at least some credit for ensuring that many of them arrived and left as quickly as possible, and with the minimum of discomfort. An estimated 200 buses at the NEC, all equipped with Pye mobile radios, transported more than half a million visitors to and from car parks during the ten days of the show.

# Revolutionary frequency synthesizer chips

A PAIR of revolutionary new chips almost passed from the workbenches of the research and development laboratories and into the telecommunications market without being noticed. The chips in question were actually used in Pye's new frequency synthesizer (see p.48, July 1978 issue) but it escaped the notice of most of the media that credit for the success of the frequency synthesizer should go to Philips Research Laboratories (briefly mentioned in the July report) and to the Mullard Applications Laboratory for the development of the chips.

When registered the silicon chip microcircuits, which can form the heart of almost any frequency synthesizer, may be given the designations LN1231 and LN1241. The LN1231 is probably the most important of the two chips because it is now being called the Frequency Synthesizer chip – implying that it is *the* chip for frequency synthesizers. However, a more technical name for the LN1231 is 'phase comparator combination'.

Frequency synthesizers have, to date, never been completely accepted as the standard device in the telecommunications field because they are prone to produce noise. According to design and research engineers at Mullard and Philips, the phase comparator was the cause of much of the trouble because it produced a lot of phase noise. This noise was passed through to the output of the synthesizer and also provided the source for other spurious signals.

Researchers at Philips, headed by Dr M. Underhill, have managed to solve this problem using a new and fundamental principle. In fact, the design principle is so basic that details cannot be revealed at present. However, *Wireless World* has been told that the principle is based on a sample-and-hold technique. Philips claim that with the LN1231 purity of output can be 1000 times better, in relation to phase noise produced at the output of a phase-lock-loop (p.l.l.) synthesizer. The LN1231 contains a crystal oscillator, a programmable reference divider, a phase modulator and two phase detectors (one high performance and one conventional). The device, which also includes an out-of-lock indicator, is produced in LOCMOS.

The second LOCMOS device, the LN1241, is called the 'universal divider' and is a programmable divider and control i.c. for external prescalers. It uses a five-decade programmable divider which employs a multiple feedback technique, incorporating feedback for non-decimal channels. It also has a facility for half-channel offsets and a subtractor is built onto the chip for i.f. offsets. Programming is done in a multiplex form to make the LN1241 compatible with matrix-type memories. The device will accept frequencies up to 9MHz (minimum) and can divide from approximately 0 to 1400, giving about 4½ decades of division.

The fundamental research work on the two chips was carried out by Philips after consultations with a number of European telecommunications companies, including Pye. These companies provided the assistance necessary to make suitable products out of the devices, and in so doing they set the parameters for the noise levels. Terry Giles, who has spent the last three to four years working on the frequency synthesizer devices in Mullard's Applications Laboratories, said that all one needs for a multiple-channel mobile radio mixer oscillator is a divide-by-ten prescaler, a general-purpose op-amp., a voltage controlled oscillator and a channel store – a diode matrix would suffice.

Many low-cost synthesizers use two loops in the phase lock loop circuitry, one which obtains frequencies down to a particular division and another loop, with a second v.c.o., which obtains the frequencies in between (an example of this can be seen in pp.65-66, Sept. 1977 issue).

Because they use two v.c.os there is more chance of the synthesizer producing spurious signals. The new chips use both linear and digital circuitry and enable frequency synthesizers to be made with only one loop. In addition the devices enable radios to have a much lower modulation distortion figure. For a modulation index of 100, at 50Hz, a distortion figure of about 1% can be obtained.

It was Mullard's aim originally to make low cost, simple frequency synthesizers for single channel transceivers and it was the result of this work, in producing fast-operating devices, and the breakthrough made by Philips during their research programme, that have made the production of these two frequency synthesizer chips possible.

The LN1231 and the LN1241 are now available to the public in sample quantities at a one-off price of £50 for the pair.

# New four-year degree course in electronics

SOUTHAMPTON University has introduced special four-year engineering degree courses for students of proven ability who plan careers as professional engineers. The University is offering these courses in Acoustical Engineering, Aeronautics and Astronautics, Civil Engineering, Electronics and Electronic Engineering, Mechanical Engineering and Ship Science.

Although other universities — Birmingham, Brunel, Cambridge, London (Imperial College), Manchester, Oxford and Strathclyde – have offered four-year full-time (as compared with sandwich) engineering degree courses, these have been 'management enriched' in that they have been backed by management subjects. They were also financed by the University Grants Committee. The courses being run by Southampton University are the first of their kind and are intended to enrich the 'professional engineering' content, of which management studies form only a small part. The whole thing is being carried out at the Universities own expense; that is, it is being done by diverting their existing funds and changing their internal operations. The Planning Director of the new courses is Professor R. C. Smith who is himself a Professor of Electronics. He has been relieved of his teaching duties for three years and his and his secretary's work are being financed by the Wolfson Foundation Fund — an industrially-backed fund.

The programmes for the first and second years of the new courses are exactly the same as those of the normal three-year courses. In the three-year course the third year is the specialization year; in either Electronics Techniques or Physical Electronics in the case of the Electronics degrees. In the four-year course this specialization period is spread over the third and fourth years and it is the extra year, mixed in with these, which makes all the difference.

One half of this extra year emphasizes 'design' and will cover all aspects of design from the first ideas of applications of systems or equipment, to costing, production and patenting, etc. Students will work with local companies (national names) who may act as 'pretend customers' or perhaps even real customers. The University is still discussing details with the companies but it is likely that a company will approach students to ask for a particular design. The students will work in teams, partly because they can get more work done that way, and partly because this is the way that they will probably work in industry. Difficulties (in ownership of patents) may arise if students should design something which a company is really interested in, but again this is something which is still to be discussed.

The other half of the extra year will be given to 'industrial studies.' While these studies will be concerned with management and business they will be engineer-oriented. Professor Smith told *Wireless World* that the four year courses are "out to produce better engineers — good engineers have to be able to cope with management-type problems".

The second half of the extra year will comprise of lecture courses on Industrial Studies, design projects which will force the students to use non-technical as well as technical techniques (marketing forecasts, etc.) and work relating to the organisation and production of electronics.

The four-year course will also include 20 weeks in industry, as the three-year course does. The student, according to Professor Smith, needs to know how the theory fits in with industry, and he believes that these courses help to do just that. When asked whether another year between school and industry could be harmful to the students or industry, Professor Smith said, "Although the electronic industry is screaming out for students it is also screaming out for well-prepared people."

Students who started their degree courses in October 1977 have already had the opportunity to apply for transfer to the four-year course (at the beginning of their second year). However, although the University would like all of its students to receive this special education — which incidentally provides them with an extra qualification, a Diploma in Engineering — the courses are so labour-intensive, from a staffing point of view, that only 10% of these students may be taken at the moment. All applicants are interviewed by panels comprising industrialists as well as members of the academic staff and success depends upon their academic record and their motivation for engineering.

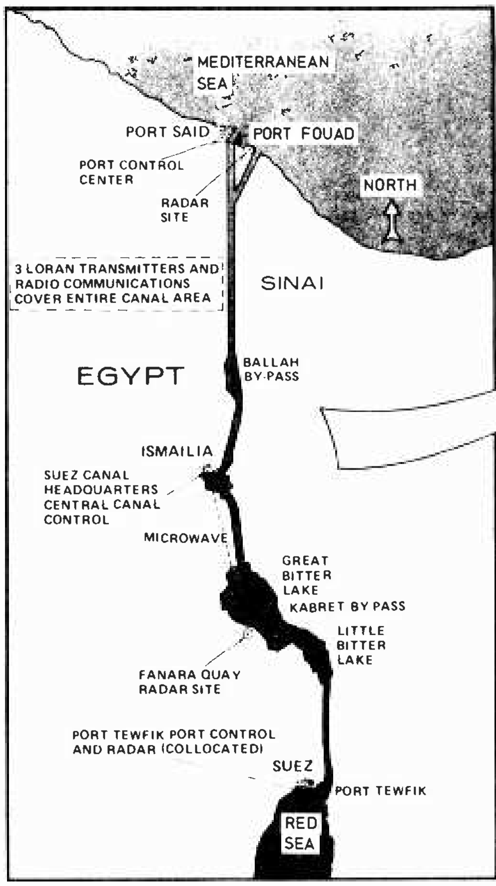
# UK ahead in fibre optics standardization

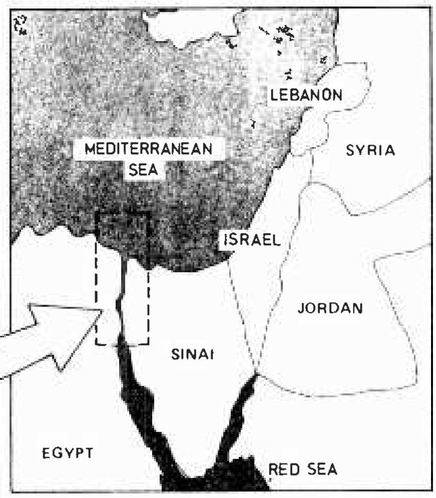
INITIATIVE by the Electronic Components Industry Federation (ECIF) in bringing together UK companies in symposia and in establishing a forum has put Britain ahead of the world in the move to determine international standards for fibre optics, according to an ECIF spokesman. The companies involved in the discussions are too numerous to mention here because they include the makers of optical fibres, fibre optics cables, connectors and suppliers of fibre optics systems, but many of them are world leaders in their own specialized areas.

ECIF got involved about two years ago when between 30 and 40 connector manufacturers, members of the ECIF, were showing interest in making connectors for the fibre optics industry. Although these companies were in competition it was in their own interests to ensure that they worked to standards which could eventually be adopted internationally, and so the ECIF held symposia to bring them all together. A forum was then set up by the ECIF to introduce firms making optical fibres and fibre optics cables, and the suppliers of fibre optics systems.

When the British Standards Institution (BSI) established a committee for fibre optics (ECL-6-9) in April this year, ECIF decided to direct their efforts to the same end and are now represented on that committee. As far as the standard's specifications are concerned it is very early days and a BSI draft is still to be made, according to a spokesmen from ECIF and BSI. However, the BSI spokesman said that it was likely to be treated in two sections, fibres/cables and connectors/terminations. Undoubtedly the specification will dictate performance rather than methods and materials. Factors which could affect the specification and which are under consideration include transmission powers from sources, dB losses at connections and along cables, cable sizes and types and dimensions of cable coverings and connectors.

According to the BSI spokesman the International Electrotechnical Commission (IEC) has already received a strong delegation from the UK and written proposals from the USA and European countries, including Britain. A working group has been formed by BSI and this now works in close liaison with a similar working group in the IEC. Work was expected to progress slowly at first and would be based largely on the papers that have already been written on the subject said the BSI representative. ECIF are presently establishing information exhanges between the UK and organisations and authorities in Europe and America.




# Traffic management system for the Suez Canal

*The AILTECH division of Cutler-Hammer's Instruments and Systems Group have been awarded a $17.8 million contract from the Suez Canal Authority for the design, manufacture and installation of a vessel-traffic management system for the Suez Canal. The system is hoped to be installed and operational by 1980, to coincide with the first phase of the Suez Canal widening.*

*In operation, a ship entering the Suez Canal at Port Said in the north or Port Tewik in the south will be detected by a radar and visually displayed on a digital-scan display system. This information will also be sent to a main computer at a central control centre at the Authority's headquarters in Ismailia.*

*The newly-acquired information is compared with information collected over a period of some weeks or months about ships intending to use the Canal. Data from as many as 20,000 vessels can be stored at any one time, permitting the controllers to form convoys, taking into account, for instance, a vessel's speed or steering characteristics.*

*Upon entering the Canal, a Loran receiver/transmitter called CORT (Carry On Receiver Transmitter) will be placed on board the ship. This device automatically determines its position by analysing signals from special Loran transmitters. It then sends a radio report of this position, which is entered in the computer system at Ismailia.*

# "Software dabblers may take over electronic system design"

A STRONG warning that electronic system design could be damaged by falling into the wrong hands as a result of the microprocessor revolution was issued by Professor H. A. Barker of Aston University in his chairman's address to the Control and Automation Division of the IEE in October. He was basically concerned with the effects of the general availability of software. Even before the microprocessor appeared, he said, the effect of circuit integration had been to erode the traditional hardware skills of the system designer in favour of other, more nebulous skills. These other skills were concerned with the structuring of systems into interconnected subsystems, rather than with the designing of special-purpose circuitry using discrete componentes. Detailed design was increasingly embodied in the integrated circuits used as the lowest-level subsystems. The advent of the microprocessor accelerated the trend of decreasing hardware skills and, by providing a fixed basis for system configurations, presaged their eventual disappearance from system design. At the same time, the nature of the new skills required by the system designer had finally clarified; they were now the software skills required to transform a problem into a program.

Professor Barker claimed that the full implications of this fundamental change in the role of the electronic system designer had not yet been widely appreciated, despite their obvious importance for the proper exploitation of the new technology. "In particular, the change must be recognised, accepted and acted on by the electrical engineering profession," he said, "otherwise the system design function will become divorced from its electronic systems designed by whoever happens to be applying them. While this may have attractions for dabblers from other professions, it is an amateur approach which contributes nothing to the development of the subject, and could be very damaging. The divisive approach has always been a bugbear in control and automation, where its dangers are well appreciated, and here, in particular, the opportunity for unification must not be lost."

Many electronic systems designers, continued the professor, had not even heard of software until a few years ago, and even now would be quite content for it to start and finish at the level of an assembler. Engineers would have to be re-educated and retrained in the new concepts, and in industry "facilities of a new, and often expensive, kind will be required for design and development".

## Establishing a local radio station

THE department of Extra-mural Studies at the University of London has introduced a university extension course on 'establishing a local radio station.' The course, which is presently taking place, covers both theory and practice and has three main aims. Firstly, it aims to study the administrative, legal, financial and technical aspects of setting up a local radio station. Secondly it aims to identify a community or group interested in applying for an IBA non-profit franchise, for a cable licence or for regular access to an existing station, and to assist that community or group in its application. Thirdly, it aims to collectively write an account of the course — in the hope that it may be helpful elsewhere.

If you think that these aims make the course sound less like an academic benefit to a student and more like a collective aid to groups trying to set up their own local radio stations, you are probably right! The course tutor, Peter Lewis, was one of the founders of the Community Communications Group (Com-Com) and he is now the public relations man for them. He is also an ex-IBA man and author of the book 'Whose Media? The Annan report and after a citizens' guide to radio and television,' see p 52, April 1978 issue. When Mr Lewis worked for the IBA he was responsible for the Bristol Channel television experiments in which five independent local stations were set up on cable systems. Unfortunately most of these stations ran into financial trouble and closed down. The leading stations were Bristol and Swindon, the latter being the only one still in operation.

Some sessions in the course are being led by visiting specialists who, it was planned, would talk specifically on the fundamental requirements for setting up a station. In one stage of the course, joint meetings are being held with representatives of the selected community or group, on location.

It has been suggested by a reliable source that the course organisers hope that the course will flourish into a continuing project which no doubt will be kindled by the publication of a report which the class and community or group representatives will prepare. *Wireless World* put this suggestion to Mr Lewis, who replied that there was an educational job to be done but they hoped primarily to assist a group or community in getting an IBA franchise, and to pave the way for other groups in the future. This project arises from Mr Lewis's other work (other than Com-Com), that of running or helping to run a community-related-curriculum study service – making courses help the community. When asked what will happen after the course, Mr Lewis said that it was very difficult to see what outcomes would occur. "It is very hard to predict. The report is hoped to be useful and perhaps of more use to someone else."

The present 'class' includes people who have experience in free radio, hospital radio and student broadcasting. There are also people from Pacifica Radio in America, Australian public broadcasting stations, commercial radio in the UK, BBC local radio and BBC tv.

At the time of going to press a project group/community was still be be found.

● Some of Com-Com's views are given on p.71, October 1978 issue.

## Night vision glasses used by helicopter rescue service

*The Swiss Helicopter Alpine Rescue Service have just completed two years service trials on a modification of ITT's night vision glasses, which were originally developed for military use. Because most calls for alpine rescue come during the worst weather conditions, the glasses are invaluable to pilots, and enable them to clearly distinguish fields, woods and hills which would normally appear as complete blackness to the un-aided eye. The night vision aids use ITT electronic image intensifiers,sensitive to light undetectable to the human eye. What the wearer sees is not an optical picture, but an electronic image on a video screen.*

## Broadcasters try programme labelling

THREE European organisations have now done on-air tests of programme labelling on their v.h.f./f.m. stereo sound transmissions — the BBC, the Netherlands Broadcasting Corporation (NOS) and the Swedish Telecommunications Administration. Details of these experiments, and other work in their laboratories, emerged from three papers presented at the recent International Broadcasting Convention in London. The idea of programme labelling – a sound broadcasting refinement which may help eventually to sell more advanced and expensive receivers to gadget-minded members of the public — is to transmit, along with the programme signal, a code signal which continuously identifies the programme service or network, the transmitting station, the type of programme material and perhaps gives other information such as the time, the programmes in other networks, and simple news or other messages. At the receiver this information can be displayed as a visual aid to tuning (especially in areas with a high density of stations) or be used for automatic search tuning (May 1977 issue, p. 39) or automatic pre-selection of stations and programmes for either listening or recording. Radio Luxembourg already uses a simple form of programme labelling, and the ARI traffic information service (October 1978, p. 73) is really based on this principle.

From the IBC papers it seems that the broadcasters envisage transmitting the labelling information on an inaudible sub-carrier within each radio channel. Obviously there is more bandwidth available in v.h.f. channels than in l.f. and m.f. channels, thus allowing a higher information rate and a greater amount of useful information to be sent. Nevertheless, the BBC authors did mention in their paper the possibility of labelling l.f. and m.f. broadcasts — by phase modulating the carrier — and they hope to do some on-air tests "in the near future."

The information itself would be a repeating sequence of characters, alphabetical and/or numerical, which would be generated electronically in binary coded form — a seven- or eight-bit word for each character — and modulated onto the sub-carrier. All three papers seemed to agree that a complete sequence of characters, or message, would have to be repeated four or five times a second (e.g. for automatic tuning systems) and this would entail an information rate on the sub-carrier of about 600 bit/s.

The great difficulty is what frequency to choose for the sub-carrier, what level it should be, and how to modulate it, and here there were some differences of approach between the papers. Clearly, programme labelling must be compatible: it must not be audible to mono or stereo listeners and must not impair sound quality by interfering with the stereo decoding process. According to the BBC paper the sub-carrier can be placed in one of the of the three bands : 15 to 19kHz; 19 to 23kHz; and above 53kHz. In the broadcast tests, whereas the British and Swedish engineers used a sub-carrier of 57kHz, the Dutch, believing that "the f.m. baseband spectrum above 53kHz was unsuitable to accommodate a sub-carrier" for compatibility reasons, used 16.625kHz. However, the BBC had carried out subjective laboratory tests using 17kHz, 21kHz, 57kHz, 65kHz and 76kHz with seven different commercial receivers. For a given degree of impairment received by the listener (Grade 4) they measured the percentage injection of the sub-carrier and signal-to-noise ratio in the data channel for the various receivers. They found wide variation between the sets and concluded "compatibility problems with existing receivers are severe." But the BBC also reported their intention to do on-air tests with different sub-carrier frequencies.

The Dutch experiments, reported in a paper from Philips Research Laboratories, Eindhoven, used phase shift keying for modulating the sub-carrier. The BBC reported "various" ways of modulation, while the Swedish paper described in some detail a system which involved differential coding of the binary information, arranging this to phase modulate a 1187.5Hz tone, and amplitude modulating the 57kHz sub-carrier with this tone. It appears that the phase relationship, of the sub-carrier to the 19kHz pilot tone and its harmonics is important in compatibility. The BBC, for example, in their on-air tests locked the 57kHz sub-carrier in quadrature with the third harmonic (57kHz) of the pilot tone — the zero crossings of the pilot tone occurring at maxima of the sub-carrier.

# Displacement current

## — and how to get rid of it

by **I. Catt** and **M. F. Davidson** (CAM Consultants)
and **D. S. Walton** (Icthus Instruments Ltd)

To enable the continuity of electric current to be retained across a capacitor Maxwell proposed a "displacement current". By treating the capacitor as a special kind of transmission line this mathematical convenience is no longer required.

CONVENTIONAL electromagnetic theory proposes that when an electric current flows down a wire into a capacitor it spreads out across the plate, producing an electric charge which in turn leads to an electric field between the capacitor plates. The valuable concept of continuity of electric current is then retained by postulating (after Maxwell)[1] a "displacement current", which is a mathematical manipulation of the electric field $E$ between the capacitor plates which has the dimensions of electric current and completes the flow of "electricity" (Fig. 1 (a) and (b) ). This approach permits us to retain Kirchhoff's Laws and other valuable concepts, even though superficially it appears that at the capacitor there is a break in the otherwise continuous flow of electric current.

The flaw in this model is revealed when we notice that the electric current entered the capacitor at one point only on the capacitor plate. We must then explain how the electric charge flowing down the wire suddenly distributes itself uniformly across the whole capacitor plate. We know that this cannot happen since charge cannot flow out across the plate at a velocity in excess of the velocity of light. This paradoxical situation is brought about by a fundamental flaw in the basic model. Work on high speed logic design[2] has shown that the model of a lumped capacitance is faulty, and "displacement current" is an artefact of this faulty model.

The true model is quite different. Electric current enters the capacitor through a wire and then spreads out across the plate of the capacitor in the same way as ripples flow out from a stone dropped into a pond. If we consider only one pie-shaped wedge of the capacitor, as in Fig 1 (c), we can recognise it as a parallel plate transmission line whose only unusual feature is that the line width is increasing (and hence the impedance is decreasing). The capacitor is made up of a number of these pie-shaped transmission lines in parallel, so the proper model for a capacitor is a transmission line.

Equivalent series resistance for a capacitor is the initial characteristic impedance of this transmission line at a radius equal to the radius of the input wires. Series inductance does not exist. *Pace* the many documented values for series inductance in a capacitor, this confirms experience that when the so-called series inductance of a capacitor is measured it turns out to be no more than the series inductance of the wires connected to the capacitor. No mechanism has ever been proposed for an internal series inductance in a capacitor.

Since any capacitor has now become a transmission line, it is no more necessary to postulate "displacement current" in a capacitor than it is necessary to do so for a transmission line. The excision of "displacement current" from Electromagnetic Theory has been based on arguments which are independent of the classic dispute over whether the electric current causes the electromagnetic field or vice versa.

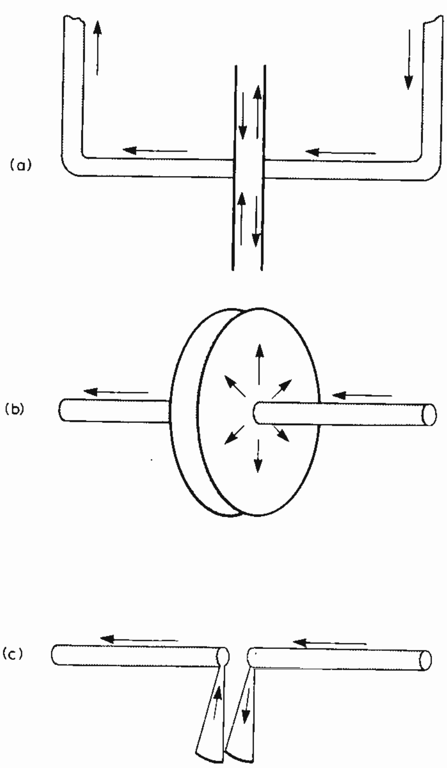



**Fig. 1** *Process of current flowing into a capacitor and spreading out across a plate is shown in (a) and (b). The structure in (b) can be considered as being made up of a number of pie-shaped wedges as in (c), each of which is a transmission line.*

### Appendix

**Comparison of the transmission line model with the lumped model of a capacitor in an RC circuit.**

Taking the above discussion further, consider a transmission line as shown in Fig. 2, assumed to be terminated with a resistance $R_T$ (not shown). The reflectian coefficient is $\rho=(R_T-Z_0)/(R_T+Z_0)$ where $Z_0$ is the characteristic impedance of the line. If the line is open-circuit at the right-hand end, as shown (and therefore $R_T$ is infinite), the $\rho=+1$. We will assume that $R \gg Z_0$.

When switch S is closed (at time $t=0$) a step of voltage $V.Z_0/(R+Z_0)$ is propagated down the line. This reflects from the open circuit at the right hand end to give a total voltage $2V.Z_0/(R+Z_0)$. Reflection from the left end makes a further contribution of $[V.Z_0/(R+Z_0)] \times [(R-Z_0)/(R+Z_0)]$ and so on. In general after $n$ two-way passes the voltage after $n$ passes is $V_n$ and,

$$V_{n+1}=V_n+2\,.\frac{VZ_0}{R+Z_0}\left[\frac{R-Z_0}{R+Z_0}\right]^n \qquad (1)$$

In order to avoid a rather difficult integration it is possible to sum this series to $n$ terms using the formula,

$$=\frac{a(1-v^n)}{1-v} \qquad (2)$$

where $a$ is the first term of a geometrical progression and $v$ the ratio between terms. (This formula is easily verified by induction.) Substituting in (2) the parameters from (1),

$$\text{i.e. } a=\frac{2VZ_0}{R+Z_0} \qquad (3)$$

$$v=\frac{R-Z_0}{R+Z_0} \qquad (4)$$

We obtain,

$$V_n=\frac{\frac{2VZ_0}{R+Z_0}\left[1-\left[\frac{R-Z_0}{R+Z_0}\right]^n\right]}{1-\frac{R-Z_0}{R+Z_0}} \qquad (5)$$

$$=V\left[1-\left[\frac{R-Z_0}{R+Z_0}\right]^n\right] \qquad (6)$$

This is the correct description of what is happening as a capacitor charges. We can now go on to show that it is approximated by an exponential. We have

$$V_n=V\left[1-\left[\frac{R-Z_0}{R+Z_0}\right]^n\right] \qquad (7)$$

Consider the term,

$$T=\left(\frac{R-Z_0}{R+Z_0}\right)^n$$

$$=\left(\frac{1-Z_0/R}{1+Z_0/R}\right)^n$$

If $Z_0/R \ll 1$ this term is asymptotically equal to

$$\left(1-\frac{2Z_0}{R}\right)^n$$

Now define $k=2Z_0n/R$. Substitution gives:

$$T=\left[1-\frac{k}{n}\right]^n$$

By definition, as $n \to \infty$ we have,

$$T=e^{-k}=e^{\frac{-2Z_0n}{R}}$$

And therefore:

$$V_n=V\left[1-e^{\frac{-2Z_0n}{R}}\right]$$

Now, after time $t$, $n=V_ct/2l$, where $V_c$ = velocity of propagation.

Therefore

$$V(t)=V\left[1-e^{\frac{-V_ct}{l}\cdot\frac{Z_0}{R}}\right]$$

For any transmission line it can be shown that:

$$Z_0=f\sqrt{\frac{\mu}{\epsilon}}$$

$$V_c=\frac{1}{\sqrt{\mu\epsilon}}$$

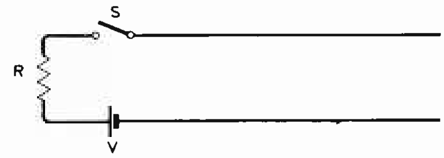
$$C_l=\epsilon/f$$

where $C_l$ = capacitance per unit length, and $f$ is the same geometrical factor in each case. The "total capacitance" of length $l$ of line $= l.C_l = C$.

$$\text{Hence } \frac{V_cZ_0}{lR}=\frac{1}{RC}$$

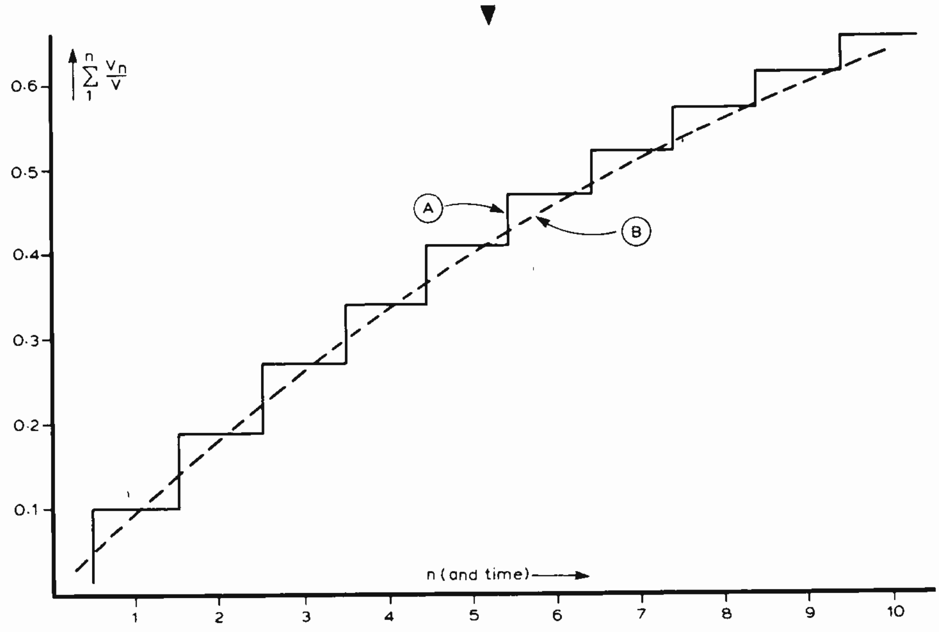
and therefore

$$V(t)=V(1-e^{-t/RC})$$




◀**Fig. 2** *An open-ended transmission line.*

**Fig. 3** *Comparison of the transmission line model $1-(1-2Z_0/R)^n$ in the curve A with the lumped model $1-e^{-2Z_0n/R}$ in curve B, for $2Z_0/R = 0.1$.*
▼




which is the standard result. This model does not require use of the concept of charge. A graphical comparison of the results is shown in Fig. 3.

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*This article is based on material from a book "Digital Electronic Design Vol. 2" by the above authors, to be published by C.A.M. Publishing, 17 King Harry Lane, St Albans, Herts, price £8.00 including postage. The next seminar by the authors on digital electronics design will be held at St Albans on February 12-13, 1979. For information, contact the above address.*

# Digital broadcasting problems

THE BBC's initial experiments with digital sound broadcasting (July issue, News, p.50) have shown that there are major reception problems in heavily built-up areas due to multipath propagation, according to James Redmond, the Corporation's director of engineering. Speaking on broadcasting developments in his inaugural address as new president of the IEE, he said that valleys running transversely to the direction of propagation from the transmitter can cause this kind of problem for people living in the valley. The hills on the transmitter side of the valley attenuate the direct signal while those on the other side provide several strong reflected signals.

It was found that the Tyne valley caused this kind of effect in parts of Gateshead. When comparing differential p.s.k. and f.m. reception while touring that neighbourhood, BBC engineers found that d.p.s.k. reception was virtually perfect for the greater part of the time but was quite unacceptable in a few regions when using a receiver with a simple digital decoder. Where reception was unacceptable the receiver muted. After giving a comparative demonstration of d.p.s.k. and f.m. reception in this region, Mr Redmond commented that clearly there was a lot to do and they probably would have to try other forms of modulation to decide which would give the best reliability. The work was only just beginning and "it is so unusual for the broadcast engineer to find himself with an absolutely clean slate in the utilisation of a frequency band that the responsibility of choosing wisely is a very heavy one. The opportunity is unlikely to arise again in our lifetimes."

● James Redmond retires as director of engineering this year after a long and distinguished career in the BBC. He joined in 1937 as a sound engineer in Edinburgh and progressed through the organization, becoming assistant director of engineering in 1967 and director in 1968.

# Audio power amplifier design — 5

## Negative feedback and non-linearity distortion

*Why does the low note contain the sound of the high note?* — ARISTOTLE

by **Peter J. Baxandall,** B.Sc. (Eng), F.I.E.E., F.I.E.R.E.

The July article in the present series concluded the treatment of the basic techniques for achieving feedback-loop stability. Attention will now be given to the effects of negative feedback on non-linearity distortion, and it will be shown that some of the ideas involved are more subtle than is sometimes appreciated.

THE following treatment, which has gradually become clarified and extended in scope over a period of many years, will, it is hoped, enable the reader to see what the answers to questions such as the following should be:

(a) Is it a valid criticism of the use of large amounts of negative feedback that it converts moderate amounts of low-order harmonic and intermodulation distortion into a multitude of small-amplitude distortion products of high order, which may be subjectively more significant?

(b) Is it always desirable to design a feedback audio amplifier to have a nearly-level audio-frequency response before feedback is applied?

(c) Does plenty of feedback at medium audio frequencies, assuming there are no slew-rate or other overload effects, necessarily ensure that two or more signal components near the top of the audio band will give rise to negligible intermodulation products at medium frequencies?

(d) Is it important for an audio amplifier to give low distortion when signals at frequencies lying outside the audio band are fed into it?

Obviously, in many amplifier circuits, owing to the presence of capacitors or transformers, or because of insufficient bandwidth in transistors, frequency-dependent effects will have to be invoked when considering distortion mechanisms. In some practical audio circuits, however, such effects may be negligible. The following treatment will initially assume no significant frequency-dependence, and will provide a foundation of theoretical understanding which may later be extended to include the influence of frequency.

### Amplifier with parabolic transfer characteristic

Consider the basic feedback amplifier configuration shown in Fig. 1. The voltage symbols represent instantaneous voltages, and each polarity marked is that which exists when the corresponding symbol has an instantaneously positive value. For the feedback to be negative, either $A$ or $\beta$ must be negative. (For a defence of the sign convention adopted, see page 41 of the March 1978 issue.) For present purposes it will be convenient to take $A$ as being positive, so that $\beta$ will be negative.

The simplest form of non-linearity to consider is that in which the transfer characteristic of the amplifying device, i.e. the graph of instantaneous output voltage (or current) against instantaneous input voltage (or current), departs from being a straight line only because of the presence of a square-law term in the corresponding equation*. Thus, referring to Fig. 1, let

$$v_{out}=Av'+\alpha\,(Av')^2 \qquad (1)$$

The graph of this equation is the transfer characteristic shown in Fig. 2. Plotted on this convenient basis, with equal scales on the two axes, the 45° broken line represents the slope at the origin, the actual characteristic departing from the ideal straight line by the amount $\alpha\,(Av')^2$ as shown. Because equation (1) is a quadratic equation, representing a parabola (of which only part is drawn in Fig. 2), the graph is sometimes called a quadratic transfer characteristic.

If there is no feedback in the Fig. 1 circuit ($\beta=0$), $v'$ becomes equal to $v_{in}$, and the complete circuit then has a transfer characteristic equation as in (1) but with $v_{in}$ written for $v'$. Suppose now that $v_{in}$ is a sine-wave signal given by

$$v_{in}=\hat{V}_{in}\sin\omega t \qquad (2)$$

Substituting this for $v'$ in equation (1) gives

$$v_{out}=A\hat{V}_{in}\sin\omega t+\alpha A^2\hat{V}_{in}^2\sin^2\omega t \qquad (3)$$

(No feedback)

The first term represents the wanted fundamental output, the other term representing the second-harmonic distortion because

$$\sin^2\omega t=\tfrac{1}{2}-\tfrac{1}{2}\cos 2\omega t \qquad (4)$$

This elementary trigonometry formula may be illustrated graphically as in Fig. 3. (I trust that those readers highly familiar with such elementary ideas will bear with me until more interesting topics are reached – I have assumed that some readers will welcome a rather slow and basic approach.)

* It is tempting to call this equation the 'transfer function', but this usage is better avoided because the term has an almost universally accepted meaning in a somewhat different context, as explained in the March 1978 article. It is thus better to refer simply to 'the equation of the transfer characteristic'.

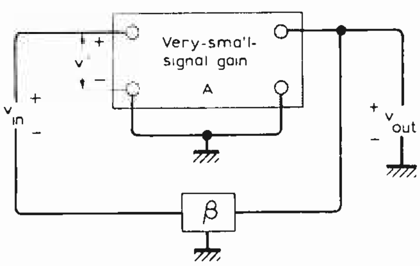



**Fig. 1** *Basic feedback-amplifier configuration.*

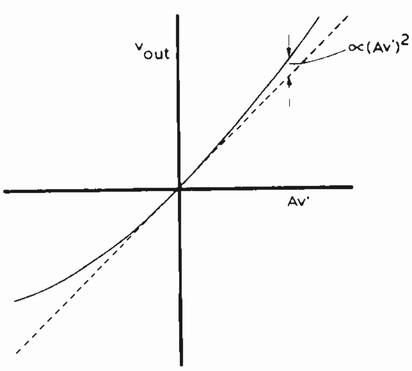



**Fig. 2** *Simple parabolic, or quadratic, transfer characteristic. α is a constant determining the degree of non-linearity, and A and V' are as in Fig. 1.*

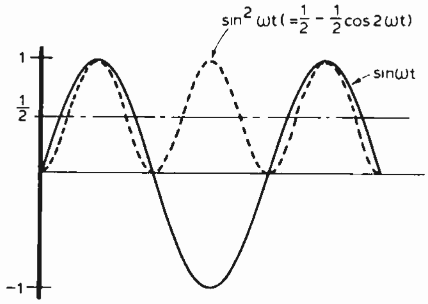



**Fig. 3** *Waveforms illustrating a basic trigonometry formula.*

If (4) is substituted for $\sin^2\omega t$ in (3), it will be seen that the magnitude of the second-harmonic output voltage component is given by

$$\hat{V}_{2nd} = \tfrac{1}{2}\alpha A^2 \hat{V}_{in}^2 \qquad (5)$$
(No feedback)

The magnitude of the fundamental output is given by

$$\hat{V}_{fund} = A\hat{V}_{in} \qquad (6)$$
(No feedback)

Dividing (5) by (6) and multiplying by 100 gives the percentage second-harmonic distortion as

$$\%2nd = \tfrac{1}{2}\alpha A\hat{V}_{in} \times 100 \qquad (7)$$
(No feedback)

Thus, from (5) and (7), the absolute magnitude of the second-harmonic output voltage is proportional to the square of the input (or fundamental output) voltage, whereas the percentage second-harmonic distortion is linearly proportional to the input voltage itself. This is a property of any circuit or device in which square-law distortion is dominant. (It may here be mentioned that a statement such as "the distortion is proportional to the square of the output voltage" is really quite ambiguous, for "the distortion" can be taken to mean either "the distortion voltage" or "the percentage distortion". This ambiguity often appears in the literature and sometimes causes very real confusion. A plea is therefore made to authors to say what they mean!)

The problem now to be considered is the effect on distortion of making $\beta$ finite in Fig. 1, i.e. applying negative feedback, still assuming a parabolic transfer characteristic for the basic amplifier. This problem may be approached from several different angles, and, as is often the case, adopting more than one viewpoint is helpful in providing a more complete understanding of the principles involved.

First of all it is possible to construct, point by point, a graph of $v_{out}$ against $v_{in}$ with feedback operative, and to show that it is much more nearly linear than without feedback. To do this, a particular value of $v'$ is taken, and from equation (1), assuming $A$ (the gain for very small signals) is known, $v_{out}$ is calculated. Then $\beta v_{out}$ is determined. Finally, with due care over signs, $v_{in}$ is obtained from the relationship

$$v' = \beta v_{out} + v_{in} \qquad (8)$$

A little thought will show that as the magnitude of $A$ or $\beta$ is increased, the resultant transfer characteristic becomes more and more nearly a perfect straight line. With very large $A$ or $\beta$, $v_{in}$ becomes enormously greater than $v'$, and the overall gain is then given very nearly by

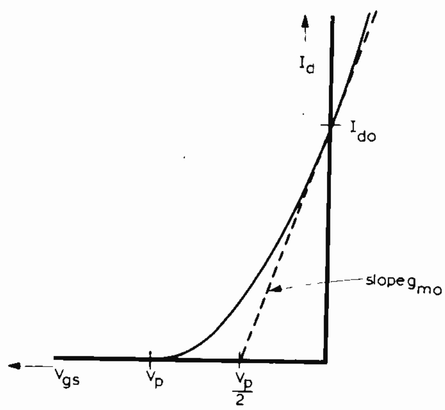



**Fig. 4** *Ideal parabolic characteristic for f.e.t.*

$$v_{out}/v_{in} = -1/\beta \qquad (9)$$
(Infinite feedback)

The change from a parabolic transfer characteristic to a straight line as the loop gain is increased from zero to infinity is a smooth and gradual process. All the intermediate transfer characteristics are absolutely smooth curves, quite free from any suggestion of kinks or other blemishes. But is each one still a parabola, of lesser curvature?

The answer to the above very important question is "no", and an indication that this must be so can be obtained without actually working out the equation of the new transfer characteristic. Start with $\beta = 0$ (no feedback). With a sine-wave input at frequency $f$, the output will contain components at $f$ and $2f$. As soon as $\beta$ is made finite, some of the $2f$ component will be let through into the input circuit, so that the basic amplifier will now be receiving inputs at $f$ and $2f$.

Now any device with a parabolic, or quadratic, transfer characteristic, when fed with two inputs at different frequencies, generates intermodulation products at the sum and difference frequencies – and the sum frequency in the present case is $3f$. (This arises from the fact that $(\sin\omega_1 t + \sin\omega_2 t)^2$ gives a term $2\sin\omega_1 t\sin\omega_2 t$ which is equal to $\cos(\omega_1 - \omega_2)t - \cos(\omega_1 + \omega_2)t$.)
Thus, while the amplifier without negative feedback gives nothing but second-harmonic distortion on a single sine-wave input, as soon as a little feedback is applied, a third-harmonic output appears. This is not the end of the story, however, for this third harmonic, like the second harmonic, gets fed via the $\beta$-network into the input circuit, where sum and difference products are again generated. This time the sum products are at $f + 3f$, which gives a fourth harmonic, and $2f + 3f$, which gives a fifth harmonic. Clearly there is theoretically no end to this process – every new harmonic considered, when fed back, gives rise to harmonics of yet higher order. Before too hastily condemning feedback, however, it is wise to consider the magnitude of these effects, and also to question whether assuming a purely parabolic transfer characteristic is sufficiently closely related to the behaviour of practical devices to be of much value. Maybe they already produce comparable amounts of high-order harmonics before feedback is applied? It is evident that a fully satisfactory understanding of the problem can best be reached by a combination of theory and experiment.

Before presenting experimental results for comparison, the theory of feedback over an ideal parabolic device will be pursued further, to obtain the actual magnitudes of the various harmonics generated. The full analysis is somewhat tedious, but an outline of the approach adopted is as follows. The aim is to obtain an expression for the closed-loop transfer characteristic in the form of a power series

$$v_{out} = a_1 v_{in} + a_2 v_{in}^2 + a_3 v_{in}^3 + \ldots \qquad (10)$$

Then $v_{in} = \hat{V}_{in}\sin\omega t$ is put in this and the resultant harmonic magnitudes are obtained. To obtain the power series, the starting point is equation (8), the value of $v'$ there given being substituted in equation (1). This produces a quadratic equation relating $v_{in}$ and $v_{out}$ which can be solved to give $v_{out}$ as a direct function of $v_{in}$. The function, however, contains a square-root sign and is not in itself a power series. The binomial theorem is then used to obtain the wanted power series. Substituting $v_{in} = \hat{V}_{in}\sin\omega t$ in this series gives terms in $\sin\omega t$, $\sin^2\omega t$, $\sin^3\omega t$ etc. As illustrated in Fig. 3, $\sin^2\omega t$ produces second harmonic, and elementary extension of this principle shows that the $\sin^3\omega t$ term produces third harmonic,† and so on. The various harmonic amplitudes are thus obtained as functions of the peak input voltage, $\hat{V}_{in}$. More conveniently, however, for practical purposes, the harmonic magnitudes are expressed as functions of $\hat{V}_{out}$, on a percentage basis. This is preferable, because in assessing the performance of a feedback amplifier, one is interested in the percentages of the various harmonics present at known *output* levels, and how these vary with the amount of negative feedback used. The results of the analysis are given in Table 1. $\alpha$ is the "distortion constant" of equation (1), $A$ is the amplifier forward gain for very small signal levels, and $\beta$ is the feedback factor.

It is instructive to plot curves from the Table 1 formulae and to see how they compare with curves based on measurements using an approximately

† Some third-harmonic is also produced by the $\sin^5\omega t$ term, but in view of the much smaller magnitude of this contribution except at signal levels approaching the overload point, it may reasonably be neglected. The output level used in the tests is just low enough to avoid serious errors from this cause.

**Table 1. Theoretic distortion formulae for feedback amplifier with parabolic forward transfer characteristic.**

| Harmonic number | Percentage of fundamental | Ratio of harmonic amplitudes | |
|---|---|---|---|
| | | Harmonics | Ratio |
| 2 | $\frac{50\alpha\hat{V}_{out}}{1-A\beta}$ | 2nd : 3rd | $1 \times \frac{1-A\beta}{\alpha\hat{V}_{out}\lvert A\beta\rvert}$ |
| 3 | $\frac{50\lvert A\beta\rvert\alpha^2\hat{V}_{out}^2}{(1-A\beta)^2}$ | 3rd : 4th | 0.800 " " |
| 4 | $\frac{62.50A^2\beta^2\alpha^3\hat{V}_{out}^3}{(1-A\beta)^3}$ | 4th : 5th | 0.714 " " |
| 5 | $\frac{87.50\lvert A^3\beta^3\rvert\alpha^4\hat{V}_{out}^4}{(1-A\beta)^4}$ | 5th : 6th | 0.667 " " |
| 6 | $\frac{131.25A^4\beta^4\alpha^5\hat{V}_{out}^5}{(1-A\beta)^5}$ | | |

quadratic device such as an f.e.t. Now it will be noticed that the product $\alpha\hat{V}_{out}$, raised to various powers, occurs throughout the formulae, and a value for this must be decided upon before a set of curves, such as those shown in Fig. 7, can be drawn. A convenient procedure is to choose the value of $\alpha$ so that the theoretical percentage second-harmonic distortion without feedback, given by the Table 1 formula as $50\alpha\hat{V}_{out}$, is the same as the measured second-harmonic distortion at the value of $\hat{V}_{out}$ adopted. This effectively matches the value of $\alpha$ to that of the practical circuit, and is more convenient than determining $\alpha$ by other means.

## F.e.t. characteristics

Most text books give the following equation for the drain current, $I_d$, of an f.e.t. whose drain-to-source voltage, $V_{ds}$, is well in excess of pinch-off voltage, $V_p$.

$$I_d = I_{do}\left[\frac{V_{gs}}{V_p} - 1\right]^2 \qquad (11)$$

This is a parabolic relationship, as illustrated in Fig. 4, and from the geometry of this diagram it follows that

$$g_{mo} = \frac{2I_{do}}{V_p} \qquad (12)$$

An f.e.t. would therefore appear to be the ideal parabolic device for checking the distortion theory evolved above.

However, several years ago, it struck me that there would be something rather queer about a device if it accurately followed a law as given by equation (11), the reasoning being as follows. Differentiating (11) gives

$$g_m = \frac{dI_d}{dV_{gs}} = \frac{2I_{do}}{V_p} \times \left[\frac{V_{gs}}{V_p} - 1\right] \qquad (13)$$

But from (11)

$$\frac{V_{gs}}{V_p} - 1 = \sqrt{\frac{I_d}{I_{do}}}$$

and substituting this in (13) leads to

$$g_m = \frac{2I_{do}}{V_p}\sqrt{\frac{I_d}{I_{do}}}$$

Finally, using the relationship (12), this becomes

$$g_m = g_{mo}\sqrt{\frac{I_d}{I_{do}}} \qquad (14)$$

According to this equation, as the working drain current $I_d$ is reduced, $g_m$ falls off in proportion to the square root of $I_d$. Now for a junction transistor $g_m$ varies with collector current $I_c$ according to the relationship

$$g_m = I_c \times \frac{q}{kT} \qquad (15)$$

where $q$ = charge of an electron, $k$ = Boltzmann's constant, and $T$ = absolute temperature.

Here $g_m$ is proportional not to the square root of the collector current, but to the collector current itself, and with silicon planar transistors the relationship holds accurately in practice down to currents of less than a nanoamp. Thus, while an f.e.t. will normally have a lower $g_m$ than a junction transistor at, say, 1mA, the more gradual fall-off in $g_m$ with working current for the f.e.t. would, if continued, give it a much larger $g_m$ than a junction transistor when operated at a low enough current. In view of the very basic quantities involved in equation (15), I felt this result was probably too good to be true! A measurement of $g_m$ for an f.e.t. over a wide range of drain current was therefore made, and gave the result shown in Fig. 5. Thus it seems that a law of nature does indeed come into action to prevent the $g_m$ of an f.e.t. exceeding that of a junction transistor. It will be seen that the steeper broken-line asymptote is fairly closely that expected for a junction transistor, and would, if continued to the right, give a $g_m$ of nearly 40mA/V at 1mA.

Because of the above discrepancy between the usual text-book equation (11) and what is found to happen in practice, if for no other reason, one would not expect the transfer chracteristic, corresponding to Fig. 4, for an actual f.e.t., to be quite precisely parabolic. Consequently, even without negative feedback, harmonic components in addition to second harmonic must be expected to appear to some extent.

However, despite the above, the assumption that the transfer characteristic for an f.e.t. is as given by equation (11) is quite near enough to the mark to permit the magnitude of the second-harmonic distortion without feedback to be fairly accurately calculated – provided the working current is not excessively small (see Fig. 5). It may be deduced from equation (11) that

$$\%2\text{nd} = 12.5\frac{\hat{I}}{I_{dc}} \qquad (16)$$

(f.e.t. without feedback)

where $\hat{I}$ is the peak fundamental drain-current excursion and $I_{dc}$ is the working d.c. drain current.

Equation (16) may be compared with the result for an ideal voltage-driven junction transistor, which is

$$\%2\text{nd} = 25\frac{\hat{I}}{I_{dc}} \qquad (17)$$

(Junction transistor without feedback)

In this latter case an alternative formula [1,2] is

$$\%2\text{nd} = \hat{V}_{in} \qquad (18)$$

where $\hat{V}_{in}$ is the peak signal input vol-

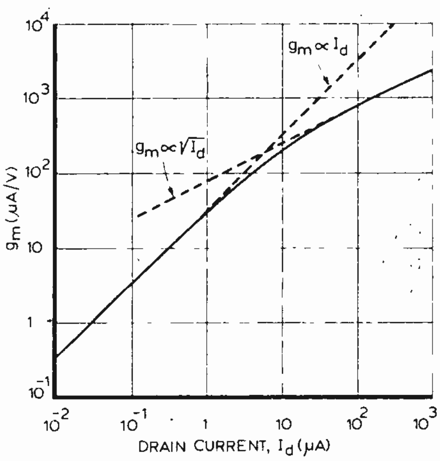



**Fig. 5** *Measured mutual-conductance characteristic for an f.e.t.*

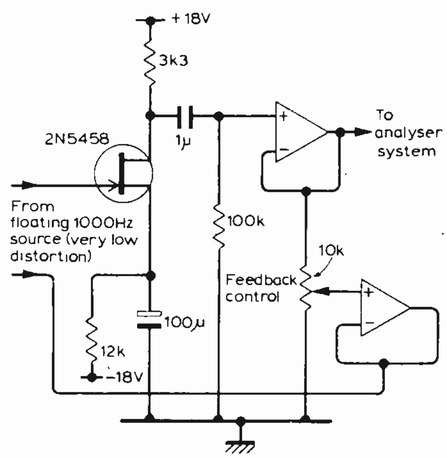



**Fig. 6** *Test circuit for harmonic-distortion measurements.*

tage in millivolts. But no such delightfully simple result applies to the f.e.t.

### F.e.t test circuit

The experimental circuit used for distortion measurements on an f.e.t. amplifier stage, with and without negative feedback, is shown in Fig. 6. No very expensive measuring equipment was used. The 1000Hz signal source consisted of a home-made low-distortion R-C oscillator feeding a Quad 50E amplifier, an air-cored tuned circuit purifying arrangement being connected to its floating output winding. The analyser system consisted of a parallel-T 1000Hz notch filter, whose output fed an R-C oscillator modified to function as a very highly selective amplifier feeding a c.r.o. For all measurements except second-harmonic, a passive notch circuit tuned to the second-harmonic frequency was inserted in front of the selective amplifier. Having tuned in a particular harmonic, the analyser system input was then switched to another oscillator, at the harmonic frequency, the known output of this oscillator being adjusted to give the same size of c.r.o. picture as before. With due care to avoid r.f. interference and hum problems, this set-up was both highly sensitive and of satisfactory accuracy. A test was done in which the signal source, at an enhanced level, was fed via a 3.3kΩ resistor straight to the integrated-circuit follower. The harmonic readings at the output of either integrated circuit, as the same fundamental voltage as before, were then negligible compared with those obtained with the f.e.t. in operation.

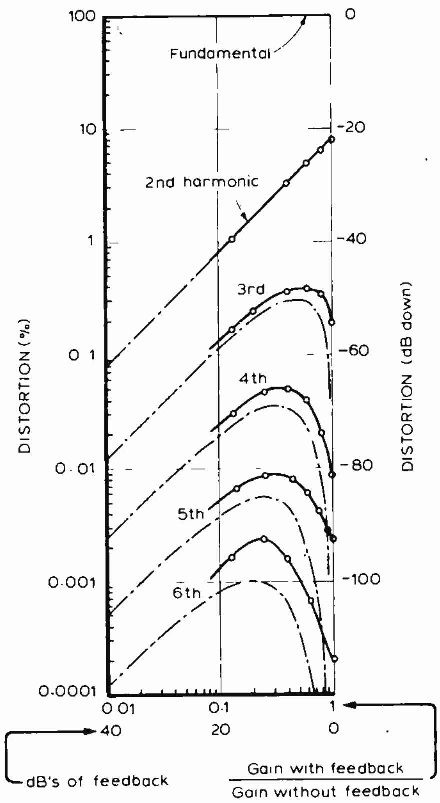



**Fig. 7** *The full-line curves represent distortion measurements using the Fig. 6 set-up. The chain-dotted curves relate to calculated distortion, assuming an ideal parabolic f.e.t. characteristic as shown in Fig. 4. All curves are for a fundamental output level of 3V peak.*

### Consideration of results

Fig. 7 shows, in full-line, the results of measurements using the Fig. 6 circuit, the chain-dotted curves being calculated from the formulae in Table 1. All curves relate to a fundamental output voltage of 3 volts peak. (A convenient fact is that, even with a large second-harmonic present, the peak value of the fundamental is accurately equal to half the peak-to-peak value of the total output waveform.)

The mean drain current in Fig. 6 is 1.55mA. The a.c. drain load is 3.2kΩ, giving a peak fundamental drain current, at 3 volts peak, of 0.94mA. Equation (16) above thus predicts a percentage second-harmonic distortion without feedback of $12.5\times(0.94/1.55) =$ 7.6%. It will be seen that the measured value is very close to this. As expected, however, the f.e.t. without feedback shows itself to be by no means ideally parabolic in transfer characteristic, so that appreciable amounts of higher-order harmonics are measured – though the largest of these, the third harmonic, is only 0.19% despite the quite large output level.

When feedback is applied, the magnitude of the measured third harmonic, conveniently expressed as a percentage of the constant fundamental output, at first rises, as more and more second harmonic is fed back into the input circuit to intermodulate with the fundamental voltage existing between gate and source and thus generate a sum component at third-harmonic frequency. As the feedback is further increased, the resulting improved linearity of the amplifier soon becomes the dominating influence and, when the amount of feedback is large, the third-harmonic output (at constant fundamental output) becomes directly proportional to $1/(1-A\beta)$. Similar effects occur also for the other harmonics, and it will be seen that the measured distortions, when the feedback is large, approximate closely to those calculated assuming a purely parabolic transfer characteristic. Thus, for an f.e.t. at least (though actually it applies also for a junction transistor), the main distortion mechanism for the production of third and higher harmonics, once plenty of feedback is applied, is the intermodulation one mentioned, rather than the existence of cubic and higher terms in the power series representing the transfer characteristic.

### Conclusions

Some important conclusions that may be drawn from the above are:

- Even f.e.ts, used without feedback, generate high-order harmonics — and therefore, on programme, high-order intermodulation products.

- A small amount of negative feedback (e.g. 6dB) in a single-ended stage, though reducing the second-harmonic distortion, and also the total (unweighted) distortion, by about 6dB, will increase the higher-order distortion, and the quality of reproduction may well become worse as judged subjectively.

- If enough negative feedback is applied, all significant harmonics (and corresponding intermodulation products) can be reduced to a far lower level than without feedback, though the amount of feedback required to achieve this becomes larger the higher the order of the harmonic considered. (For example, referring again to Fig. 7, 16.5dB of feedback is sufficient to reduce the third harmonic to the same level as it has without feedback, whereas about 35dB is required for reducing the sixth harmonic to its no-feedback level.)

- The magnitude of harmonics of extremely high order will be increased by the application of negative feedback, no matter what practical amount of feedback is employed, but this is of no consequence if, when thus increased, they are, say, 120dB below the fundamental.

- Fig. 7, as already stated, applies at a particular output level of 3V peak in the Fig. 6 circuit, the peak drain current excursion being about 60% of the working drain current — in other words, it is high-level class A operation. When the signal level is reduced, the various harmonics fall off at different rates, as may be seen from Table 1. The percentage second-harmonic is proportional to $\hat{V}_{out}$, whereas the percentage fifth-harmonic, for example, is proportional to $\hat{V}_{out}^4$. On a logarithmic plot, as in Fig. 7, the effect of reducing the output signal level is that all the curves remain of the same shape, but each curve shifts downwards by a distance proportional to $(n-1)$, where $n$ is the order of the harmonic, so that the spacing between the curves becomes wider. Thus at a reduced output level the higher-order harmonics rapidly become negligible.

*(To be continued)*

### References


1. Baxandall, P. J., "Low-distortion amplifiers – Part 2", *J. British Sound Recording Association*, Nov. 1961, pp. 246-256.
2. Taylor, E. F., "Distortion in low-noise amplifiers", *Wireless World*, Aug. 1977, pp. 28-32.

# LETTERS TO THE EDITOR

## RECEIVING DISHES FOR SATELLITE BROADCASTING

I suggest that there is a serious misconception about satellite broadcasting systems being propagated by "headlines" and news items like your July 1978 item "Will the dish antenna replace the chimney pot?"

It is informative to drive or walk down a street and see how few homes have a direct-sight line to a broadcasting satellite. A direct sight-line is essential to reception. Antennas will have to be outside, unless very efficient radomes are provided for inside antennas. Trees in leaf effectively block the satellite signals in the 12 GHz band.

I do not doubt that broadcast satellites will be developed and in use within a few years but I seriously doubt that there will be many homes able to receive these broadcasts on their own antennas. Most reception is likely to be community antennas of various kinds, i.e. antennas that serve a group of buildings or a whole community, probably in the form of cable television distribution systems.

We have some experience with terrestrial broadcasting services at 2150MHz (the MDS service in the United States). Even at this lower frequency we require absolutely clear sight-line and find that in many communities such sight-lines are not available for a large proportion of homes.

*I. Switzer*
*Switzer Engineering Services Ltd*
*Mississauga*
*Ontario, Canada*

*Our report dealt with a talk given by Dr G. J. Phillips, so we have asked Dr Phillips to comment on the letter:*

The question raised by Mr Switzer is an interesting one. I would first, however, say that there is no misconception in the proposals for broadcasting by satellites in the 12GHz microwave band. There has been very wide international agreement on the principle that the transmitted power should be sufficient to permit individual reception where practicable. It was assumed that the majority of people will have at least some part of their premises or adjoining ground in line-of-sight from the satellite. The chance is very much greater with an elevation of some 25 degrees than with the terrestrial case Mr Switzer mentions. Of course, it will be more practical in a large number of cases to have local cable distribution systems. apart from some cases where they are essential because direct reception is not possible.

However, we can all find our own answer to the line-of-sight problem very simply. On October 12th at 3 p.m. BST the sun was at a position in the sky that represents the satellite position assigned for UK services. It is near enough in the right place on any afternoon at this time from 6th to 18th. We can see which part of our premises or garden are in shadow, and whether or not there is any position left in sunlight that would be a practical one for a 3-foot dish. Incidentally, I agree that trees are a major problem, and we have to anticipate the next few years of growth of potential offenders.

What is sometimes forgotten is that terrestrial broadcasting and cable systems share a basic difficulty; extending coverage to remote areas of low population is expensive with either of these methods. Satellite broadcasting gives an opportunity for those prepared and able to install a simple system to receive the service, in whatever part of the country they live. In some ways it comes close to the ideal of broadcasting than anything hitherto. But it still allows a cable system to be used when it can be installed and proves to be cheaper or where our observations of the sun in October show you need it!

*G. J. Phillips*
*BBC Research Department*
*Tadworth, Surrey*

## MICROCOMPUTERS AND MICROPROCESSORS

New developments will probablv always bring with them problems of description. A current area of difficulty seems to be the word 'microcomputer'. Indeed, in a recent vocabulary of microprocessor terminology[1], a microcomputer is said to be:

"1. Synonymous with microprocessor.
2. Computing system which usually consists of a microprocessor unit memories and i/o circuits mounted on a p.c. board, and sells for about 500 dollars, comparable to a minicomputer but smaller in size, slower and less powerful."

Many readers will probably agree with definition number 2, i.e. a microcomputer is a microprocessor-based system. However, definition 1 seems dubious.

When the manufacturers recently started putting a microcprocessor, memories and i/o onto a *single chip* they had to use a new description to differentiate it from a microprocessor, as the following examples show:

Intel 8048 Single component 8-bit microcomputer
Intel 8022 Single chip microcomputer
Motorola 6801 Microcomputer unit (MCU)
T.I. TMS 1000 One-chip microcomputer
Rockwell PPS4/1 Single circuit microcomputer
AMI 9940 Single chip microcomputer
Mostek 3870 Single chip microcomputer

I should have explained this in more detail in my recent article "Trends in microprocessors" in the September issue as this may have prevented your editorial staff from changing the word 'microcomputer' to 'microprocessor' in a number of places, in an attempt to be consistent with their current beliefs on terminology. The section on page 68 headed 'Single chip microprocessors' should have been headed 'single chip microcomputers' and the word 'microcomputers' used throughout this as appropriate. Also 'microcomputers' should have been used in the section headed 'two chip expandable systems' on page 69 (lines 17 and 24). Similarly, Figure 4 and Figure 5 should have referred to microcomputers rather than microprocessors.

It is also interesting to look at the manufacturers' descriptions of single board microcomputers:

Intel SBC Micromputers
Packaged microcomputer systems
O.e.m. computers
Motorola Microcomputers (Micromodules)
Zilog Z80 MCB microcomputer board
TI TM 990 Series microcomputer modules
DEC LSI-11/2 microcomputer

The current state therefore seems to be clear; a microcomputer contains a microprocessor, memory and i/o, and you will need more information from the text to determine whether it does this in a box, on a board or in a chip. (Thinks: will we have single-chip minicomputers (sic) one day?)

I should also point out some other minor misprints in the article. On Figure 7, the words 'minimum system,' 'address buffer', 'data buffer', 'control' and 'interrupt' are incorrectly sprinkled around the diagram, and on page 70, the Z8000 address range in expanded mode s'.ould have read 8 Mbyte.

*David A. Russell*
*Computer Technology Ltd*
*Hemel Hempstead*
*Herts*

**Reference**

1. B. Becciolini "MPU Vocabulary" Motorola Publication, 1977.

## RELATIVITY AND TIME SIGNALS

A great deal of present knowledge and understanding is directly opposed to what was earlier thought to be the case and the first chaps to come up with these new-fangled notions, e.g. a round Earth, have always had an unwelcoming reception. However, it does not seem likely that Dr Essen ("Relativity and time signals", October issue) will fall into this distinguished band for his concepts of Relativity, despite his pre-eminent work on establishing time standards at a single location or between stationary locations. In fact he seems to be clinging to older (Newtonian) ways of thought on this subject.

In the preamble to the article he is quoted as saying that "no one has attempted to refute my arguments." This is not the case. At a lecture he gave on this topic some four or five years ago at this institution, several of the audience (from Fellows of the Royal Society downwards) put powerful and cogent arguments at variance with his own, but unhappily Dr Essen seemed barely to hear them, let alone try to grasp what was being said.

A principal difficulty most of us have in attempting to comprehend Relativistic theory is that it systematically encompasses a proposition which is totally at variance with everyday experience — that is, that the velocity of light is the same for all observers. As far as I am aware, this proposition has not been falsified and is in accord with all relevant observations so far made.

Why is this such a difficult idea to handle? Imagine you let off a firework with a bang and a flash; the acoustic and optical wavefronts spread out spherically from you at the speed of sound and the speed of light respectively. Suppose someone is hurrying towards the pyrotechnic display; he sees the acoustic wave approaching him more quickly (than it left you), since (?) he is moving towards this sound wavefront — but, astoundingly, the optical wavefront *still* approaches him at the velocity of light, the self same speed it was receding from you.

Most people find this stunning, not to say distressing, too, but it is wholly in accord with all observations so far made. This is so "unreasonable" that attempts to use everyday language to discuss such situations are usually doomed to the errors and paradoxes which Dr Essen eloquently portrays. It seems that only the strict unbending formality of a mathematical language can cope with discussing effects which are so at variance with everyday experience.

Simultaneity is one such obvious and self-evident everyday idea which is a 'casualty' when constrained to be in accord with the constancy of the speed of light for all uniformly moving observers, who now see the same event happening at different times depending on their speed.

Dr Essen is worried by where the 'missing' ticks go in his clock thought-experiment. Because a sentence can be grammatically and syntactically correct, it still does not imply that any meaning can necessarily be ascribed to it – the classic example of Russell's, "Monday is square" or "Is Monday square?", demonstrates this beautifully. It is not that Dr Essen's ticks are 'missing'. Relativistically, each observer sees his own clock functioning normally and sees the other chap's clock running more slowly. The observers are thus equivalent; that is, they each get identical results for the same observation (watching the other chap move off) and this seems very satisfactory. The ticks only appear to be missing if one takes the old Newtonian concept of time (and simultaneity) as being something absolutely established everywhere 'at once' throughout all space. 'Missing' ticks would be very strange, as Dr Essen perhaps unwittingly emphasises, and good grounds for preferring all of Relativity theory rather than what seems to be his partly Newtonian viewpoint.

A dazzlingly clear exposition on simultaneity and other such matters is given by Einstein himself in the paperback by Methuen called *Relativity (The Special and the General Theory)*, translated by Lawson. In the early parts of this book there is no algebra to 'confuse', just beautiful thought experiments using railway trains (!) etc. and brilliant careful exposition.

*D. Griffiths*
*Physics Department*
*Imperial College*
*London SW7*

*Dr Essen replies:*

I remember the meeting at the Imperial College to which Dr Griffiths refers and if my recollection is correct my talk was given a courteous hearing and friendly reception apart from a few gasps of disbelief which were firmly suppressed by the chairman. The discussion was a disappointment to me, however, since it consisted largely of a reiteration of some of the arguments I had been trying to demolish. It could be that I was too polite or too slow witted to deal adequately with this part of the discussion.

In my article I only dealt with one specific point – the error in Einstein's thought-experiment, but Dr Griffiths' criticism ranges over a much wider area, including the velocity of light and simultaneity. For a discussion of these I would refer the reader and Dr Griffiths to the references given at the end of the article. He advances the view that relativity effects can only be dealt with by "the strict unbending formality of a mathematical language" but I suggest that, on the contrary, an error in a thought-experiment can be explained only by the stricter formality of experimental technique. Although Dr Griffiths calls it my experiment I hasten to disclaim ownership as I am strongly opposed to the use of such devices. However, if they are used they should be conducted with the correct technique and I have shown that if Einstein's experiment is carried out correctly it does not give the paradoxical result obtained by Einstein. I would have thought that relativitists would be grateful to have this paradox explained and removed from the theory.

Dr Griffiths states that each observer sees the other chap's clock running more slowly than his own and I agree that this is a simple way of expressing Einstein's first prediction. My expressions (1) and (2) are a more precise way of saying the same thing. It could be called an apparent effect since it is the result of a measurement made at a distance and is symmetrical for the two observers. If he considers in detail how the comparison is made as I have explained in my article he will be forced to the conclusion that ticks must be lost or at least that they are not received and recorded on the clock dials. Dr Griffiths suggests that I am worried by this loss, but I merely state that it is inexplicable. It was Einstein who was worried and he stated later that it was absurd. He thereby implicitly abandoned his first set of assumptions and the results obtained from them.

If Dr Griffiths wishes to make a serious criticism of my article he must show where my analysis of the thought-experiment is wrong.

*L. Essen*
*Great Bookham, Surrey*

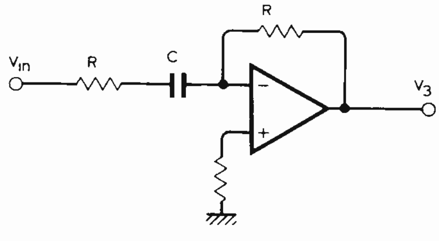
*Editor's Note.* We have received many more letters on this subject and hope to publish a selection of them in future issues.

## HIGH FREQUENCY DIFFERENTIATOR

In Mr S. Cussons's "High frequency differentiator", Circuit Ideas, August issue, the proposed circuit is, of course, not a true differentiator, having the transfer function

$$\frac{sRC}{1 + sRC}$$

instead of the true differentiator's sRC. Mr




Cussons's circuit approximates the true differentiator at low frequencies, $f << 1/2\pi RC$, i.e. $f << 807$kHz, not the claimed 5MHz, with the component values shown. It will run out of loop gain at 5MHz anyway, the second stage will have only × 1.67 typically left.

Rules of nature cannot be altered: a true differentiator has to have gain proportional to frequency with all the associated noise and stability problems.

Incidentally, an identical (except polarity) transfer function can be obtained in a simpler circuit, shown here, with less output offset.

*Andrew E. Romer*
*Bognor Regis*
*Sussex*

## DISCUSSION OF WARC 79 PROPOSALS

It is not true that the United States of America is the only country which encourages public discussion of WARC proposals. Here in Canada the government gives every opportunity for industry and members of the public to read the current draft proposals, comment on them, and participate in the revision.

The process here is not quite the same as in the US, but it achieves the same objectives. It is true that much of the detailed discussion which leads to draft proposals goes on within government, but the group which does this work welcomes submissions from anyone, and there is plenty of evidence that such submissions are given active consideration.

When draft proposals are ready the text is publicised through several channels, including news releases in the printed press. Comments are invited, and all responses (excepting only those for which the authors have specifically requested confidentiality — and these are few) are available for inspection at regional centres of the Department of Communications throughout the country. The third draft of Canada's proposed position at the WARC 79 is now being prepared.

It is normal procedure for the DOC to call a meeting of interested parties each time a new draft revision is published, for explanation and discussion.

In parallel with this activity, industry participates in many studies relating to domestic sub-allocations of present and proposed ITU frequency allocations. Our government in fact indulges in quite a lot of pushing and prodding to excite more interest and comment from both industry and the public at large.

I should mention that the Canadian Radio Technical Planning Board is not a government body. We are the working interface representing all users of the radio spectrum and suppliers of radio equipment. Our normal emphasis is on the review of type approval specifications for radio and tv equipment, and standard radio systems plans for efficient use of the spectrum within Canada (this kind of thing also being done here in the knowledge and with the participation of all those in industry and the public who care about such things).

I just felt that credit should be given where credit is due; our government does its best to encourage participation.

*Bob Eldridge*
*Canadian Radio Technical Planning Board*
*Ottawa, Ontario*

## BIRD'S GEOMAGNETIC SENSE

As a neurophysiologist I read with interest recent letters regarding the problem of avian geomagnetic sense (February and June). As someone more familiar with animals than transistors I feel that I ought to voice some thoughts on the subject.

As I understand it your correspondents have suggested that some avian organ or tissue may be receptive to small potentials induced therein by the bird's passage through the earth's magnetic field. These potentials are presumably induced in exactly the same way as in any normal metallic conductor under similar conditions.

My first point is that such a mechanism could not be used for the detection of magnetic north. Given that magnetic lines of force have no thickness, the same number of lines will be 'cut' by horizontal movement through them in any compass direction. Thus the potential induced in our receptive organ would be independent of compass course, which would therefore be undetectable.

However, the angle of dip of the earth's magnetic field is a function of latitude, being zero at the magnetic equator and nearly 90° at the magnetic poles. Thus our mechanism could be used for the detection of latitude, the potential due to flight increasing as angular distance from the magnetic equator (and reversing in the southern hemisphere).

Which organ or tissue may be responsible for this detection? It has to have the properties of a cable conductor, and would be more efficient if it were long and straight. The obvious answer is nerve cells (neurones), some of which may be several centimetres long in the pigeon. In addition, they do show some properties characteristic of cable conductors.

It is unlikely that these neurones would be found in the wings, as previous contributors have suggested, since wing movement is in three dimensions and any induced signals would reverse their polarity on upstroke and downstroke. The neutral circuitry needed to analyse this kind of information would have to be exceedingly complex. It is one of the axioms of modern biology that things are never complex when they can be simple! In addition, the point previously made concerning interference from wing muscles (current flow which would also produce a magnetic field) is valid and powerful.

Alternatively, I would propose that such neurones would be found in the spinal cord of the bird in question. This has the advantages of being long, straight and moving in one dimension only when the bird is in flight.

The objection that signal-to-noise ratios would be such as to make signal processing impossible does not hold water on two counts. Firstly, there could be many tens, if not thousands, of neurones involved in field detection. Parallel information processing of this kind is relatively common in nervous systems, one of the best examples being the human ear. Secondly, many other sensory systems can extract extremely weak signals from large amounts of noise. Good examples are the electric field detectors of certain fish and the lateral line vibration detectors of others.

The magnetic field sensing neurones of our navigating bird are likely to be of the 'leaky' kind. Such neurones constantly fire nerve impulses at fixed frequencies, and these are superimposed on a resting potential of some 70mV (negative inside the neurone). Any magnetically-induced alteration of this resting potential by as little as a fraction of a microvolt would alter the neurone's firing frequency in such a manner as to make it detectable by relatively simple neural processing. It is such a mechanism which enables electric fish to detect minute field changes.

Regardless of whether magnetic field detection is theoretically possible, there is indisputable evidence that many birds (and indeed some other animals) do use it for navigation. It must be viewed, however, as only one of many mechanisms which birds have been shown to use. Such include visual cues from local geography, astronavigation (both by sun and stars), and, incredibly, the use of a very accurate 'biological clock.'

One must ask oneself whether the use of geomagnetic sense alone could guide a bird to an accuracy of half a mile or so over a distance of many hundreds of miles. Personally, I doubt it.

*I. Seath*
*Lowestoft*
*Suffolk*

## ALTERNATOR REGULATOR

Having designed a regulator similar to that of Mr Watkinson (August issue), I have discovered that stabilising the regulator is not as straightforward as he suggests.

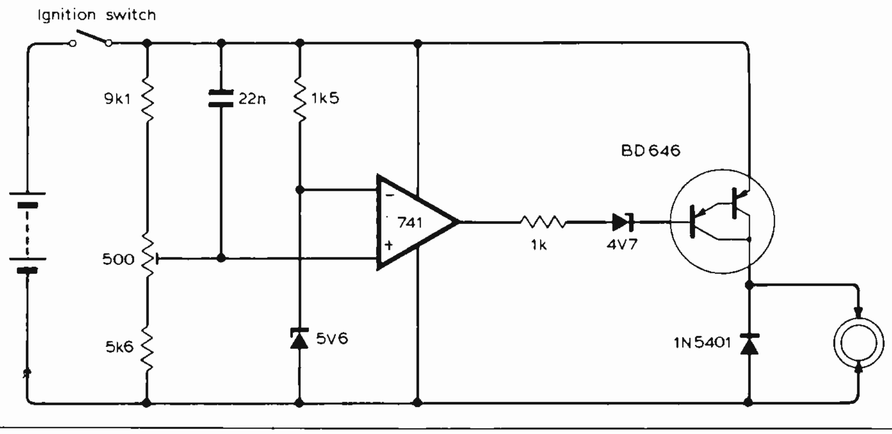
I found that with a circuit very similar to his, including stabilising capacitor $C_1$, I was getting gross instability to the extend that at night a 2Hz flicker was apparent in the headlight beams. The battery potential was varying by about 0.5 volts, indicating that the regulator was switching the alternator fully on or fully off. After some thought I realised, as Mr Watkinson states, that the transfer function of the alternator has poor bandwidth. Because of the inductance of the field winding, a sizeable lag is introduced into the feedback loop.

The instability this causes may be eliminated by lowering the loop again, i.e. decreasing the gain of the regulator. However, this then has the effect of widening the error band of the loop, so that for light loads the battery voltage is high, leading to overcharging during daylight in the summer, and conversely low battery voltage for heavy loads such as rear screen heaters and lights — not a desirable phenomenon.

The alternative that I chose was to accept that the feedback loop will be unstable, and to ensure that the regulator switches at a few hundred hertz. This has the advantage that the output transistor dissipates very little power. (An analogy is the switched mode power supply compared with the linear regulating type.) Loop gain can be very high, giving constant battery voltage whatever the load.

This is achieved by connecting $C_1$ between the base of $Tr_1$ and the positive rail instead of earth, in Mr Watkinson's Fig. 1. In fact, my circuit as shown is very similar to his Fig. C, differing mainly in that my alternator field winding is earthed at one end. I therefore inverted the connections to the op-amp, and used a p-n-p Darlington transistor between the positive supply rail and the field winding. Using a 741 op-amp with its low output slew-rate helps avoid fast switching transients coupling through the alternator.

*C. Stephens*
*Woodbridge*
*Suffolk*




## MICROPROCESSOR BUSES

I was surprised to see (October letters, p.60) that P. Borril is still trying to establish a microprocessor standard bus for Eurocards with indirect connectors.

For some reason he seems to have chosen to ignore the existence of a bus that fits his requirements, that is the E-78. This has been designed for the new generation of 16-bit microprocessors and their large amounts of address space. Special emphasis has been given to making this bus suitable for use with all the micros that Mr Borril lists, as well as with the Intel 8086, the Zilog Z-8000 and the Motorola 68000. Provision is also made, as with the Intel Multibus, for multiprocessing.

Anyone who is interested in learning more about E-78 is advised to contact: Mr A. Secker, 209 Albury Drive, Pinner, Middlesex, who is the secretary of the E-78 committee.

*Anthony J. Aylward*
*Gillingham*
*Kent*

## EDISON VOICE WRITER

We have acquired an Ediphone, Edison Voice Writer, serial number 505151, made by Thomas A. Edison Inc., West Orange, N.J., USA. Can any of your readers give us any information on this item?

*J. Firth*
*Firth-Guthrie Instruments Ltd*
*70 Twist Lane*
*Leigh WN7 4DP*

## TECHNICAL KNOWLEDGE

I am puzzled by the increasing use in written and spoken English of the word "expertise" (pronounced "experteeze", and therefore, presumably, a borrowing from the French).

My French dictionary defines it thus:

*expertise*, n.f., survey, valuation, assessment (of specially appointed surveyors); report, appraisement, arbitration. *Faire une expertise:* to make a survey.

It is most distracting to see the ghostly forms of quantity surveyors and estate agents flitting across the page as I struggle to come to terms with the march of progress in electronics. So, to all of your contributors:

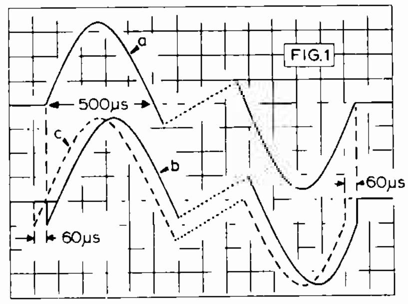
I beg you on my bended knees
say skill not "expertise".

*F. L. Devereux*
*Hindhead*
*Surrey*

## SPECTRA OF TONE BURSTS

Before replying to Mr Driscoll's June letter on the interpretation of tone burst spectra it might be useful to summarise what has gone before. In the December 1976 letters he mentioned an experiment of his which showed that it was possible to distinguish between two rectangular tone bursts which differed only in the 'phase' of the sinusoidal carrier with respect to the burst envelope, and interpreted this experiment as showing that the ear could sometimes distinguish periodic waveforms whose spectra differed only in the phases of the components. In the February 1977 letters I pointed out that the tone bursts he described had different discontinuities at their ends, which would produce differences in the amplitudes of the spectrum components, thus invalidating his interpretation. In the July 1977 letters he denied this, and asserted that the only difference between the spectra of the tone bursts he had used was 'a simple linear phase shift of all spectral lines'. In the October 1977 letters I quoted an algebraic expression for the spectrum of an isolated rectangular tone burst and showed that the spectrum amplitudes were indeed functions of the carrier 'phase', and that the component phases depended in a nonlinear fashion both on the component frequency and on the carrier 'phase'.

From the June letters, one of Mr Driscoll's students has checked this expression and has been unable to fault it, Mr Driscoll, however, now asserts that the amplitude changes and nonlinear phase changes are very small, that these spectrum changes lack practical significance,' and that the important effect of altering the carrier 'phase' is to alter the phase of each component of the spectrum by an amount proportional to its frequency, leaving its amplitude unchanged. In fact this last effect is essentially a trivial one brought about by Mr Driscoll's student's unfortunate choice of 'synchronising times' (see my letter in the September 1976 issue) in calculating the toneburst spectra. Fig. 1(a) shows part of a repeated rectangular toneburst waveform with 'onset angle' 0°, Fig. 1(b) a waveform with onset angle 20°, and Fig. 1(c) the same waveform just shifted back in time by (20/360)/1000s or 60μs. Clearly the second and




third waveforms will sound identical, but in the spectrum of the third waveform these linear phase shifts simply do not appear. An elementary theorem on Fourier transforms, touched on in my letter of September 1976, states that the effect of shifting a waveform backward by a time $t$ is to subtract from the phase of each component an amount $2\pi ft$, where $f$ is its frequency, leaving its amplitude unchanged. The waveform of Fig. 1(c) differs from that of Fig. 1(a) only for intervals of 60μs at the beginning and end of each toneburst, and the two spectra differ only in the amplitude changes and nonlinear phase shifts which Mr Driscoll is so anxious to ignore. The differences are certainly small, since the end sections amount only to 1.5% of the length of each burst, and by Gabor's acoustic uncertainty principle spread their contributions out over a frequency range of about 10kHz. However, if Mr Driscoll's experimental observations are correct these differences must provide their explanation,. and clearly invalidate his original interpretation.

His algebra is also at fault. The range of integration of $\omega$ in complex Fourier transforms from spectrum to waveform is from $-\infty$ to $+\infty$. Thus if his $P(\omega-\omega_c)$ (June letters) is large when $\omega\sim\omega_c$ then $P(\omega+\omega_c)$ must be large when $\omega\sim-\omega_c$, and cannot be neglected, so that his demonstration collapses.

In closing may I repeat my observation from an earlier letter that in the frequency domain common sense can be a dangerous guide, even it would seem for someone with access to a digital computer. There is indeed no substitute for a sound 'grasp of basic principles'.

*C. F. Coleman*
*Wantage*
*Oxon*

## PUSH-BUTTON TUNERS WITH AFC

I note with approval Cathode Ray's call for the use of push-button tuning arrangements (September issue). In the same issue Mr Nelson-Jones publishes his revised circuit of his f.m. tuner using as before push-button tuning. However, on examining his circuit I find no precautions against a very annoying problem. It is this: if a station is selected at the high frequency end of the band, then on switch-on the supply to the varicap diodes builds up slowly and the tuner may lock on to a lower frequency station. In my area, if LBC was selected then it was very likely that there would be an adventitious lock on to BBC Radio London or even Radio 4. On momentarily disabling the a.f.c. the proper tuning results, but it is an annoyance.

The remedy is simple in the extreme: an electrolytic capacitor connected across the contacts of the "disable a.g.c." switch. At switch-on this capacitor must charge up, thus in effect creating the position that the contacts were closed until some degree of charge is established in the capacitor. In this "breathing space" before the a.g.c. comes on the varicap voltage becomes established so the correct station is captured.

The value of the capacitor should be chosen to suit the circuit but it is by no means critical. The readily available 160μF, 10-volt type seems generallyappropriate. Often there is no room for it on the p.c. board but it is easily mounted on the appropriate terminals of the push-button unit or on the a.g.c. on/off switch. It would be a worthwhile addition to the new Nelson-Jones tuner, at least in districts where the problem arises.

*Ivor Abelson*
*London N14*

## POOR PROSPECTS IN ELECTRONIC ENGINEERING

In your September issue, Tim Williams wrote that large companies would have only "inexperienced youngsters and experienced no-hopers (some would have it that this is already so); in which case, if their senior management were unaware or, through inertia, unable to rectify the situation, they would simply collapse, due to inability to compete — in the absence of other market factors. It may be that this process is already in motion, and that the elephants have had their day."

During the last two years my close colleagues and I have by chance studied a very large number of companies at close quarters. We would confirm that the large companies in our field *have* collapsed, by which I mean that the decline is far gone and irreversible unless drastic action is taken. There has been a sustained attack on its own technocratic base by the management of every large company of which I have experience in the field of computers and electronics. They are now generally propped up by cost plus, no-results-demanded, government contracts.

It is not good enough for people like myself to stand by looking wise, saying "I told you so," (see *Computer Worship*, 1972, pub. Pitman, page 48) and do nothing positive about picking up the pieces and making something constructive out of the near empty shells that PQR, STU and the other large electronics companies have become. As Tim Williams says, "It would be a shame if the vast resources inherent in [the elephants] were to go to waste."

Only *we*, the technocrats, are in a position to know that today our major high technology companies generally have only badly paid, souped-up wiremen and office boys masquerading as senior research engineers and designers.

I would like *Wireless World* to host a dialogue, premised on the assumption that technology-free management has dismantled the technorcracy in our industries, to discuss what we should do next. At technocrats, it is *our* job to pick up the pieces left by the vandalism of other groups.

*Ivor Catt*
*St. Albans*
*Herts*

# Effective length of ferrite rod aerials

A topic that has received almost no treatment in the literature

by **H. Sutcliffe,** M.A., Ph. D., F.I.E.E, F.I.E.R.E. Department of Electronic Engineering, University of Salford

The theory given in this article was recently checked by my colleague M. D. Samain and was at first received with some scepticism because his measurements comparing a frame aerial with ferrite rod aerial were inconsistent. The discrepancy was not explained until he telephoned the BBC and found that the Moorside Edge medium wave transmitter, which had been used as the signal source, has its power boosted as daylight fades and this occurred half way through the exercise. As Sherlock Holmes pointed out, if there is only one possible explanation it must be right, however improbable.

A COMPLETE ANALYSIS of the behaviour of any aerial should be conducted using the concepts of gain, aperture and radiation resistance but this approach gives a tortuous route in answering the following simple question. "If a ferrite rod aerial is located in a radiated field of strength $E$ volts per metre and the p.d. at the coil terminals is $V$ volts, how do we find the effective length $L$ appropriate to the relation $V = LE$ ?" This is a fair question but, surprisingly, has received almost no treatment in the literature of electromagnetic theory and aerial design. There is a fairly simple approach to a solution which will be presented later in this article, but first examine that simpler structure, the loop or frame aerial.

Suppose a loop, small in size compared with a wavelength and with $n$ turns enclosing an area $A$ square metres, is sitting with its plane in line with the transmitter. Then the transmitted magnetic field will pass normally through A and if no current is taken from the coil the p.d. can be calculated from the flux-changing law. If the magnetic field is $H = H_m \sin 2\pi ft$ the linked flux is $\mu_0 AH$ and the p.d. is

$$V = \frac{d}{dt}(\mu_0 AnH)$$

$$= \mu_0 AnH_m 2\pi f \cos 2\pi ft$$

It is conventional to describe aerial performance in relation to electric field strength $E$ rather than magnetic field strength $H$. For normal propagation the two are in phase and at right angles to each other, and have the ratio $E/H = 120\pi$ ohms $= R_0$, and called the impedance of free space. We insert this relation and get

$$V = E_m\left(\frac{\mu_0\ Anf}{60}\right)\cos 2\pi ft$$

or $V = LE_m \cos 2\pi ft$

where $L$ can be defined as the effective length of the loop aerial.

The next stage in considering the connection of a loop aerial to a receiver is to draw the equivalent circuit. The real circuit might be as shown in Fig.1(a) and then the equivalent circuit appears as at(b)

In the equivalent circuit $L_L$ and $R_L$ are the inductance and series resistance of the loop. $R_{rL}$ is a component that has been ignored in the discussion so far. It is the radiation resistance of the loop and represents the power lost by radiation when current flows. For loops of size small compared with a wavelength, $R_r$ is found to be so minute compared with $R_L$ that it is of no practical importance. The voltage $V_o$ across the capacitor may be regarded equally legitimately as the output voltage of the aerial circuit and is greater than $V$ in proportion to the Q-factor of the circuit. It would be quite acceptable to define $L$ as $V_0/E$ or to define the $L$-value for one turn only of the loop, so it appears that the $L$-value of this kind of aerial is not a unique property but must be related to some particular aspect of the associated circuit.

So much for the loop aerial, which was discussed solely to explain a sequence leading from an easily understood physical process, voltage induction in this instance, via concepts of equivalent circuits to a method of calculating voltage and current signal levels in circuits associated with the aerial. Can we follow the same argument with the ferrite rod aerial?

It is tempting to regard the rod as an extension of the loop, collecting and concentrating the radiated magnetic field and channelling it through a coil wound round the middle of the rod. This approach is strangely unrewarding, though it has provided several theoreticians with a challenging exercise in field theory and mathematics. There is another route to the solution of the problem* more appropriate to circuit designers, and this alternative approach will now be presented.

The argument begins by considering an idealized ferrite structure similar in shape to the ball-ended magnet that was, and perhaps still is, common in school physics laboratories. This structure is called a magnetic dipole and has the property that its magnetic flux enters and leaves the magnetic material only at the ends, which are distance $l$ metres apart. Now suppose the dipole to be wound with $n$ turns of wire and to be aligned with an alternating magnetic field $H$ amps per metre. Flux will oscillate through the winding and voltage will be induced, but we must postpone this concept. Instead we imagine the application of a current generator $I$ to the terminals of the winding as shown in Fig.2. The magnitude and phase of $I$ is adjusted exactly to balance the magneto-motive forces, so that no flux passes through the dipole and no voltage is induced in the winding. In these circumstances the relation between $I$ and $H$ is very simple and is

$$nI = Hl, \quad I = Hl/n$$

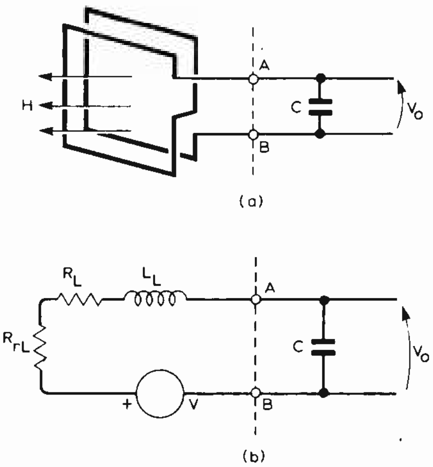



**Fig. 1.** *Loop aerial (a) and its equivalent circuit (b). $V$ is $LE_m \cos 2\pi ft$, where $L$ is the effective length.*

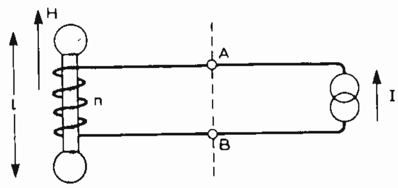



**Fig. 2.** *Magnetic dipole in $H$ field connected to a current generator. Flux and voltage are zero if $nI = Hl$.*

* Ferrite rod aerials, by H. Sutcliffe. *Int. J. Elect. Enging Educ.* Vol.13 1976, pp. 35-40.

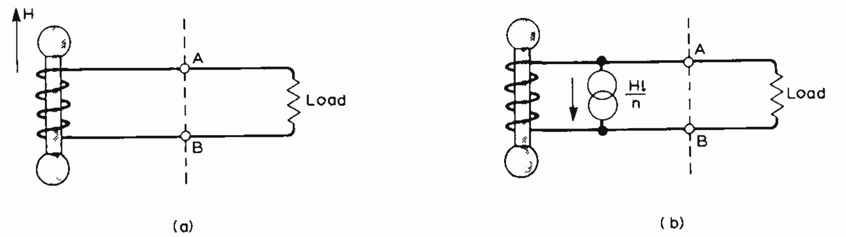



**Fig. 3.** *Magnetic dipole in H field connected to load (a) and its equivalent circuit (b) in which the dipole is now a passive component.*

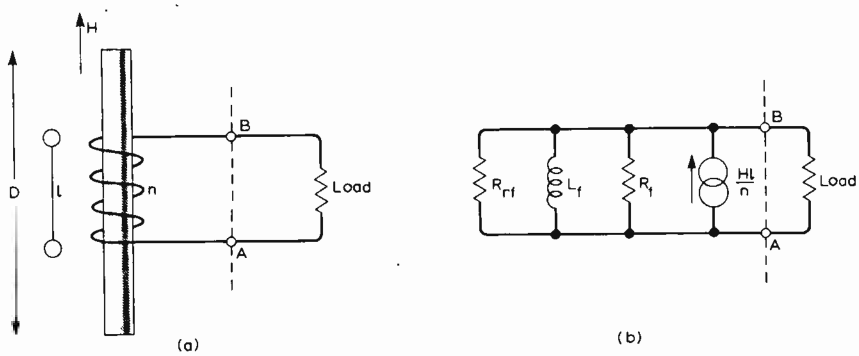



**Fig. 4.** *In equivalent circuit of ferrite rod aerial, I is calculable, $L_f$ and $R_f$ measurable and $R_{rf}$ negligible. Effective length can be defined as $lR_f / nR_0$, manufacturers should quote l.*

The next step is to invoke the principle of superposition and add another generator in parallel with the first, identical to it but with opposite polarity. This step will achieve two things. Firstly and obviously it will nullify the effect of the previous external generator, so that any p.d. appearing at terminals AB is now caused by the transmitted field $H$. Secondly, the voltage that now appears is calculable solely from the effect of applying the second generator. The equivalent circuit of the magnetic dipole is therefore related to the real circuit as illustrated in Fig.3.

This result is somewhat surprising, for we expect from the physical behaviour of the dipole as a receiver that the generator will appear as a voltage generator in series with the coil. Instead we find that in the equivalent circuit the most natural and basic form of the generator is a current generator in parallel with the coil. Before proceeding further with a discussion of circuit topics though, we must examine the situation where the coil is wound not on an ideal dipole but in the usual form of a concentrated coil at the centre of a cylindrical ferrite rod. If we are to use the expression for the size of the current generator ($I = Hl/n$) for a ferrite rod we need to know the length $l$ of the equivalent ideal dipole. The argument becomes less precise at this point but still yields useful results.

An illuminating experiment is to excite a rod by a coil at its centre and measure the voltage induced in a coil which can slide along the rod. This provides a measure of the magnetic flux in the rod at various distances from the centre. It is found that the flux is a maximum at the centre and negligible at the ends, and the distribution follows approximately a raised cosine pattern. This experiment has been performed with rods of various lengths, diameters and permeabilities, and for the types common in receivers there is very little difference in the general pattern of behaviour. Further experiments based on the equivalent circuit of Fig.3, in which the $H$ field was generated by a local air-cored coil, confirmed the conclusion that for common ferrite rod aerials the equivalent dipole length $l$ is approximately 1/3 of the rod length. The ratio rises to 1/2 for thick rods of high permeability and falls to 1/4 for thin rods and low permeability ($\mu_r \approx 200$). It can be concluded therefore that the equivalent circuit of a ferrite rod aerial can be described conveniently by reference to Fig.4.

In Fig.4(b) the value of $I$ is readily calculable with no requirement to know the diameter or permeability of the rod, though there is some lack of precision because the effective dipole length $l$ is only approximately given by 1/3 of the rod length.

The inductance $L_f$ and parallel loss resistance $R_f$ of the coil are easily measured. Both are approximately proportional to $n^2$. The resistance $R_{rf}$ is the radiation resistance in its parallel form and is so large in practice compared with $R_f$ that its effect is negligible.

It would be quite proper to halt at this stage in the discussion, for the circuit of Fig.4(b) provides everything a circuit designer needs to know, but since the whole exercise was generated by a question about equivalent length, in formulae of the type $V = LE$, it may be appropriate to continue with a little more analysis.

Suppose the load in Fig.4(b) is a capacitor and the aerial voltage is specified as the p.d. $V_0$ across the resulting parallel LC circuit at resonance. Then

$$V_0 = IR_f = HlR_f/n,$$

and since $E/H = R_0$,

$$V_0 = \frac{lR_f}{nR_0}E = LE, \text{ where } L = \frac{lR_f}{nR_0}.$$

A typical situation is $l$ 0.05m, $R_f$ 80 kilohms, $n$ 50 turns, and $R_0$ 377 ohms, for which $L \approx 0.21$ metres, or volts per (volt/metre).

This definition of $L$ is arbitrary as a definition of aerial performance but it does at least have the merit of being easy to remember. Also it gives a correct answer subject to a lack of precision about the value of $l$, the effective dipole length. This normally lies between 1/4 and 1/2 of the rod length, but it would be advantageous if manufacturers of ferrite rods were to quote this most useful parameter when specifying their products.

## UK firms' microelectronics "incompetence"

ACCORDING to union leader Ken Gill, the recent ACARD report on the utilization of microelectronic devices in British industry is "a damning indictment of employers' incompetence". Gill, who is general secretary of TASS (the technical, administrative and supervisory section of the Amalgamated Union of Engineering Workers), was speaking at an AUEW officials' conference at Eastbourne in September. He quoted the ACARD report as saying that we have been overtaken by competitors in fields such as cash registers, food processing equipment, process instruments, machine tools, telephone switching systems, printing machinery and even in ship chronometers. In many of these fields we had previously had a dominant position. "Moreover, we failed to recognise new opportunities until others produced the products" (said the report). "Examples are calculators, electronic watches and clocks, word processing and television games ........ On production methods the picture is just as gloomy. Industrial firms are only slowly incorporating new technology such as numerically controlled machine tools into their manufacturing and into production planning control". The main conclusion in the report, said Gill, is that every department and agency of the Government including nationalised industries must accept the importance of the new semiconductor technology.

"Technology must be our slave and not our master," he went on. "Our members must be alerted to negotiate on every aspect of the new technology and warn them of those areas of importance of which they may not be immediately aware. The multi-national corporations see this technology as a means for greater profits, and greater controls over their employees and the consumer. The union movement see it as more employment and more purchasing power and more leisure for the workers. The massive increase in productivity derived from these developments must go to the benefit of all and not to the few."

FRONT COVER

# Britain joins Europe (again)

## Goonhilly earth terminal looks towards the Continent

IN SEPTEMBER the UK joined an association of 17 European countries set up to manage a future European communications satellite system. Called Eutelsat, this organisation is run by the telecommunication administrations of the various countries — the British Post Office being one of them — and an agreement has been signed about dividing up the cost of the project. The whole system will be based on a 11/14GHz European communications satellite (ECS), carrying telephone, telex and tv traffic, which will be launched at the end of 1981. Meanwhile, a test satellite called OTS2 (Orbital Test Satellite 2) has already been launched (July issue, News, p.48) to allow various experiments to be carried out for the European scheme. Since May this has been in geo-stationary orbit at 10°E above Gabon — a line of longitude which runs through the middle of Europe, passing near Oslo, Hamburg, Lake Constance, Milan, Sardinia and Tunis.

### Dual polarization

Our front cover this month shows the British contribution to the OTS2 experiments, an earth terminal at the Post Office's satellite earth station at Goonhilly Downs. Cornwall. Known as Goonhilly 4 (the earlier terminals being part of the Intelsat scheme), it is now sending speech and television test signals up to OTS2 on 14GHz and receiving them back on 11GHz. It was designed and built by Marconi Communications Systems Ltd in a £3½m joint venture with the Department of Industry and the Post Office. The aerial is a 19-metre dish with Cassegrain feed and a gain of 66dB in the 14-14.5GHz transmitting band and 65dB in the 10.95-11.8GHz receiving band. An unusual feature is that it allows two separate beams to be transmitted simultaneously on the same frequency, one being horizontally polarized and the other vertically polarized, so that spectrum space is saved by handling two groups of signals in the same frequency band. Part of the test programme is to find out whether atomospheric conditions will affect the degree of polarisaton between the two beams.

The 14GHz transmitter, installed in the cylindrical building below the dish, feeds the aerial through a waveguide system and horn. It uses a five-cavity klystron in an r.f. amplifier giving a c.w. power of 1.6kW with a gain of 32dB and a bandwidth (1dB) of 90MHz. In turn this r.f. amplifier is fed with 14GHz signals from a double up-converter which receives an input of either 140MHz, carrying 120Mbit/s digital information or 70MHz carrying 60Mbit/s digital or f.d.m. video information. The receiver consists of a low noise amplifier mounted near the feed horn, and the 11GHz signals from this pass through a double down-converter to give the 140MHz or 70MHz outputs mentioned above.

Part of the test programme with OTS2 will include trials with digital transmission. During the 1980s this technique will be increasingly used within British and other national telephone networks and will therefore be required on international networks. With satellite communications, digital transmission also provides much greater flexibility and economy than earlier analogue methods. By means of time division multiple access (t.d.m.a.), a number of earth stations can use the same satellite radio channel. They use the channel in sequence, in a series of carefully synchronised bursts of radio transmission. For the t.d.m.a. tests with OTS2, Goonhilly 4 can provide the signals to synchronise all four European aerials involved (the other three being in France, Germany and Italy).

A t.d.m.a. burst consists of a preamble, containing identification, control and signalling information and other details, followed by a data burst. This is built up from consecutive sub-bursts, such as digitised f.d.m., p.c.m., and one for digital speech interpolation (see later), which are generated separately.

For transmission purposes the digital signals are provided by two modems (modulator-demodulators), one for 120Mbit/s and the other for 60Mbit/s In these, the modulator accepts two parallel binary inputs at a symbol rate of 60Mbit/s for each channel, together with a clock and burst control signal. A differential encoder is used to resolve carrier phase ambiguity. The parallel bit streams are fed to balanced linear modulators, and by means of a 90° phase shift in the local oscillator drive, a 4-phase p.s.k. signal is produced. Burst control is achieved by controlling the local oscillator drive.

The demodulator includes facilities for reference clock extraction, clock recovery, regenerating the demodulated data, and a.g.c. control of the mean input signals. The 140MHz input four-phase p.s.k. signal is distributed to two double-balanced mixers driven by the recovered carrier fed via a 90° phase splitter. The two demodulated signals are regenerated and differentially decoded to give the two data outputs. The outputs are correlated in a phase correction circuit to adjust the phase of the recovered carrier for minimum crosstalk. A narrow band filtering technique is used in an a.f.c. circuit in the carrier recovery unit.

### Digital speech interpolation

In addition to the dual polarisation, further economy in the use of the available spectrum will be achieved by means of digital speech interpolation. In this technique, which is similar in principle to the TASI (Time Assignment Speech Interpolation) system used for many years in international cable communications, the digits of one telephone conversation are interposed in the spaces resulting from pauses occurring in other conversations, thus reducing the number of channels needed for the whole of the traffic. The interpolation equipment has been designed by Cambridge Consultants and is a distributed microprocessor system employing seven Texas Instruments TMS9900S devices.

The equipment is arranged to process the two directions of traffic separately, so the terminal contains both an interpolation transmitter and an interpolation receiver. Functions of the transmitter are the detection of the activity of incoming speech channels, the assignment of active channels to currently inactive channels in a conversational "pool", and generation of assignment messages for transmission to interpolation receivers, indicating the changing state of the channel associations. The receiver's functions are the interpretation of assignment messages and the assignment of channels from the conversational "pool" to the correct outgoing speech channels.

The specification of the equipment was so advanced that a speech activity simulator had to be built to test it. This includes two microcomputer cards, and simulates speech activity on up to 240 terrestrial channels in the interpolation equipment, employing stored statistical distributions of various parameters of a typical conversational "pool". These distributions can be based on the acitivity found in live traffic situations or can be generated to provide special characteristics. The additional equipment was necessary because simulated speech traffic allows the loading of circuits to be controlled. This permits a more consistent indication of equipment performance. To evaluate the performance of the interpolation equipment, and hence the effectiveness of the technique, one or more test channels are continuously monitored while the equipment is loaded with dummy traffic from the simulator.

**European Communications Satellite** is being developed to handle intra-European telephony and the distribution of Eurovision programmes during the 1980s. The general design of each satellite will be similar to that of OTS2 – in particular it will operate in the 11 and 14 GHz frequency bands and re-use the available spectrum by means of dual polarisation. The main differences between the ECS and OTS2 satellites are:

1. ECS will have twelve 80MHz transponders instead of six of different bandwidths.
2. It will not have inclination control and will therefore be seen from the earth as moving daily in a figure-of-eight path between the latitudes of 3.5°N and 3.5°S.
3. It is designed for a seven-year life instead of five for OTS2.
4. It has three spot-beam aerials instead of only one on OTS2.
5. It carries sufficient batteries to power five transponders during an eclipse, whereas OTS2 can power only two.
6. It is likely to be launched by the European Ariane Launcher instead of the US Thor Delta 3914.

All twelve transponders are accommodated within the frequency band of 500MHz allocated to the transmitting and receiving radio paths: six transponders are accommodated on vertical polarisation and six on horizontal polarisation. The output of the solar cell panels – one on each side of the vehicle – is sufficient to power nine of the twelve transponders, each of which has a final travelling-wave-tube amplifier output of 20W. The remaining three transponder chains are available as replacements for failed or deteriorating units.

ECS will allow for the interchange of telephony traffic between any two CEPT members – covering an area bounded by Iceland, Scandinavia, Finland, West Germany, Turkey, Portugal, and the Atlantic Islands. Exchange of Eurovision programmes within the European broadcasting region also includes the European Broadcasting Union member countries in North Africa and the Middle East.

To meet the coverage requirements, the telephony area has been divided into three, each covered by a circular spot-beam transmitted by its own aerial. The spot-beams will illuminate East and West Europe and the Atlantic (Azores and Canary Islands). A fourth transmitting aerial provides coverage of the entire European zone by an elliptical "Eurobeam," and there is one receiving aerial (with a spare) also covering the entire zone.

Some 15 earth stations, with dish aerials of 16-19m diameter, are expected to be working to ECS by the mid-1980s, plus six television-only earth stations with 13m diameter antennae.

The telephony system will use digital transmission, with four-phase, phase-shift-keying modulation in t.d.m.a. as explained above. The traffic from each country is concentrated into a short burst of modulated carrier transmitted in a pre-determined time slot, with careful synchronisation of all the earth station involved. Transmitting the bursts of 120Mbit/s would give each 80MHz transponder a capacity of some 1,600 telephony channels. This can be approximately doubled by use of the digital speech interpolation system explained above. Television transmission will use frequency modulation with "sound-in-sync."

**Eutelsat.** The telecommunications satellite organisation set up by the European administrations and operating agencies is, for the time being, provisional and its full title is "Interim Eutelsat." It has a permanent secretariat in Paris. Its consitution, which came into force on June 30, 1977, allows all 26 members of CEPT (the European conference of postal and telecommunication administrations) to be a party to it. So far 17 administrations or operating agencies have become "signatory parties."

Interim Eutelsat is preparing to set up two satellite systems. Known as "space segments," there are, first, the ECS space segment, providing telecommunications services between fixed terminals on land; and secondly the MAROTS space segment, providing a mobile maritime telecommunication service. The arrangements for each segment are covered in supplementary agreements to the constitution. One of these came into force on September 14 and relates to the ECS space segment. That for the MAROTS space segment came into force on October 22, 1977. Each segment is controlled by its own Interim Eutelsat Council.

Interim Eutelsat will allocate capacity in each space segment to the organisations using it, and will also approve earth stations.

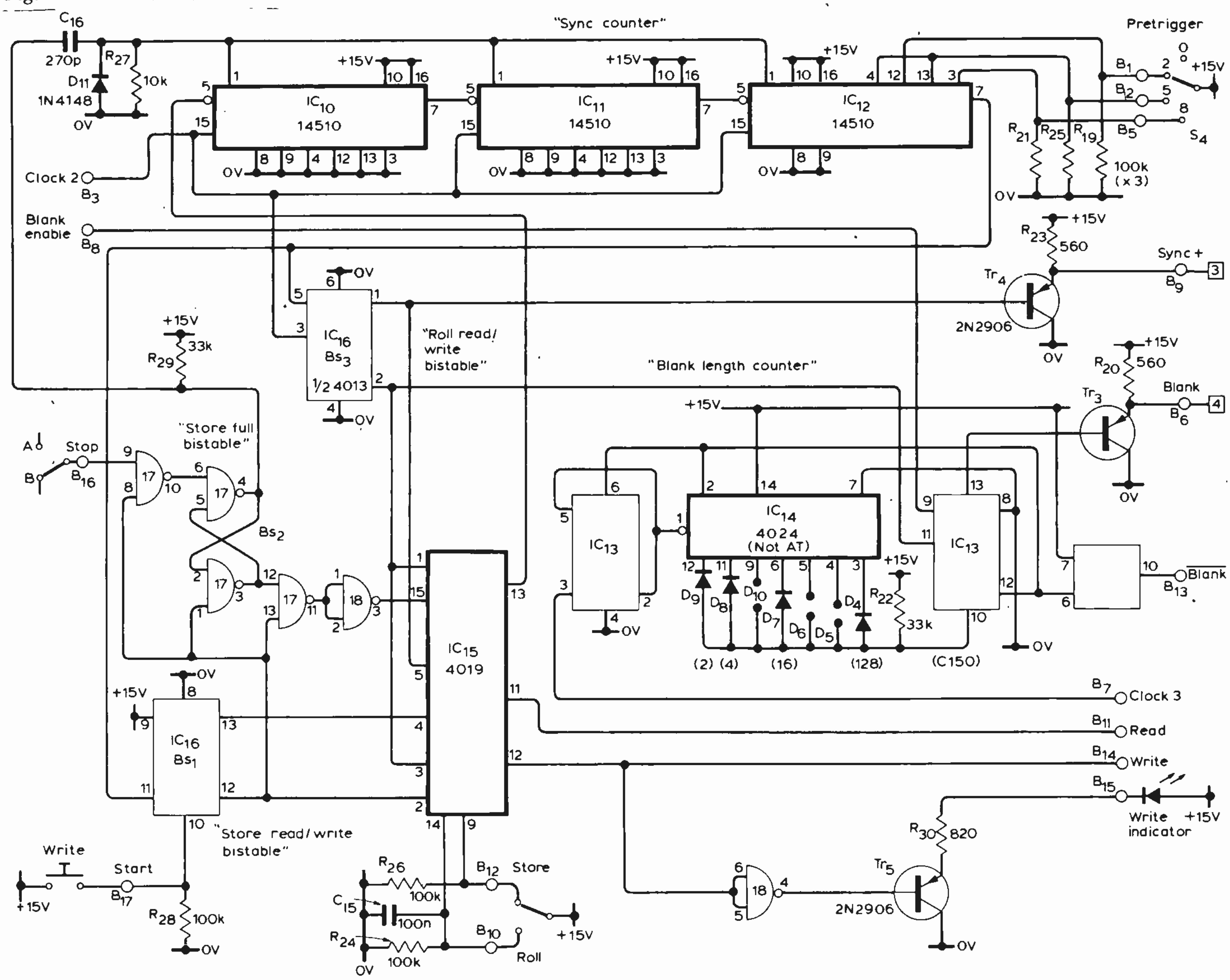
As a provisional organisation, Interim Eutelsat has no "juridicial personality" and is therefore unable to enter into agreements or contracts until it becomes a definitive organisation in about 1980. For the time being, it assigns mandates to particular administrations to enter into agreements on its behalf.

Britain will be acting for Interim Eutelsat in matters relating to the MAROTS space segment. France has a similar role for the ECS segment.

## Add-on oscilloscope waveform store

Readers who are following this project will have been baffled by the inclusion in part 2 of the article in the November issue of a totally irrelevant Fig. 7. We apologize to Mr Fastner and to readers. The correct diagram is reproduced below.

*Fig. 7. Master control circuit.*



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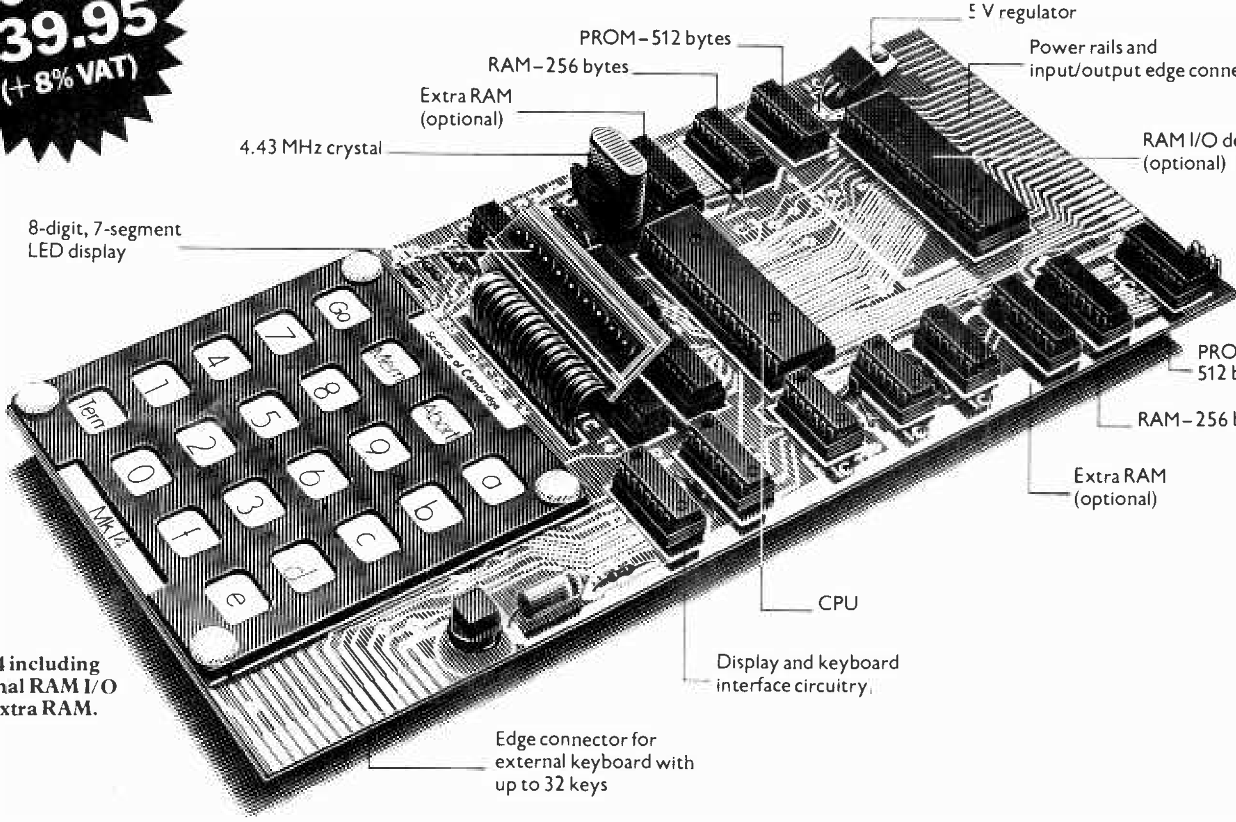


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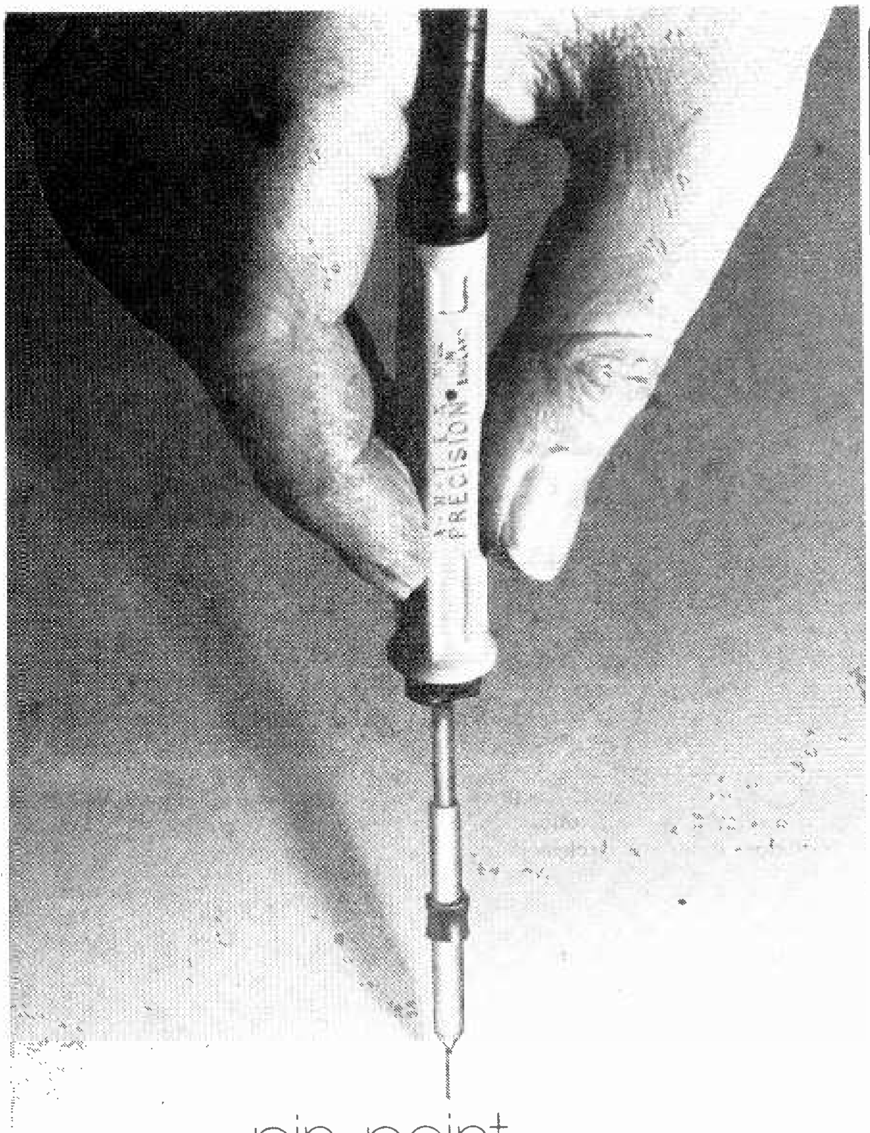


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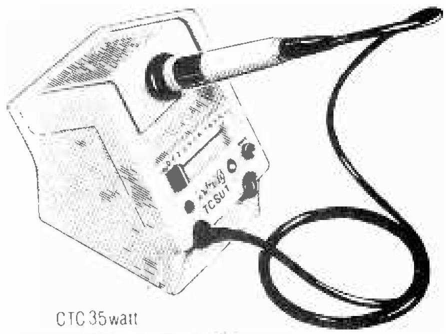


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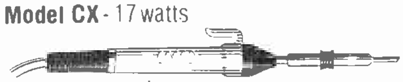

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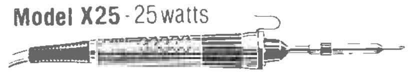

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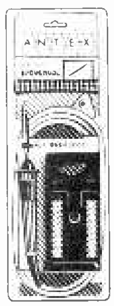


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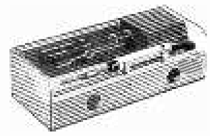

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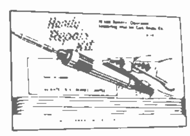

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# Did you know?

## Some puzzles in radio engineering fundamentals

**by Epsilon**

THE ART of radio engineering is now well into its second half-century; many of the fundamentals, probably once well understood, are perhaps too easily accepted today and seldom explained adequately in basic engineering courses. Take, for example, a capacitor. Readers will know that there are quite fundamental laws which describe its behaviour. These are the laws of charge and energy, and they are often used to solve certain problems in much the same manner as momentum and kinetic energy are used in mechanics.

A typical problem is shown in Fig. 1.

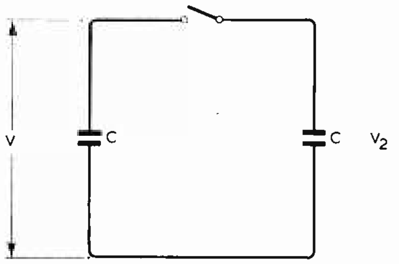



**Fig. 1.** *What is the voltage on the right-hand capacitor after the switch is closed?*

Here a capacitor of capacitance C is charged to a voltage $V$. At a particular time, the first capacitor is connected to a second capacitor, also of value C, but containing no charge. By the law of charge conservation, the charge before and after the connection is the same, and is given by

$$Q = CV = 2CV_2$$

and therefore the voltage $V_2$ is equal to $V/2$. But by the law of energy conservation,

$$E = CV^2/2 = (2C)V_2^2$$

and the voltage $V_2$ is equal to $V/\sqrt{2}$.

Now since capacitors are essentially lossless, energy cannot vanish without trace, and so the second answer should be the correct one. But this would imply that charge had increased by a factor of $\sqrt{2}$, thus violating the law of conservation of charge. The problem becomes really ridiculous if one capacitor is charged to $+V$, the other to $-V$. The net charge is then zero, and the use of one method would predict a final voltage of zero, the other a finite voltage of indeterminate sign.

Unfortunately, *both* conservation laws happen to be cornerstones of electrical engineering theory and are not to be discarded lightly. Some means must be found to reconcile the two laws, but how? No doubt readers will reassure themselves at this point by claiming that all real capacitors have resistance, and that the losses associated with this account for the discrepancies between application of the two laws.* A natural reply is to make the capacitors operate at superconducting temperatures and to reconsider the problem. Another ingenious way out might be to note that it is very difficult to discharge a capacitor without forming an arc (and hence getting rid of excess energy). Unfortunately for this suggestion, semiconductor technology does enable an arcless contact to be made, and so this explanation is at best a weak one. Accepting that simple measurements with a voltmeter show that the charge is conserved, what is the explanation of the apparent disappearance of the energy?

A second example, representing such an everyday feature of electronic equipment that its correct operation is taken for granted, is shown in principle in Fig. 2. A coaxial cable takes an r.f. signal from one part of a system to another. The system has a metallic ground plane which can be considered as being infinite in extent. Standard practice dictates that the outer braid of the coaxial cable is connected to the ground plane at both ends. An interesting question now emerges: what path does the return current from the load take? One answer (which is certainly true at d.c.), is that it takes the path of least resistance, or rather, it shares itself between the outer braid of the coaxial cable and the ground plane in the ratio of conductances. At a.c., the impedance between two points on a ground plane is effectively zero, whereas between the two ends of the outer conductor of a coaxial cable it is roughly

$$X = 0.21f\log_e(2l/D)$$

where $l$ is the length in metres, $D$ is the braid radius, and $f$ is the frequency in MHz. Clearly the impedance increases with length and frequency, and therefore most, if not all, of the return current does not flow in the outer conductor at all, but in the ground plane. Of course, this situation does not happen; if it did, the outer conductor would be redundant, the cable would be unscreened, and the concept of characteristic impedance would be quite meaningless. Obviously, no matter what the cable length or the frequency, *none* (well, almost none) of the current flows in the ground plane. Why?

*It so happens that this statement is exactly true for any finite value of resistance.

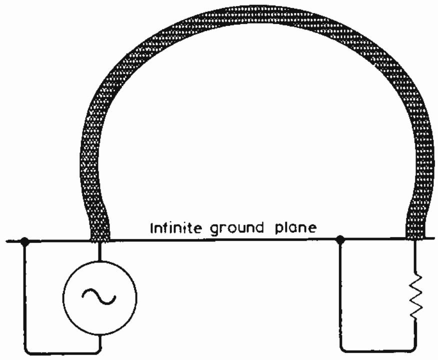



**Fig. 2.** *Does the return current from the load flow in the ground plane or the outer braid of the cable?*

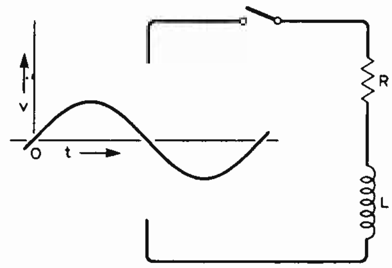
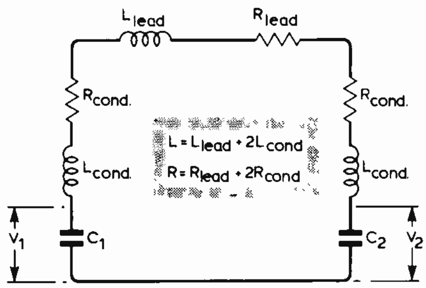


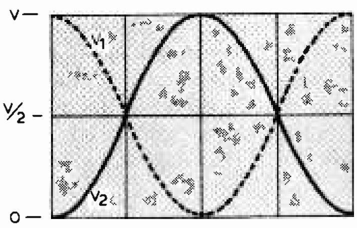

**Fig. 3.** *The switch is closed at t = 0. What is the current in the inductance?*

A third example is not so much one of fundamental principle as one of observed fact. It concerns switch-on surges in transformers. If a transformer (the larger the better) is connected directly to a mains supply, a distinctive hum is often heard which decays away over a period of tens of cycles. If the transformer is large enough it may blow a quite substantial fuse. Why? Those who have experienced the effect will mutter "switching-on surge," but that is a description of the problem and not a quantifiable explanation of its cause. A related problem, which will help to obtain the answer, concerns the circuit shown in Fig. 3. Assuming that the switch is closed when the applied sine wave is at zero and, for the present, that the resistance is zero, is the current in the inductance sinusoidal and does it have an average d.c. value of zero?

Before continuing to two more problems less related to real life, let us examine the answers to the questions already presented. The first example is an interesting one, if only because it is so fundamental. As a first step it can be noted that all capacitors must have physical size; *it is simply not possible to make a finite capacitance of infinitely small dimensions;* secondly, whenever a capacitor is discharged the current must flow through a finite distance, and thirdly, current flowing through a distance generates a magnetic field, which in practical terms means that every capacitor possesses a small inductance.




(a)




(b)

**Fig. 4.** *The solution to Fig. 1 with* $R = 0$

Fig. 4(a) shows the equivalent circuit of Fig. 1, and Fig. 4(b) shows the actual voltages of the two capacitors as a function of time. The whole circuit is resonant at a frequency given by

$$\omega^2 LC/2 = 1$$

$V_2$ starts at zero, oscillating between a value of zero and $V$, the mean value being $V/2$. $V_1$ has the same sinusoidal form as $V_2$ but starts at $V$ and decreases down to zero. Both charge and energy can now be accounted for. The total charge in the two capacitors remains constant at $Q = CV$, thus satisfying the requirement of conservation of charge, but the charge in each separate capacitor oscillates from one to the other about the mean.

The energy flow is more complicated, there being a continual transference between capacitive and inductive storage. Thus, beginning at time $t = 0$ in Fig. 4(b) capacitor $C_2$ starts with zero voltage and zero energy. $C_1$ starts at $V$. One quarter-cycle later both capacitors have the same voltage $V/2$, and there is zero voltage across the inductance. Since the current in an inductance lags the voltage by a phase angle of 90°, the former is now at a maximum and it will be found that exactly one half the energy resides in the inductance. This accounts for the "missing" energy. One half a cycle later the voltage across $C_2$ is a maximum and equal to $V$, and that across $C_1$ is zero; all the energy has now been removed from the inductance and resides in $C_2$. The reader can follow the remainder of the cycle.

No matter how small the lead inductance, the oscillation just described is always present, and, taken with the steady voltage, it fully accounts for both the original charge and the energy. The reason that an erroneous result can be obtained, in this case by neglecting inductance, is because the laws of conservation do not tell us *how* charge or energy may be stored, only that they cannot disappear.

The explanation may now be developed a little further, to begin with by allowing a small series resistance to be present as shown in Fig. 4(a). The oscillation, instead of persisting indefinitely as before, now decays exponentially (the multiplying factor is actually $\exp(-Rt/2L)$) and leaves a steady state voltage of $V/2$ on both capacitors. This is, of course, the voltage measured by a d.c. meter. Taking a further step, just as a capacitor possesses inductance, so it also possesses radiating properties, and there will in general be an apparent resistive loss because of this. Taking a third step, capacitance, inductance and radiation resistance are not lumped circuit elements but are distributed, and so even the reasoning given above is at best an approximation.

The explanation of the screening properties of the coaxial cable concerns the self and mutual inductance of the two conductors of which it is comprised. Fig. 5 shows a longitudinal cross section of the cable, large letters being used for the outer conductor and small letters for the inner.

A current $i$ flowing upwards in the inner conductor sets up a magnetic field whose lines of force go around it. As a simplification we shall assume that the conductor is straight and long, and then these force lines have a magnetic field strength of

$$h = i/2\pi x \text{ ampere turns per metre}$$

where $x$ is the distance from the centre of the conductor (but note that this expression is not applicable when $x$ is less than $d$). A current $I$ flowing downwards in the outer conductor also causes a magnetic field strength, this time given by

$$H = -I/2\pi x,$$

where $x$ is measured from the centre of the hollow tube which forms the outer conductor and $I$ is distributed uniformly around the periphery. Inside the tube the field due to $I$ is everywhere zero.

The magnetic fields cause back voltages to be generated in each conductor whenever they change with time. The current $I$ causes a large back voltage to appear in the outer conductor (the self inductance term) but this is cancelled by the back voltage caused by the cur-

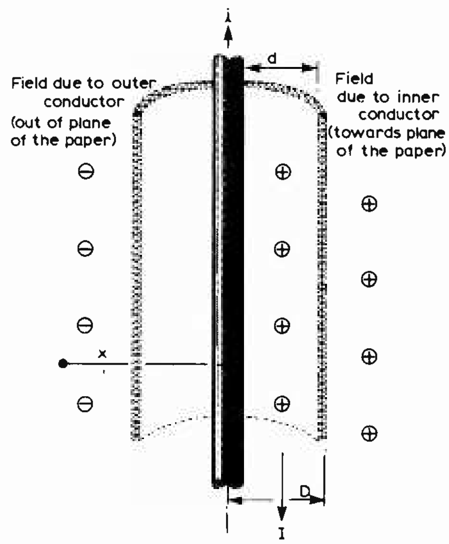



**Fig. 5.** *Fields due to the inner and outer conductors of a coaxial cable go around the cable. The left and right sides show the field separately.*

rent in the inner conductor (the mutual inductance term). Now it so happens that the magnetic field *inside* the outer conductor does not have any effect, and the total back voltage is thus proportional to $(h-H)$ or $(i-I)/2\pi x$. If $i = I$, all external magnetic fields are exactly equal to zero (in other words, the cable is properly screened) and the back voltage is also zero. Each end of the cable is at exactly the same potential and no current flows in the earth plane; if it did, a potential in the correct sense to cancel it would appear along the cable. We can all breathe a sigh of relief at the result, because otherwise r.f. engineering would be impossible. However, at low frequencies, particularly audio, cable resistance starts to become important and screening against magnetic pick-up is not at all so easy.

The full explanation for the third example can only be found satisfactorily by recourse to differential equations. Before giving the solution, it is as well to recall that the properties associated with inductance are expressed solely in terms of the back voltage developed when a current experiences a rate of change. Specifically:

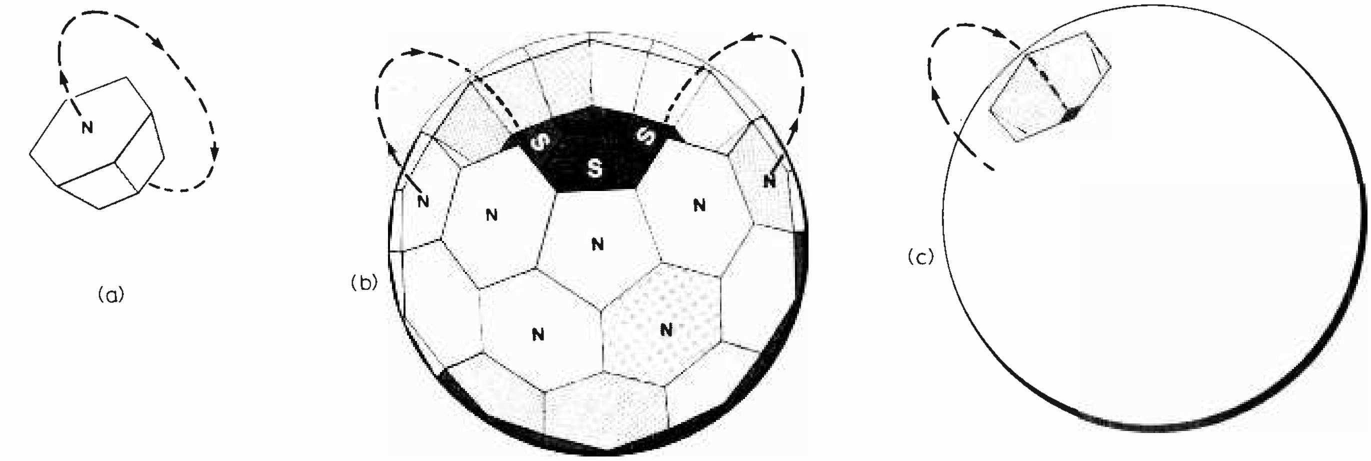
$$V = L \times \text{no. of amperes changed per second}$$

It is important to realize that the voltage $V$ is not a function of any constant current, which could be infinite without altering $V$ in any way. With this in mind, the full solution for the current in Fig. 3 becomes understandable. It is

$$I = (E/Z)\sin(\omega t - \phi) + (E/Z/\exp(Rt/L)\sin\phi$$

$$\text{where } \tan\phi = \omega L/R \text{ and } Z = \sqrt{R^2 + (\omega L)^2}.$$

The solution will be seen to consist of two terms, the first being the one generally used in a.c. impedance calcu-




lations, the second being a transient term which is d.c. with an exponentional decay.

The solution for the case when $R$ is zero is given by:

$$I = -(E/Z)\cos\omega t + (E/Z)$$

and there is thus a standing d.c. term equal in magnitude to the peak alternating current. The total current starts at zero and builds up to twice the value normally expected, but it never reverses in sign. There is a constant direct current circulating on a nominally a.c. supply and this persists indefinitely. In real life, resistance is always present and the d.c. term decays to zero; the lower the resistance, the lower the rate of decay. Knowing this, an explanation of why a switch-on occurs can now be given.

When a transformer is connected to the mains supply, a circulating direct current is set up as just described. If the switch-on occurs at or near the zero voltage point of the a.c. cycle, the d.c. is at a maximum, and the total current runs up to nearly twice the normal value given by $I = E/\omega L$. Twice the normal magnetization current is often more than sufficient to run the iron core of the transformer into saturation, and the laminations start to protest loudly. With the transformer iron saturated, the instantaneous value of $L$ is grossly reduced and so the magnetizing current must increase to generate a back voltage which is equal to the mains supply. The effect persists until the direct current dies away or until the fuse blows.

After these questions and answers on rather everyday topics, here are two problems of a more thought-provoking nature.

A small bar magnet is launched into outer space, where it can be assumed to be free of any external influences. The magnet is set spinning about an axis which passes through its middle and is perpendicular to the line joining the two poles. What happens to the rotational speed of the magnet with the passage of time? No mechanical forces on the magnet (such as air resistance) need be considered.

Our second problem is also concerned with permanent magnets. Fig. 6 (a) shows a magnet made in the form of a six sided tapered plug. The lines of force of this magnet run from north to south (by convention). A number of these plugs† can be assembled as in Fig. 6 (b), and the result will be part of a hollow sphere. Lines of force will emanate from the outside of the sphere and will enter the inside as shown in Fig. 6 (b). The assembly of the sphere can continue until the situation in Fig. 6 (c) is reached, at which point lines emanating from the outer surface still return via the single hole to the south pole of the inner surface. A compass needle passed anywhere near the outer surface would record that it behaved as a magnetic north pole except near to the hole. The final plug is now inserted into the hole. What is the external magnetic field of the sphere at large, intermediate, and zero distances from the surface?

**Fig. 6.** *What is the external magnetic field when the last plug (a) is placed into the hole in the hollow sphere (c)?*

On a superficial level the two answers happen to be rather obvious: the spinning bar magnet slows down and the magnetic field outside the sphere is everywhere zero. The more quantitative explanations are as follows.

The spinning magnet generates an alternating magnetic field that gives rise to an electromagnetic effect and hence to radio waves. The power associated with these comes from the only available source, the kinetic energy of the spinning magnet, which therefore slows down. The explanation is rather an interesting one, because it shows that there is no reason why mechanical energy should not be turned directly into radiation without the use of electronic devices. However, I should point out that the idea is intriguing rather than practical!

To carry the explanation a little further, the magnet can be assumed to be replaced by a solenoid carrying a current $I$ whose field matches that of a magnet. Next, the rotating magnetic field can equally well be created by two such solenoids fixed in an inertial reference frame at right angles to one another and carrying currents.

$$I_1 = I\sin(2\pi v_0 t),$$

$$I_2 = I\cos(2\pi v_0 t)$$

$v_0$ being the speed of the real magnet in revolutions per second. By this substitution the problem has been reduced to one of radio engineering. Each solenoid acts as a small loop antenna, the radiation from which results in a circularly polarized radio wave. Now the radiation resistance of an electrically small loop is given by

$$R = 31,200\, A^2N^2V^4/c^4$$

where $A$ is the area of the solenoid, $N$ is the number of turns, $V$ is the frequency in cycles per second, and $c$ is the velocity of light. By equating the kinetic energy stored in the rotating magnet to the $I^2R$ losses in radiation it can be shown that the speed after a time $t$ is

$$v = v_0(1 + kt)^{-1/2}$$

$$k = 31{,}200\,(IAN)^2(2\pi v_0)^2/(c^4W)$$

where $W$ is the moment of inertia of the magnet.

The explanation for the magnetic field outside the sphere being zero can be given by reducing the problem to absurdity. Since the sphere is perfectly symmetrical in a three-dimensional sense there can be no preferred axis of magnetization; if lines of force do exist, they can only be perpendicular to the surface and they must all have the same direction of flow. But then this is tantamount to saying that the sphere acts as if it were a unit magnetic pole. Now man has been searching for unit magnetic poles for a long time, and, like the philosopher's stone, they have never been found (except possibly at the subatomic level). Unless you believe otherwise, the only possible solution is for the field outside the sphere to be everywhere zero. A more formal proof exists.

†In practice, and in theory, a sphere cannot be assembled from six-sided plugs alone. To get a perfect fit it must be done with a mixture of six-sided and five-sided plugs (see Fig. 6 (b)), as in the truncated icosahedron. However, this awkward fact should not affect the author's discussion. — Ed.

# Solar heating temperature controller

## Differential circuit gives precise control of a pump motor

by **A. J. P. Williams** Gwent College of Higher Education

This solar heating controller uses a recently introduced sensor to accurately detect the temperatures of a solar panel and a water tank. The circuit allows an electric pump to be controlled at precise selectable temperatures for optimum heat exchanger efficiency. The circuit is easily calibrated, and is not affected by interference form local mains wiring.

In the basic system of Fig. 1, a heat transfer fluid, usually water, is pumped through the solar collector where it gains heat. The fluid then passes through a heat exchanger coil where most of the heat gained previously is transferred to the stored water. The outputs from a temperature sensor attached to the collector output, and a second sensor attached to the storage tank operate a differential temperature controller. This controller switches the pump motor on when sensor 1 is hotter than sensor 2, which transfers heat to the stored water, and off when sensor 1 is cooler than sensor 2, thus preventing the stored water from being cooled during the night or when the weather is dull.

Because solar collectors are more efficient when they are operated at low temperatures, it is beneficial to run the system at the minimum temperature which will allow energy to enter the stored water and justify the pump operating.

For example, if the average rise in temperature of the stored water is 40 deg C, and the stored water is increased by only a further 2 deg C with precise control, this represents a 5% increase in efficiency, or an extra 348Whr for each 150 litres of water heated.

### Circuit details

The complete circuit in Fig. 2 is based on the Analogue Devices AD590K temperature transducer which is a constant current temperature sensor. The current through the device is almost independent of the voltage across it within the range of 4 to 30V. This characteristic ensures that any mains induced voltages in the leads cause negligible 50Hz current through the sensors. Connections to the sensors can be by an unscreened twisted pair of wires of up to 50m in length if required, provided that they are well insulated. It is essential that the connections to the sensors are well insulated and dry so that all of the sensor current is detected by the control unit. The current through each sensor is directly proportional to the absolute temperature of the sensor. Therefore, at 0 deg C or 273 deg K the nominal current is 273μA, and at 100 deg C or 373 deg K the current is 373μA. This relationship also makes the device suitable for measuring temperature.

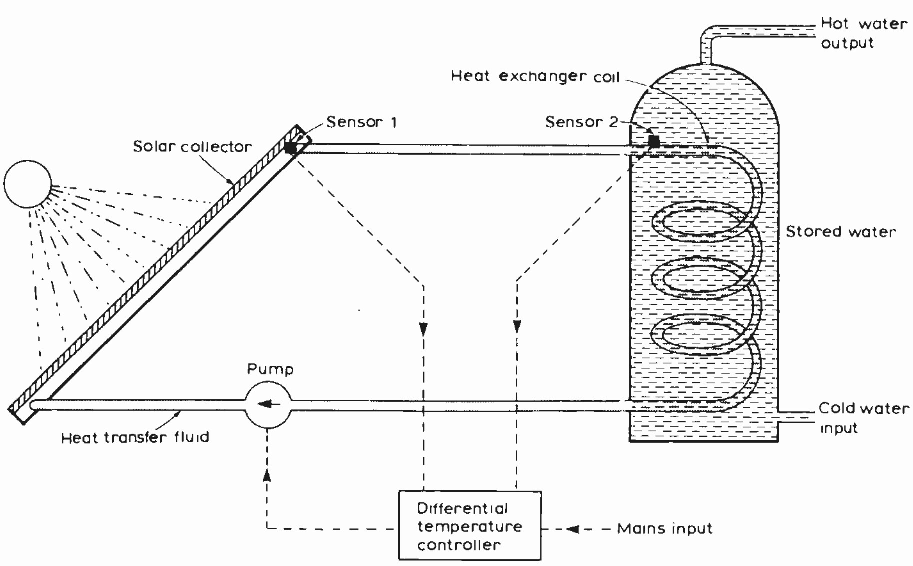
Because $IC_2$ has a high input resistance, the difference between the currents through the two sensors, $I_1$—$I_2$ mainly flows through $R_4$. When the temperature of the stored water is greater than that of the collector, $I_1$ is greater than $I_2$, and $V_1$ is positive. This causes pin 2 of $IC_2$ to become positive and the output at pin 6 to move close to ground. At this point $D_5$ cannot conduct and $Tr_1$ switches off the pump motor via the relay. When the temperature of the collector is greater than that of the stored water, $I_2$ is greater than $I_1$, so $V_1$ is negative which drives pin 6 of $IC_2$ close to the positive rail. This in turn switches the relay and pump on via $Tr_1$ and $D_5$.

With a temperature difference of 1 deg C between S1 and S2, a current of 1μA will flow through $R_4$ which makes $V_1$ 100mV. The value of $V_3$ is arranged to be approximately 125mV which ensures that $V_2$ can be varied from 0 to 100mV. As $V_2$ is increased it tends to switch $Tr_1$ off therefore, $I_2$ must be greater than $I_1$ to make $V_1$ sufficiently negative before $Tr_1$ can be switched on. Thus, adjustment of $R_{19}$ determines the collector temperature that switches the pump on. The range of $R_{19}$ is at least 10 deg C. At 25 deg C the tolerance of the current through the temperature transducer is ±2μA, so $V_1$ could be ±40mV when it should be zero. To correct for any such unbalance beween the sensors, and any input offset voltage on $IC_2$, $V_4$ can be varied from about 0 to 75mV. Varying $R_{19}$ and $R_{21}$ only has a small effect on the total resistance between pins 2 and 3 of $IC_2$ and point C respectively. This ensures that the calibration of different control units will be similar.

### Feedback circuit

Positive feedback around $IC_2$ makes sure that $V_1$ must be made more positive than $V_5$ before $Tr_1$ can be switched off. This switch-off hysteresis enables the pump to be switched on when the collector is, for example, 5 deg C higher than the stored water, and off when the collector is 3 deg C higher than the stored water. The amount of hysteresis is determined by $R_{22}$ which is a log-potentiometer. This control is wired so that the low resistance end is connected to $D_1$. The hysteresis control can be calibrated over the range 0.4 to 9 deg C,

**Fig. 1.** *Basic solar heating system. The pump only operates when the collector temperature is above that of the stored water.*



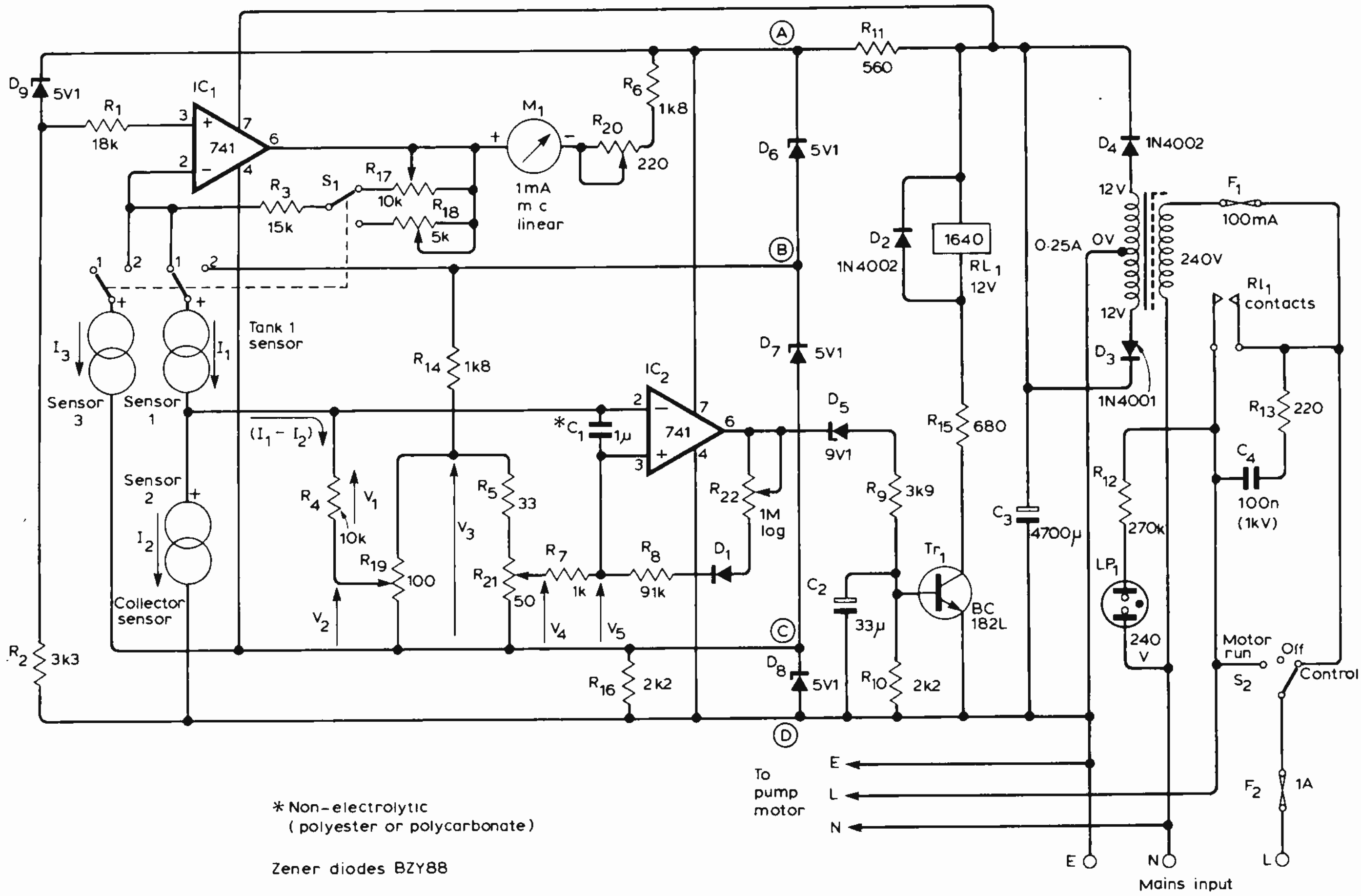



**Fig. 2.** *Complete circuit for the differential temperature controller. Sensors 1 and 2 are sited as shown in Fig. 1, and sensor 3 can monitor the temperature anywhere in the system.*

but for a temperature resolution of better than 0.1 deg C, the feedback resistance may be increased to 4.7MΩ.

## Measuring circuit

The measuring circuit operates as a current-to-voltage converter where the current from S1 or S3 flows through $R_3$ and $R_{17}$ or $R_{18}$. The voltage at pin 6 of $IC_1$ moves sufficiently positive to maintain the sensor current through $R_3 + R_{17}$. The potential at pin 2 of $IC_1$ is always close to the potential at point B which ensures that S1 has the same internal power dissipation with SW1 in position 1 or 2. When the current through S1 is 273μA, and $R_3+R_{17}$ is 18.68k, the p.d. across the two resistors will be 5.1V which holds the positive side of the meter at the same potential as point A. The meter then reads zero which represents 0 deg C. When the current through S1 is 373μA, the p.d. across $R_3 + R_{17}$ will be 6.97V with respect to point B. Therefore, the positive end of the meter will be 6.97 — 5.1V with respect to point A. The resistance in series with the meter can therefore be set to 1.87kΩ to represent 100 deg C. More sensitive meter movements may be used by changing $R_3 + R_{17}$ accordingly.

The temperature coefficient of the 5.1V zener diodes is comparatively low so that changes in ambient temperature only have a minor effect. This also applies to sensor S3 which may be used for monitoring any part of the system. A separate control for each sensor is not used because of their high linearity. The circuit may be simplified by omitting the measuring circuit and connecting the top end of S1 to point B.

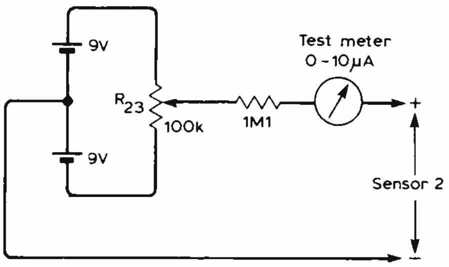



**Fig. 3.**

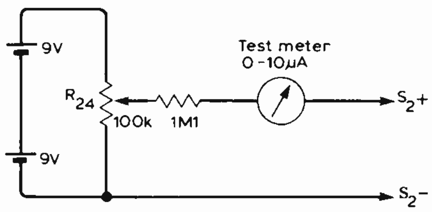



**Fig. 4.**

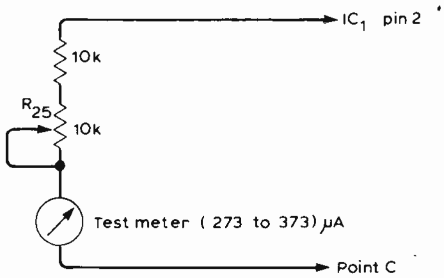



**Fig. 5.**

## Calibration

For the differential temperature, remove S1 and S2, connect the calibration circuit of Fig. 3 in place of S2 and switch SW1 to position 2, or replace S3 by a 15kΩ resistor to prevent the meter reading backwards. Load the pump motor output with a 40W lamp so that $LP_1$ can turn on. Set the slider of $R_{19}$ to within a few degrees of point C and mark as zero degrees temperature difference. Set $R_{22}$ for minimum hysteresis, i.e. maximum resistance, and then set the current on the test meter to zero by adjusting $R_{23}$. Slowly adjust $R_{21}$ until $LP_1$ just lights, and set $R_{23}$ to give 1μA on the test meter. Adjust $R_{19}$ until $LP_1$ goes out, and then return $R_{19}$ slowly until $LP_1$ just lights. This position is marked 1 deg C on the dial of $R_{19}$. Reset $R_{23}$ for 2μA and re-adjust $R_{19}$ until $LP_1$ goes out. The point at which $R_{19}$ just lights $LP_1$ is marked as 2 deg C. This procedure is repeated at 1μA steps to calibrate up to 10 deg C.

To calibrate the hysteresis control, connect the circuit in Fig. 4, and set the differential temperature control to zero. Set the hysteresis control to maximum, i.e. minimum resistance. Adjust $R_{24}$ until $LP_1$ lights and then set $R_{24}$ so that the meter indicates the hysteresis required, e.g. 2μA for 2 deg C hysteresis. Slowly move the hysteresis control to the point where $LP_1$ goes out and mark the calibration point. Repeat the procedure for temperatures from 0.5 to 9 deg C.

For the temperature measuring circuit the following method is suitable if an accuracy of ±3 deg C is sufficient, or ± 2 deg C if the more expensive AD590L sensor is used. Connect the test circuit in Fig. 5, and set SW1 to position 1. Adjust $R_{25}$ to give 273µA on the test meter and set $R_{17}$ so that M1 indicates zero, i.e. 0 deg C. Switch SW1 to position 2 and adjust $R_{18}$ so that M1 indicates zero. Set the test meter to indicate 373µA by adjusting $R_{25}$ and adjust $R_{20}$ so that M1 reads full scale, i.e. 100 deg C. If the meter M1 is scaled 0 to 100 in 10 steps, then each step will indicate an increment of 10 deg C.

For maximum accuracy, the sensors are used directly. Keep S1 and S3 at 0 deg C, switch SW1 to position 1 and adjust $R_{17}$ so that M1 indicates zero. Switch SW1 to position 2 and adjust $R_{18}$ so that M1 indicates zero. Keep S1 at 100 deg C, switch SW1 to position 1 and adjust $R_{20}$ until meter M1 indicates full scale, i.e. 100 deg C.

The linearity of the AD590K sensor is better than ±0.5 deg C over the range —55 to +150 deg C, but because all of the senors have the same general characteristic they should track within about 0.1 deg C.

It is not easy to check the accuracy of the switching-temperature differences by varying the temperature of the senors because the control is more precise than most readily available temperature measuring instruments. The overall error for differential temperature and hysteresis is generally less than ±0.3 deg C.

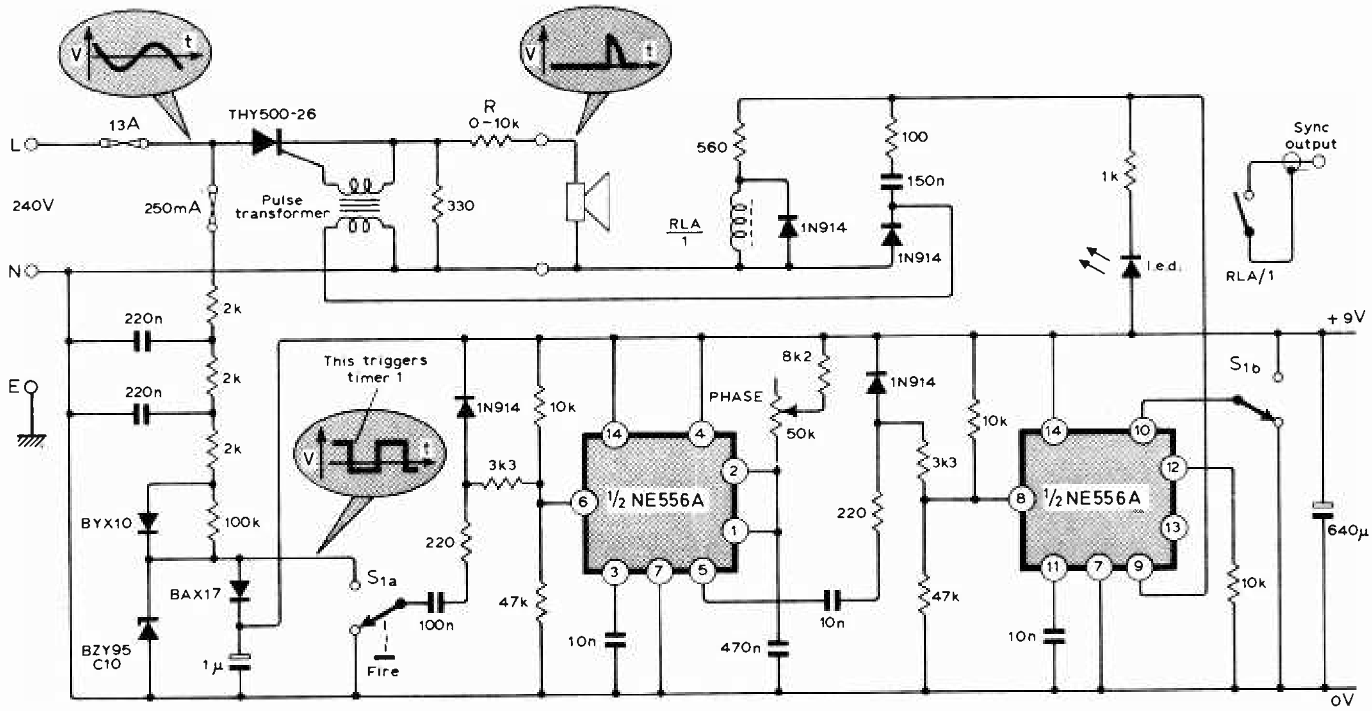
# CIRCUIT IDEAS

## Sonic pulse generator

This circuit produces an intense audible click, suitable for sonar experiments, by connecting the mains supply to a loudspeaker for part of a mains cycle. The 240V a.c. input provides a 9V supply and also an a.c. trigger waveform, which is fed to the first timer via a push switch. This timer will only trigger on the negative slope zero-crossing point of the mains cycle. After a delay, set by the phase control, the second timer is triggered which then fires the thyristor. Timer 2 is used to prevent multiple firing, and is reset by releasing $S_1$. The reed relay takes about one millisecond to provide a synchronizing output, but an opto-isolator can be used for faster operation.

Other applications of this circuit include driving a coil for producing permanent magnets. Because the circuit is not isolated from the mains supply, appropriate safety precautions must be taken.

Dr B. G. Gaydon
G.E.G.B.
Kent.



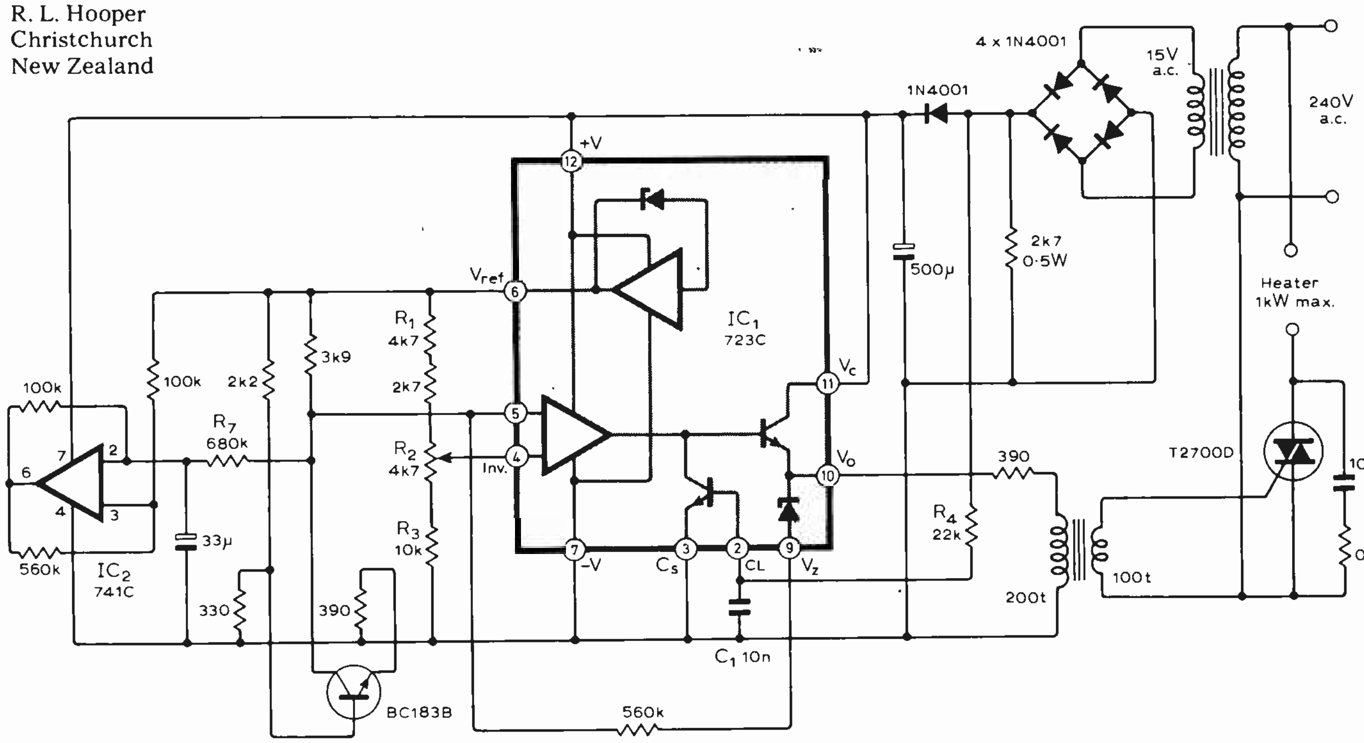
## Temperature dependent power controller

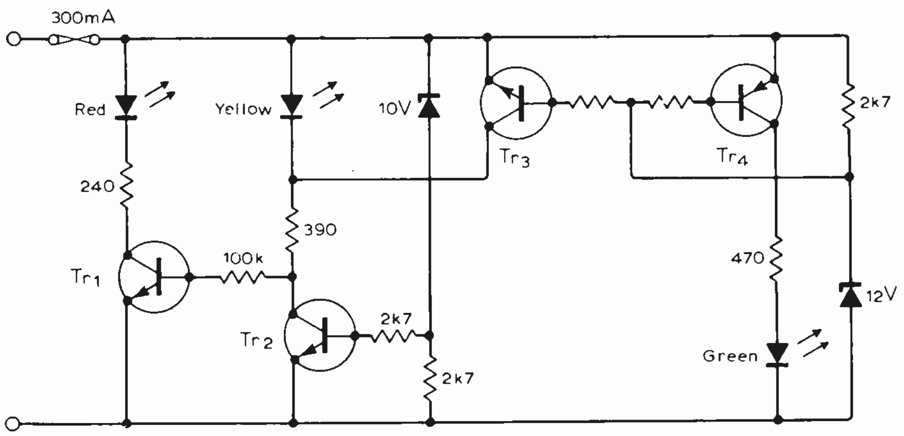
By using a 723C i.c. regulator as a sense-bridge, a low-cost water temperature controller can be constructed. The base-emitter junction of a BC183B senses the water temperature and gives a base-emitter voltage variation of about 2mV per deg C in the range 0 to +100 deg C. This voltage change is amplified in the collector circuit and applied to the non-inverting input of a comparator within the i.c. A voltage set by $R_2$ is applied to the inverting input, and determines the sensor temperature at which the comparator switches its output positive. A stable supply for this part of the circuit is provided by $V_{ref}$. Rectified a.c. is applied to the CL input through a delay network $R_4C$ which allows a positive pulse to pass from the comparator to $V_o$ just after the zero-crossing point of the applied a.c. This pulse drives the triac via a transformer of 36 s.w.g. wound on a 1in × ⅜in ferrite rod.

Positive feedback around the comparator is applied through isolating diode $V_z$ which ensures that feedback is only effective when a pulse appears at the output. A 0.5Hz triangular wave, generated by $IC_2$, is applied to the input of the comparator and provides proportional pulse width modulation. The amplitude of this waveform defines the proportional bandwidth of the controller, which is 0.5deg C with the values shown.

Control of a three gallon well-stirred water bath at 40 deg C is better than ±0.05 deg C. A thermistor may be substituted for the transistor to give a wider temperature range and less sensitivity to ambient temperature.

R. L. Hooper
Christchurch
New Zealand




## Automotive voltage indicator

An indication of battery voltage is useful to the motorist for monitoring the battery's capacity to delivery current, and as a check on the efficiency of the dynamo or alternator. This circuit is a solid-state alternative to a moving coil meter. The table shows the outputs obtained over the critical range of 10 to 14V.

When the input is below 10V, $Tr_2$, $Tr_3$, and $Tr_4$ are off and $Tr_1$ is turned on. As the voltage rises the 10V zener diode begins to conduct, $Tr_2$ receives base current and turns $Tr_1$ off.

At approximately 11V both $Tr_1$ and $Tr_2$ are on, but at 12V only $Tr_2$ is on. Similarly, $Tr_4$ is turned on as the voltage rises to 14V and the 12V zener conducts. Transistor $Tr_3$ takes current from the yellow l.e.d. and turns it off while $Tr_2$ remains in conduction to keep the red l.e.d. off. The circuit can be easily modified for different voltages by changing the zener diodes.

| Red | Yellow | Green | Voltage |
|---|---|---|---|
| 1 | 0 | 0 | ⩽10V |
| 1 | 1 | 0 | 11V |
| 0 | 1 | 0 | 12V |
| 0 | 1 | 1 | 13V |
| 0 | 0 | 1 | ⩾14V |

S. C. Mathur
Weybridge
Surrey

# Breadboard survey — 2

## Assemblies and systems

Part one described the basic breadboard blocks. This concluding article covers breadboard assemblies and systems, many of which are based on the individual blocks.

THREE ASSEMBLIES based on the Bimboard 1 consist of either 2, 3 or 4 blocks mounted on a rigid aluminium base plate as shown in Fig. 9. Four screw-terminals are also supplied for connection to incoming power supplies. As with the single block, a vertical panel can be mounted to support switches and potentiometers.

Eight assemblies from A.P. Products, based on either their distribution strips or super strips, offer from 728 connection points and two screw terminals, to 3,648 connection points and four screw terminals.

Six assemblies from Continental Specialities, based on their bus strips mounted on a base plate, offer from 630 connection points with four screw terminals, to 3,060 connection points also with four screw terminals.

**The Vector Klip-Blok** breadboard system shown in Fig 10 consists of 0.1in matrix blocks organised as 12 rows each with four interconnected beryllium copper sockets. These blocks have four pins which locate in a base plate which contains a matrix of holes. Because the individual blocks can be moved, the system automatically accommodates all dual-in-line i.cs and most discrete components with lead diameters between 0.38 and 0.8mm. For larger lead diameters, special sockets are supplied. To supplement the blocks, metal socket strips are supplied, also with locating pins, which serve as power supply rails. These metal strips can be cut into shorter lengths to produce several supply rails. Both sides of the matrix base board are printed with a labelled grid to help with component placement. A useful feature of the Klip Blok system is the ability to wire on both sides of the base board.

Three board sizes are available from model 49X, which measures 67 × 114mm and accommodates two blocks and two metal socket strips, to model 51X which measures 114 × 203mm and accommodates eight blocks, eight metal socket strips and three screw terminals. All of the base boards are mounted in an aluminium frame, and two larger frames will accommodate two or four 51X baseboards.

**Function boards** are modules designed to be used with the Ramp base board which also accommodates up to four Bimboards. A power board, see Fig. 11 which measures 150 × 50mm, allows breadboard circuits to use either TO3P, TO126, TO220, TO66 or TO3 type semiconductor cases on two 10W heatsinks. The components are either plugged into a fixed socket and bolted to the heatsink or bolted and wired with plug in leads to a breadboard circuit. Two terminal blocks allow external connections to, for example, a loudspeaker. The power board is supplied with connector leads and mounting hardware.

An oscillator board, which measures 150 × 50mm, contains a 1MHz crystal oscillator, six counters and a one-shot circuit. All inputs and outputs are brought out to labelled connectors which accept stripped wire connections in the same way as the breadboard. A set of four display boards, which again all measure 150 × 50mm, range from a four digit 5V version to a six digit 5 to 15V type. All of the boards accept multi-

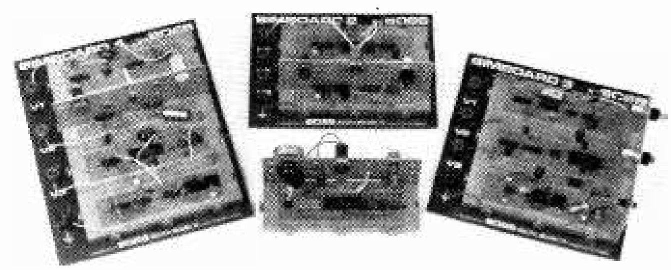


Fig 9

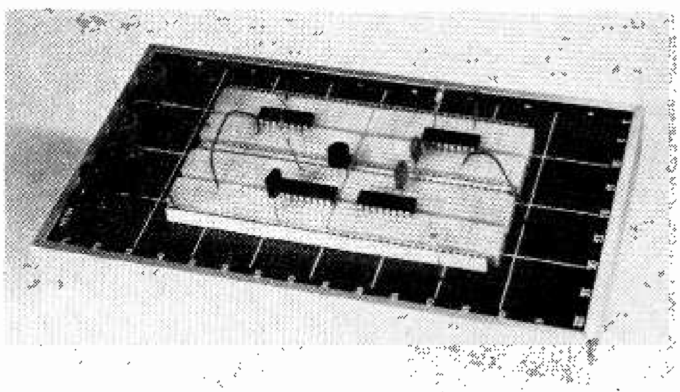


Fig 10

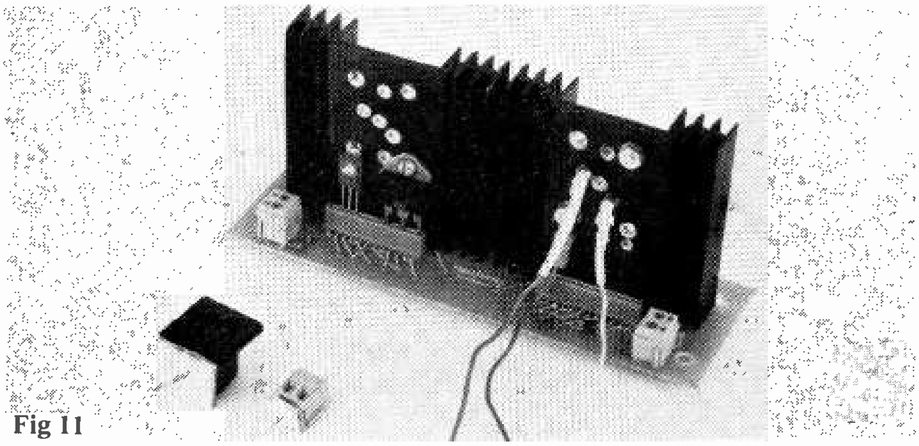


Fig 11

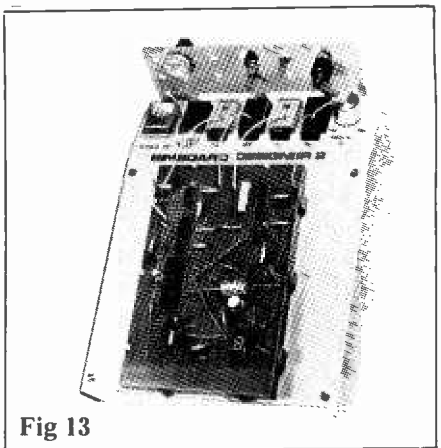


Fig 13

| BREADBOARD | PRICE | SUPPLIER |
|---|---|---|
| **Augat Breadboard Panels** | | **Rastra Electronics Ltd,** 275 King Street, London W6 9NF. |
| 8 130-36DG1R | £269.72 + v.a.t. | |
| 8 130-36DG1R-25 | £139.16 + v.a.t. | |
| 8 130-36DG1R-10 | £58.97 + v.a.t. | |
| Bimboard 1 | £8.83 inc. | **Boss Industrial Mouldings Ltd,** Higgs Industrial Estate, 2 Herne Hill Road, London SE24 0AU. |
| " 2 | £21 01 inc. | |
| " 3 | £29.84 inc. | |
| " 4 | £38.79 inc. | |
| Bimboard designer 1 | £55.62 inc. | |
| " " 2 | £61.02 inc. | |
| " " 3 | £66.42 inc. | |
| Euroblock | £5.80 inc. v.a.t. | **David George Sales** 74 Crayford High Street, Crayford, Kent DA1 4EF. |
| Experimenter 300 | £5.75 + v.a.t. | **Continental Specialties Corporation,** Spur Road, North Feltham Trading Estate, Feltham, Middlesex. |
| " 600 | £6.30 + v.a.t. | |
| Assembly 6 | £9.20 + v.a.t. | |
| " 100 | £11.80 | |
| " 101 | £17.20 + v.a.t. | |
| " 102 | £22.95 + v.a.t. | |
| " 103 | £34.45 + v.a.t. | |
| " 104 | £45.95 + v.a.t. | |
| Breadboard system 203A | £74.70 + v.a.t. | |
| Hirschmann Experimental Plate | £45.00 + v.a.t. | **Lectroustic Ltd,** 20 Wilbury Grove, Hove, Sussex BN3 3JQ. |
| IC breadboards | | **Cambion Electronic Products Ltd,** Castleton, Sheffield, S30 2WR. |
| 705-2105-02 | £16.40 + v.a.t. | |
| 705-0169-01 | £173.40 + v.a.t. | |
| " -0269- " | £92.80 + v.a.t. | |
| " -0369- " | £54.20 + v.a.t. | |
| " -1020- " | £150.20 + v.a.t. | |
| " -1022- " | £73.30 + v.a.t. | |
| " -1024- " | £41.50 + v.a.t. | |
| Klip block 51X | £21.00 + v.a.t. | **Rhopoint Ltd,** Eastman House, 98-102 Station Road, East Oxted, Surrey RH8 0AY. |
| " 50X | £14.00 + v.a.t. | |
| " 49X | £7.50 + v.a.t. | |
| Laboratory Breadboard (kit) | £72.15 inc. v.a.t. | **Heath (Gloucester) Ltd,** Gloucester GL2 6EE. |
| Ramp base board | £5.00 + v.a.t. | **Ramp Electronics** 105 Harehills Avenue, Leeds LS8 4HU. |
| " power board | £10.95 + v.a.t. | |
| " oscillator board | £22.95 + v.a.t. | |
| " display board A | £18.50 + v.a.t. | |
| " B | £19.95 + v.a.t. | |
| " " C | £25.95 + v.a.t. | |
| " " D | £28.50 + v.a.t. | |
| Super strip | £11.05 inc. | **Lektrokit Ltd,** Sutton Industrial Park, London Road, Reading, Berks RG6 1AZ. |
| Assembly 200 | £12.53 inc. | |
| " 201 | £16.75 inc. | |
| " 208 | £19.35 inc. | |
| " 212 | £23.60 inc. | |
| " 218 | £31.70 inc. | |
| " 227 | £40.35 inc. | **OK Tool Co Ltd,** 48a The Avenue, Southampton, Hants SO1 2SY. |
| " 236 | £53.50 inc. | |
| 236 with power supply | £78.95 inc. | |
| S Dec | £3.50 + v.a.t. | **Bandridge Ltd,** 80a Battersea Rise, London SW11 1EH. |
| T Dec | £4.50 + v.a.t. | |
| μ-Dec A | £4.65 + v.a.t. | |
| μ-Dec B | £7.20 + v.a.t. | |
| Wonderboard small | £2.80 inc. v.a.t. | **Charcroft Electronics,** Charcroft House, Sturmer, Haverhill, Suffolk. |
| " large | £11.20 inc. v.a.t. | |

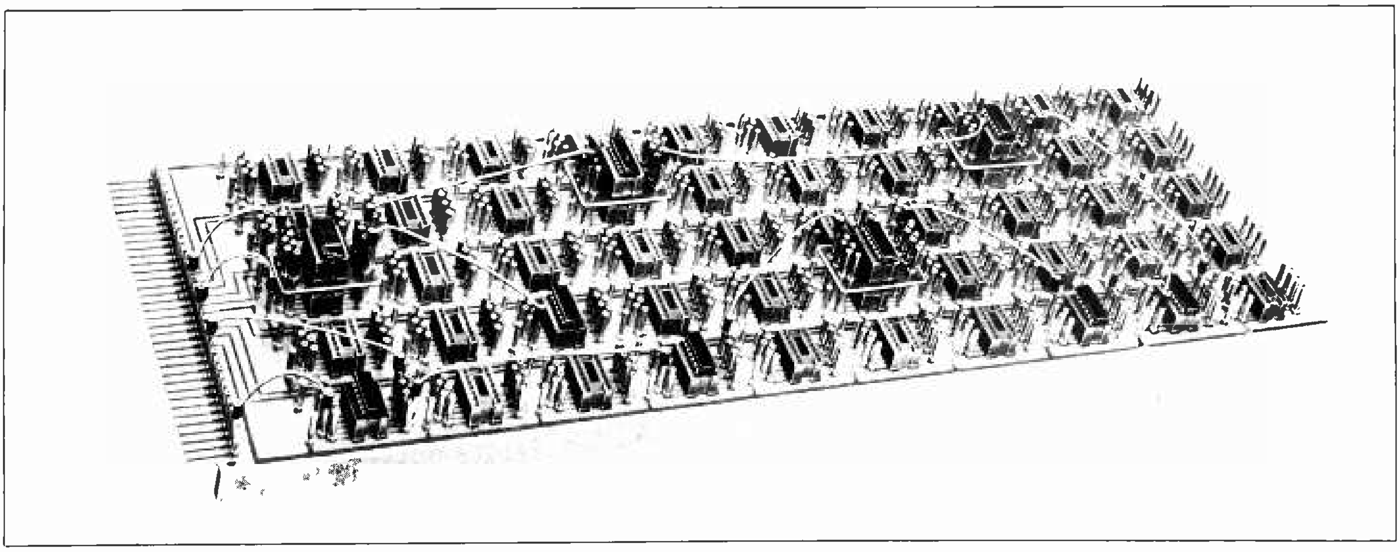


Fig 12

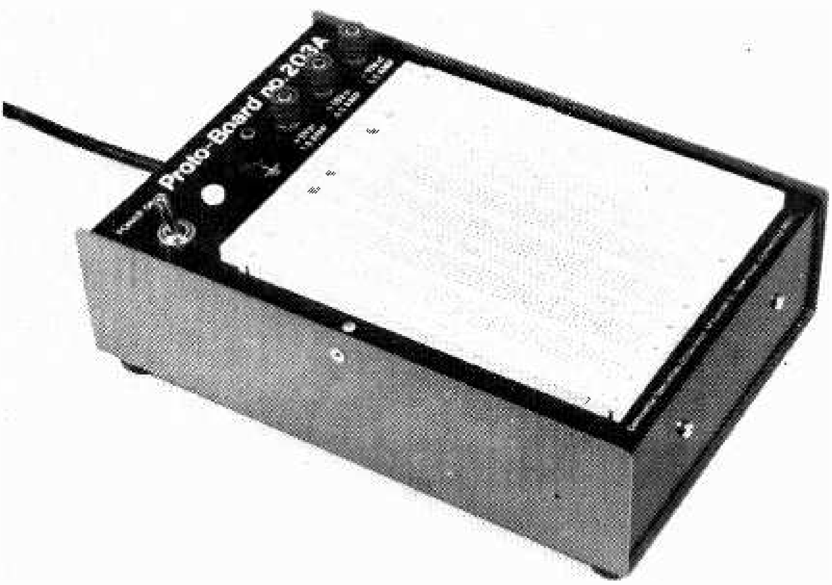



Fig 14

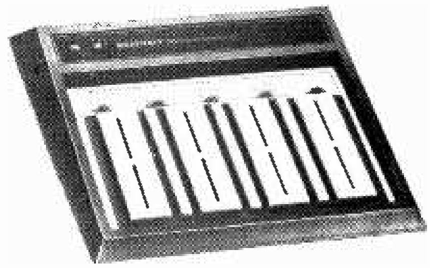


Fig 15

plexed b.c.d. or seven segment inputs via labelled sockets and stripped wires.

To supplement the function boards, there is a range of terminal blocks, sockets and a multi-zener, all designed to plug into a 0.1in matrix breadboard. The last mentioned is a single circuit-block which gives an adjustable zener voltage from 2.7 to 30V.

**Augat i.c. test panels** are available in three sizes, each 155mm wide by 106, 231, or 441mm long. These panels accommodate 10, 25 and 50 i.c. sockets respectively. Each i.c. pin has a vertical socket constructed from beryllium copper with gold-over-nickel plating, see Fig. 12, and connections are made by special patch leads. A 36-way edge connector, also with vertical sockets, is used for input/output connections and several power supply busses which travel in between the i.c. sockets.

This system can be extended by using single breadboard units. These small boards contain similar vertical sockets together with pins on the underside which will locate on top of any one i.c. on the main board. The individual breadboards can accept more i.cs or other components as required. A special plug/socket patch lead enables a connection to be made to the socket underneath the piggy-back module.

**The Bimboard Designer** in Fig. 13 consists of one, two or three Bimboards mounted on a console which contains a triple-rail d.c. power supply, comprising a dual tracking 100mA supply which can be varied from $\pm 5$ to $\pm 15$V, and a fixed 5V output rated at 1A. All of the supplies, which are isolated from earth and from each other, offer short circuit protection. Power supply terminals on the top of the console accept either 4mm plugs or stripped wire.

The console is fitted with a mains switch/neon indicator, a fuse holder, and a vertical panel.

**Proto Board 203A.** Fig. 14, is composed of three Continental Specialties 0.1in breadboard strips and five power supply strips mounted on a steel case. A total of 2,270 connection points will accommodate up to 24 14-pin i.cs together with discrete components. An internal power supply with short circuit protection gives three d.c. outputs of 5V at 1A and $\pm 15$V at 0.5A. Four screw terminals are provided for supply and earth connections, together with a mains switch and neon indicator. Dimensions for the unit are 247 × 165 × 90mm.

**Laboratory Breadboard** Type ET3300 from Heathkit, see Fig. 15 is available in kit form or ready built. The console comprises four 0.1in matrix strips and three bus strips which will accept up to 24 14-pin i.cs. The internal d.c. power supplies offer +5V at 1.5A, $\pm 12$V at 100mA, and are short circuit protected. Overall size of the unit is 89 × 304 × 304mm. □

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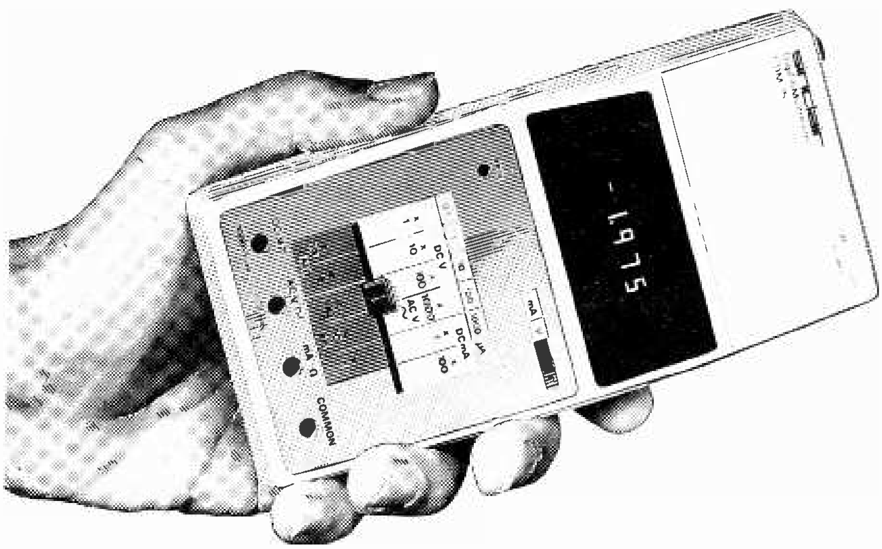


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### Technical specification

**DC Volts (4 ranges)**
Range: 1 mV to 1000 V.
Accuracy of reading 1.0% ± 1 count.
Note: 10 MΩ input impedance.

**AC Volts (40 Hz-5 kHz)**
Range: 1 V to 500 V.
Accuracy of reading: 1.0% ± 2 counts.

**DC Current (6 ranges)**
Range: 1 nA to 200 mA.
Accuracy of reading: 1.0% ± 1 count.
Note: Max. resolution 0.1 nA.

**Resistance (5 ranges)**
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Also provides 5 junction-test ranges.

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I understand that if I am not completely satisfied with my PDM 35, I may return it within ten days for full cash refund.

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# Loudspeaker system design

## Changes and refinements to the system described in the May and June issues

by **Siegfried Linkwitz,** Dipl. Ing., Hewlett-Packard Co., Santa Rosa, California

It is unfortunate that there are still so few loudspeakers commercially available which achieve a high standard of accuracy, according to Mr Linkwitz. "After all," he says, "the design concepts are rather straightforward and rational." The design of a loudspeaker system has to include a large number of electrical, mechanical and acoustical parameters if optimum results are desired. There is not one single parameter which by itself will turn a poor loudspeaker into a superior one; attention has to be given to all parameters, including the driver, enclosure and crossover.

THESE NOTES are intended to encourage further development of loudspeakers, and bring increased enjoyment to those who want to undertake the task of building their own systems. The changes and refinements made to the original loudspeaker system, described in the May and June issues, are presented to show the completeness of the analytical design approach, and should not be taken as an indication that the previous system is obsolete. The audible effects of the changes are subtle and the added complexity of the circuits would be worthwhile only to someone trying to achieve greatest accuracy of reproduction. But the techniques described should be of general interest to any loudspeaker design.

I feel the weakest link in recreating the illusion of a life source with loudspeakers lies at the microphone pick-up end of the signal chain. It seems likely that more than two loudspeakers are needed, but first a much better understanding for recording and reproducing the appropriate sound field has to be developed and demonstrated. Then it may be possible to transport oneself to Symphony Hall without moving out of the living room chair. Meanwhile the loudspeaker as the necessary electro-acoustic transducer can approach a high state of development.

Any moving coil driver has the general frequency response of Fig. 22 (Fig. 17 ref 16*) when driven from a constant voltage source. This is a second-order filter with an asymptotic slope of 12dB/octave below the resonant frequency $f_0$ and flat sound pressure output above it. The height of the peak near $f_0$ is governed by $Q_0$. Both parameters $f_0$ and $Q_0$ are easily determined from an impedance measurement of the driver, Fig. 18. This general transfer function between terminal voltage and sound pressure output applies to woofers, mid-range units and tweeters as long as their cone dimensions are small acoustically, Fig. 2, and must be taken into account when designing a crossover network.

As an example, consider the high-pass section of a crossover to a 25mm dome tweeter which has a resonance of 800Hz with $Q_0$ of 0.9, Fig. 23(a). The desired acoustic output should follow the fourth-order high-pass characteristic of the 24dB/octave crossover with 1.5kHz as the −6dB crossover frequency (b). At first glance it seems sufficient to shape the driver terminal voltage to follow the 24dB/octave high-pass function of (b) because the

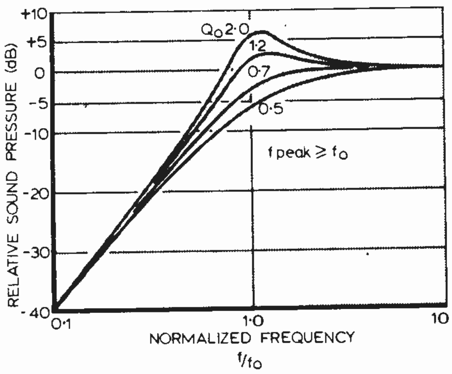



**Fig. 22.** *Frequency response of a moving-coil driver with dimensions small compared to a wavelength, which must be taken into account when designing crossover networks.*

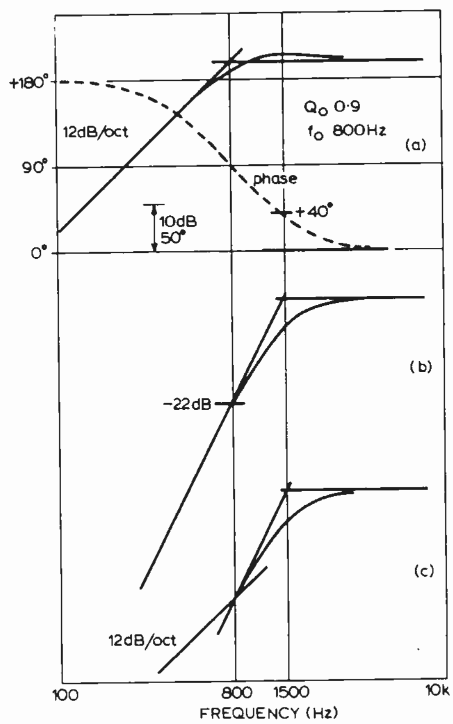



**Fig. 23.** *To achieve an acoustic or overall high-pass filter response with 24dB/octave slope (b), requires the terminal voltage to follow a 12dB/octave slope below resonance to compensate for the effects of the driver, whose sound pressure and phase response are shown at (a).*

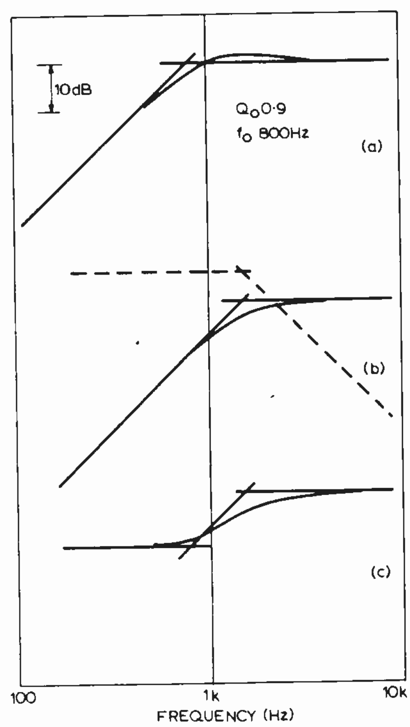



**Fig. 24.** *Required drive voltage (c) has to be constant below the driver resonance frequency $f_0$ to give the desired acoustic h.p. response (b) (cone excursion shown dashed), as a result of driver response (a).*

*Figure numbers prior to 22 refer to the author's previous articles, ref. 16.

filter has 22dB of attenuation at the driver resonance. Indeed, this was the procedure in the original crossover design for the T27 tweeter, Fig. 10. Such terminal voltage, however, causes a 36dB/octave roll-off in acoustic output from the driver for frequencies below resonance $f_0$. To achieve the exact acoustic frequency response of (b) the terminal voltage must follow a 12dB/octave slope below the 800Hz driver resonance (c). This then compensates exactly for the phase shift and group delay which the driver would otherwise add to the acoustic high-pass function. The additional phase shift would cause a tilting of the radiation pattern as the sound pressures from the tweeter and mid-range unit would add to a maximum at a point off-axis[10]. The amount of the phase shift introduced by a second-order high-pass filter can be calculated for $Q_o \geq 0.5$ from

$$\phi = 180^0 - \arctan\left[2Q_0\frac{f}{f_0} + \sqrt{(2Q_0)^2-1}\right]\ldots$$

$$-\arctan\left[2Q_0\frac{f}{f_0} - \sqrt{(2Q_0)^2-1}\right]$$

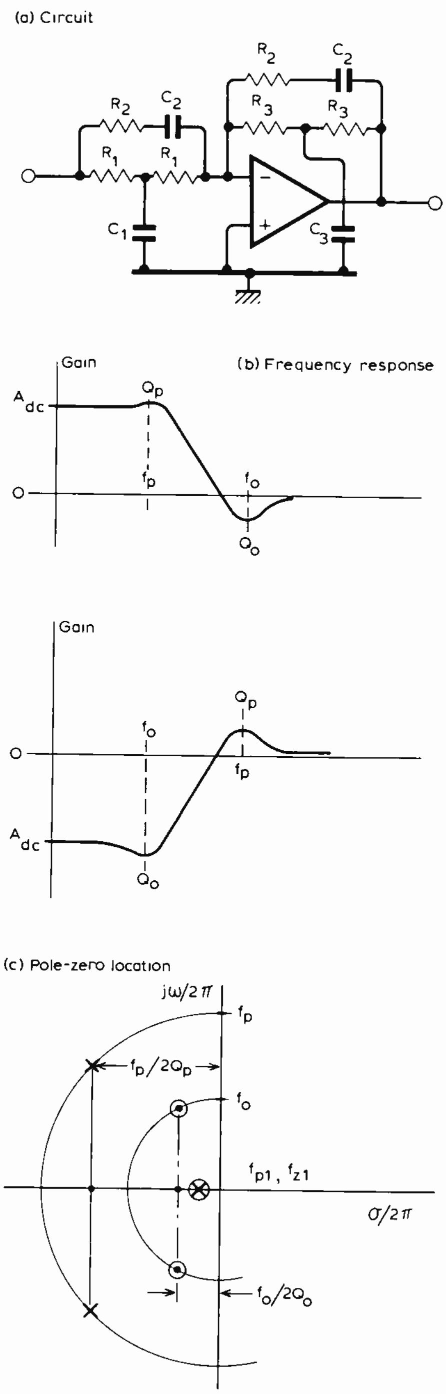
For the above example, the driver contributes 40° of phase shift at 1.5kHz. Sound pressures form the mid-range unit and tweeter are therefore not in phase unless the measures described are taken.

## Driver terminal voltage

The acoustic high-pass function of the previous example requires an exactly-shaped terminal voltage to compensate for the driver's own frequency response.

A fourth-order high-pass response is equivalent to the cascade of two second-order Butterworth sections[10]. The first step then is to equalize the driver output to follow a second-order Butterworth function by shaping the terminal voltage applied to it, Fig. 24. Design formulas were developed for a very useful network, Fig. 25. It is a modification of Fig. 20 and will later be used also to extend the woofer response. A note to those familiar with the description of transfer functions by poles and zeroes in the complex frequency plane: This network will generate a pair of complex zeros ($f_0$, $Q_0$) which are positioned to cancel the complex poles of the driver ($f_0$,$Q_0$). In addition, a pair of complex poles ($f_p$,$Q_p$) is available which are placed at the crossover frequency in the case of the tweeter highpass or at the lower cut-off point of the woofer in the case of woofer equalization. The factor K in the design formulas is necessary for cancelling a pole-zero pair ($f_{pl}$,$f_{zl}$) which would otherwise be introduced by the network.

The second step in designing the acoustic high-pass filter is to follow this network with a standard second-order Butterworth section to achieve the overall drive voltage of Fig. 23(d). The complete circuit of Fig. 26 is only slightly more elaborate than Fig. 14 but it achieves the exact fourth-order acoustic output, Fig. 23(b).




(d) Design formulas

(1) Specify $f_o$, $Q_o$, $f_p$, $Q_p$

(2) $$k = \frac{\frac{f_o}{f_p} - \frac{Q_o}{Q_p}}{\frac{Q_o}{Q_p} - \frac{f_p}{f_o}} \qquad k > o \text{ required}$$

(3) Choose $C_2$ (4) $R_1 = \dfrac{1}{2\pi f_o C_2 [2Q_o(1+k)]}$

(5) $R_2 = 2kR_1$ (6) $C_1 = C_2[2Q_o(1+k)]^2$

(7) $C_3 = C_1\left(\frac{f_p}{f_o}\right)^2$ (8) $R_3 = R_1\left(\frac{f_o}{f_p}\right)^2$

(9) $A_{dc} = 40 \log \frac{f_o}{f_p}$ [dB]

(e) Circuit analysis

$$\left.\begin{aligned} f_{p1} &= \frac{1}{\pi C_1 R_1} \\ f_{z1} &= \frac{1}{\pi C_3 R_3} \end{aligned}\right\} f_{p1} \approx f_{z1} \text{ required}$$

$$f_o = \frac{1}{2\pi R_1\sqrt{C_1 C_2}} \qquad Q_o = \frac{R_1}{2R_1+R_2}\sqrt{\frac{C_1}{C_2}}$$

$$f_p = \frac{1}{2\pi R_3\sqrt{C_2 C_3}} \qquad Q_p = \frac{R_3}{2R_3+R_2}\sqrt{\frac{C_3}{C_2}}$$

**Fig. 25.** *Useful network for compensating driver resonance at $f_o$ and extending frequency response to $f_p$ for woofer equalization or providing cut-off at $f_p$ for mid-range or tweeter high-pass, responses. Calculated values should be checked with the circuit analysis equations.*

## Crossover frequencies and drivers

The techniquie described could be used to modify the original T27 high-pass filter ($f_o$ 1.2kHz, $Q_o$ 1.1). Instead, I used a Son-Audax HD12×9 D25 soft-dome tweeter with a 1.5kHz crossover frequency to the B110. At 3kHz, the previous crossover point, the B110 cone diameter is about one wavelength, so that a certain amount of directionality can be expected, Fig. 1. Further, the mid-range and tweeter units are separated by one wavelength at 3kHz so that the combined radiation patter begins to narrow in the crossover frequency range, Fig. 3(b). The lower crossover reduces the acoustical dimensions by a factor of two so that a wider and more uniform dispersion is obtained over all frequencies in both the vertical and horizontal planes of radiation, Fig. 2. The loudspeaker then approaches more closely the acoustical point source. While the mid-range unit has to cover one octave less in frequency, the tweeter must now have four times the excursion capability to maintain the same acoustic output. The Son-Audax unit works well in this application and there is no sacrifice in overall smoothness of response compared to the T27. The new unit does not roll off towards the high end. For most commercial recordings a slight droop of about 3dB between 2k and 15kHz seems subjectively preferable and such response can be easily adjusted with properly designed treble controls.

The crossover point between woofer and mid-range units has been raised from 70 to 100Hz, thus reducing the maximum cone excursions for the B110 by a factor of two for constant sound output. Experience has shown that only the mid-range power amplifier is occasionally driven into clipping. If carefully fused a 100W amplifier might be considered for driving each B110. The three-way system is very forgiving to clipping of the mid-range amplifier. It is not audible on short transients because the woofer and tweeter channels still reproduce their undistorted portion of the total signal. The reduced frequency coverage of the B110 at both low and

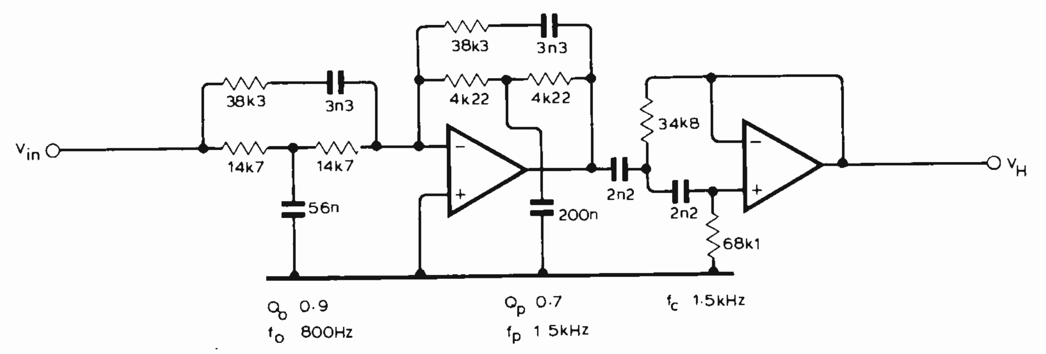



**Fig. 26.** *Network for a 1.5kHz 24dB/octave acoustic highpass filter for a Son-Audax HD12×9 D25 dome tweeter. The first op-amp stage compensates exactly for the driver resonance at 800Hz and gives a 12dB/octave 1.5kHz acoustic high-pass response. The second op-amp stage is a conventional Butterworth section. Design formulas for this network are from Fig. 25 and Fig. 14.*

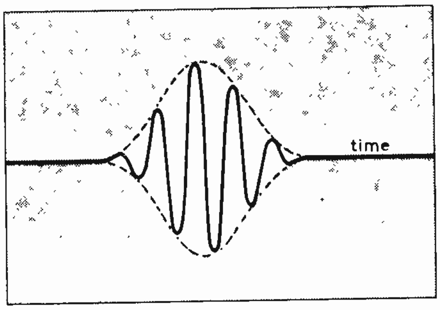



**Fig. 27.** *Shaped toneburst used to evaluate the audibility of phase distortion.*

high frequencies improves the amplifier power distribution between the drivers.

The crossover frequency between woofer and mid-range units was not raised further because the centre woofer is positioned 0.84m behind the mid-range unit and the phase shift due to this path length would become excessive. Further, the stereo effect might suffer from the blending of left and right-channel information for too high a crossover frequency.

In the future it could become necessary to have truly full range, separate speakers for reproducing an appropriately recorded sound field. Previously the mid-range resonance at 70Hz was used as one section of the 24dB/octave acoustic high-pass function. The second section was provided by an active network. Now, both sections are implemented electronically using the circuit of Fig. 25 to compensate for the B110's resonance in its enclosure, with $f_0$ and $Q_0$ determined from Fig. 18 ($f_0$ 73Hz, $Q_0$ 0.6). The complete network has therefore a configuration similar to that of the tweeter, Fig. 26.

## Woofer equalization

The centre channel woofer covers a relatively narrow frequency range. Of particular interest is the lower cut-off point and cut-off rate. There is some indication that the low-end phase behaviour of a system can have audible effects. A 5Hz square wave for example, which sounds like a sequence of clicks, will change its tonal character when transmitted through an all-pass network[10]. From network theory it is known that any high-pass filter with a slope of more than 6dB/octave will produce some amount of ringing to a step input[17]. It is impractical to roll off the woofer at a 6dB/octave rate because it would mean that its cone excursion has to continue to increase at 6dB/octave even below the 3dB corner. The only practical way is to use a 12dB/octave rate. If the Q of this high-pass network is kept low at 0.5 then a minimum of overshoot is combined with a minimum of cone excursion.

The original network Fig. 13 is a good approximation. The revised crossover uses the circuit of Fig. 25 with $f_p$19.3Hz and $Q_p$0.5 which gives a 30Hz, 3dB corner frequency.

The high-pass nature of the woofer channel introduces phase shift at the 100Hz crossover to the mid-range unit according to the previous formula for $Q_0$ 0.5:

$$\phi = 180^0 - 2\arctan\frac{f}{f_p} = 22^0$$

This amount of the phase shift by itself is insignificant, but combined with the phase shift due to the woofer location of 0.84m behind the mid-range it becomes necessary to add delay to the mid-range channel. It is implemented with the network of Fig. 16 which has a phase shift of

$$\phi = -2\arctan(2\pi fRC)$$

Both the absolute value of the phase shift and the slope of the phase curve, or the group delay, can be made to coincide between woofer and mid-range channel. The specific network component values R and C depend upon the set-up of the loudspeaker system and no compensation is needed when mid-range and woofer radiate from the same plane.

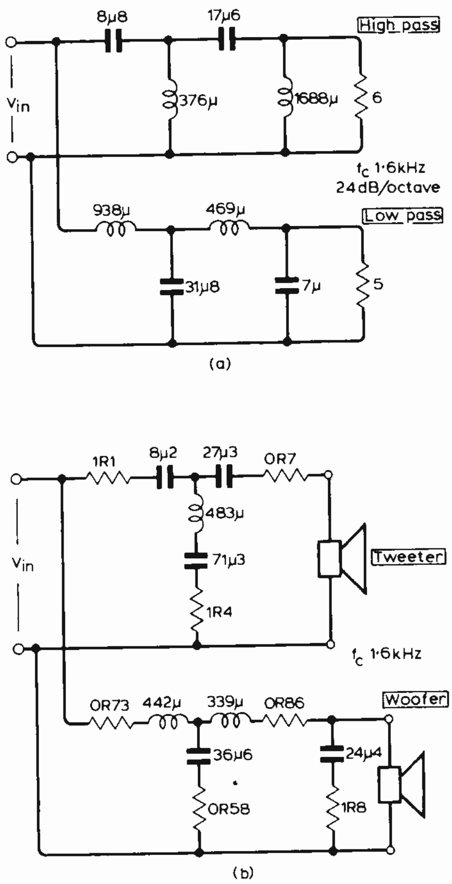



**Fig. 28.** *Passive network for 24dB/octave acoustic slopes and 1.6kHz crossover frequency. If constant terminal impedance is assumed for the drivers then the network and its element values can be determined analytically[20] (a). Computer optimized network for actual drivers shown at (b).*

## Audibility of crossover networks

Lowering of the tweeter crossover to 1.5kHz raised some concern over the audibility of phase distortion. The combined mid-range of tweeter sound pressure has all-pass characteristic. Sound pressures from the two drivers are in phase at all frequencies relative to each other but the overall sound pressure has a frequency-dependent phase shift relative to the electrical signal at the input to the crossover network. The group delay is not constant with frequency[10].

A new form of test signal was used which consists of a five-cycle tone burst of variable frequency. The tone burst is

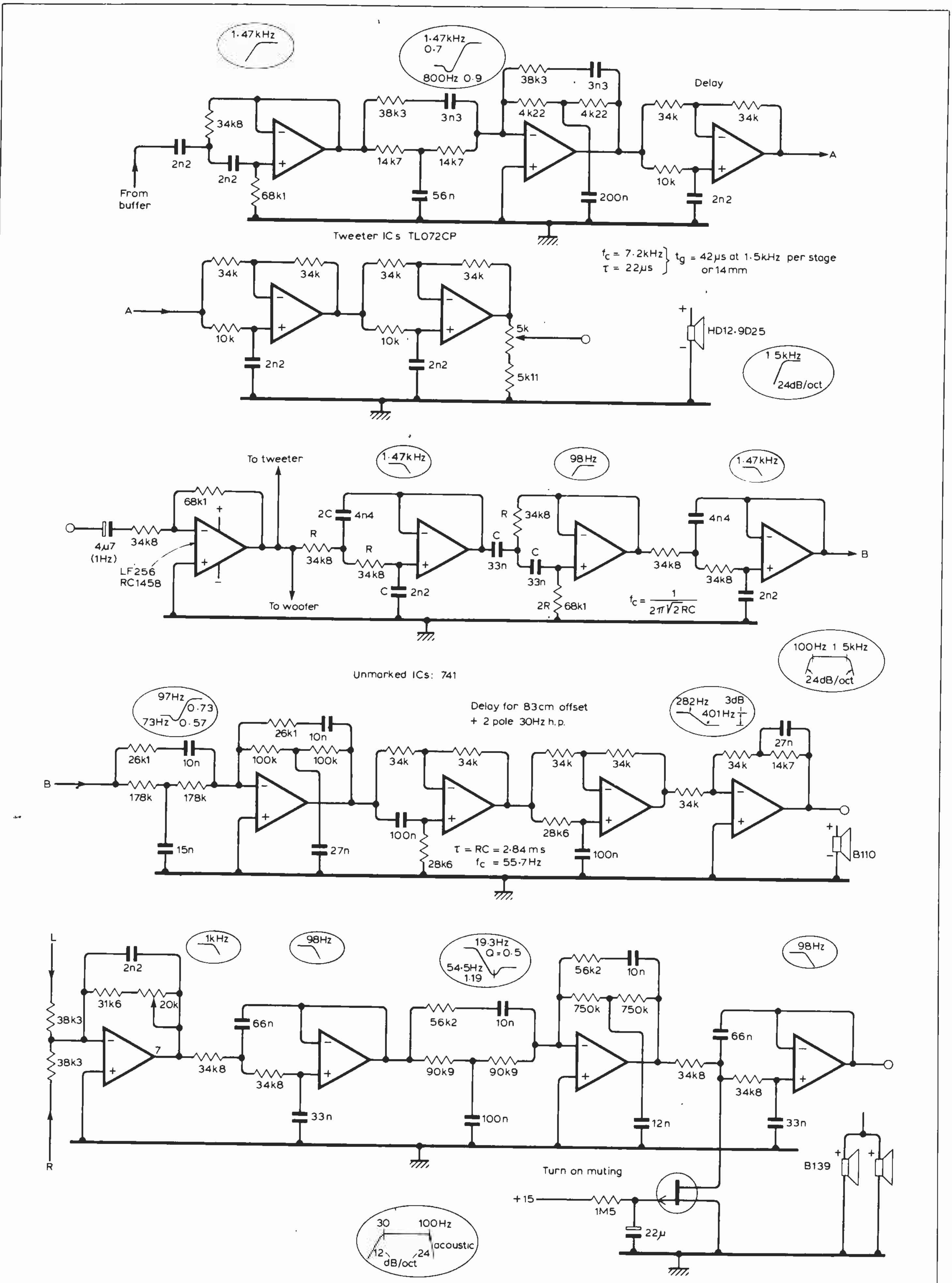



**Fig. 29.** *Complete schematic of crossover network and equalization of the author's system.*

not turned on and off in the usual abrupt fashion but instead it builds up and decays gradually, Fig. 27. The envelope of the burst follows a raised cosine function[18]. The spectral content of the shaped tone burst is concentrated in a narrow frequency range. The ear appears to be very sensitive to phase distortion of this signal, while a square wave or rectangular envelope burst are almost useless at higher frequencies for such tests. A system with 24dB/octave crossover filters has the phase shift of a second-order all-pass network with complex poles and zeroes of Q=0.7. No audible change could be noticed on insertion of this network into the test signal path. The Q had to be increased to 2.4 before any effect was noticed with the test signal at 1.5kHz. Observation with an oscilloscope indicated ringing of the trailing edge of the shaped burst which became increasingly more audible as Q was raised above 2.4. It can be concluded safely from these tests and others with program material that the phase distortion of a 24dB/octave crossover is insignificant.

Often, claims are made for the superiority of low-order crossover networks with 6dB/octave slopes. It should be obvious from Fig. 24 that a 6dB/octave acoustic response cannot be realized with a passive network because the driver itself introduces a 12dB/octave slope and the aforementioned associated phase shift. Merely applying a terminal voltage which changes with 6dB/octave would guarantee an 18dB/octave slope below the driver resonance and 6dB/octave above it, but with excessive phase shift which defeats the whole phase argument for this type of network.

Even a 12dB/octave acoustic high-pass filter would be extremely difficult to achieve passively as can be seen from the required terminal voltage of Fig. 24(c).

The lowest-order acoustic high-pass filter which can be realized with a passive network has 18dB/octave slope, sometimes called an acoustic Butterworth[19]. This filter still suffers from the phase quadrature between low and high-frequency driver outputs and the resulting frequency-dependent irregularity in the radiation pattern[10]. Surprisingly then, the 24dB/octave crossover is the lowest-order function for which the all-important radiation pattern has a stable axis. So-called "linear phase" loudspeakers are based on wishful thinking and not on physical realities.

## Enclosures

Further investigation into the constructon of a well-damped enclosure for the mid-range and tweeter led to the following conclusion.

A small box with 20mm thick walls is too stiff for tar-based damping layers. The tar has not enough stiffness of its own to control the motion of the panels at resonance. A better match between the two stiffnesses is required[20]. Building the enclosures out of 6mm plywood with a 15mm damping layer consisting of a 3:1 mixture of water-based roof patching tar and sand gave optimum results.

A simple and quite revealing test is to knock on any box to hear how dead acoustically it is.

## Passive crossovers

Not everyone is at home with the electronics and the rather elaborate op-amp circuits for this loudspeaker system. A passive crossover seems attractive as it would consist only of inductors, capacitors and resistors in a relatively simple interconnection. Unfortunately it is considerably more difficult for the home constructor to arrive at the correct element values for a passive network than to design active networks with their great flexibility to change transfer functions and gain[19].

To design a passive network for a 24dB/octave acoustic crossover requires a computer optimization routine unless one is satisfied with the trial and error procedure on which most loudspeaker design has been based on up to today. If a driver could be represented by a resistor then exact network values are easily calculated[21], Fig. 28(a). Real drivers have complex terminal impedances, Fig. 18. This not only affects the component values of the theoretical network but also the topology as can be seen by comparing the two networks of Fig. 28. Here a prototype design is shown for a 1.6kHz crossover between a 25mm dome tweeter and a 100mm woofer/midrange. Even the computer-optimized network of Fig. 28(b) has the desired acoustic amplitude and phase characteristic only for about two octaves either side of the crossover frequency.

The active network in contrast to this can be exact because the voltage source at the driver terminals is able to impose any desired acoustic frequency response to the driver, without interaction between the source's frequency response and the driver impedance.

**Note.** In addition to the points noted on page 91 of the October issue, Mr Linkwitz points out that the horizontal scale for Fig. 6 is d/λ.

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10. Linkwitz S.H., Active crossover networks for non-coincident drivers, *JAES*, vol. 24, 1976. p.2.

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19. KEFTOPICS, International Edition, vol. 1, no.2A, 1976, and vol. 3, no 1, 1978, KEF Electronics Ltd, Tovil, Maidstone ME156QP, Kent.

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21. Linkwitz S.H., Passive crossover networks for non-coincident drivers, *JAES*, vol. 26, 1978, p.149.

# Association of audio consultants

IN AN ATTEMPT to improve the standard of audio equipment reviews, an Association of Professional Audio and Radio Consultants has been formed. Acting secretary is James Moir, 16 Wayside, Chipperfield, Herts WD4 9JJ. The aims are as follows.

## Aims of the association

The Association of Professional Audio and Radio Consultants was formed in July, 1978 to improve the standard of services offered by consultants, work towards protecting the interests of their clients and advance the reputation of the profession. It recognised that the work of unqualified consultants sometimes fell below desirable standards and the membership requirements of the association ensure that a high level of professional and technical competence is maintained.

The objects of the Association are:

(a) To maintain and where possible improve the standards of professional conduct and competence of consultants concerned with audio and radio engineering.

(b) To represent and make known the views of its members upon matters relating to, or affecting the profession.

(c) To promote further education and knowledge in audio, radio and acoustic engineering.

Some consultancies tend to specialise in particular aspects and members of the Association will be bound by their Code of Ethics to restrict their activities to areas where their professional expertise is relevant. The range of expertise available is fully comprehensive. For example, the prospective client will be able to choose consultants from within the membership of the Association to give assistance with:

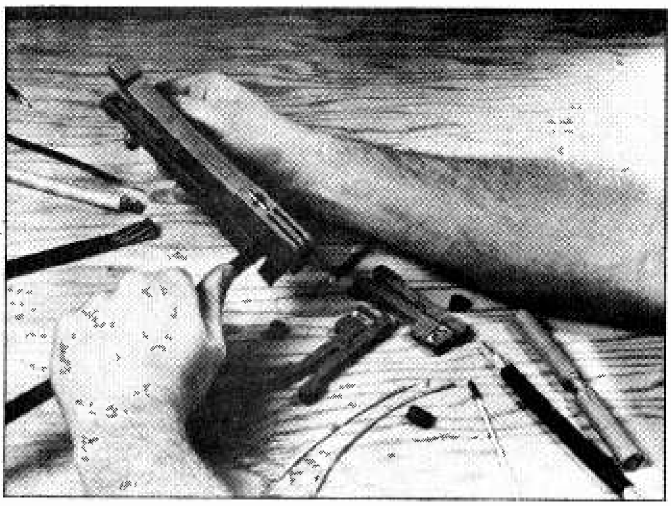
1. The assessment of the performance of audio and radio equipment and the associated software.
2. All aspects of the acoustics of concert halls, studios and theatres, including speech reinforcement, sound recording and associated techniques.
3. Fundamental redesign for development of improved products.

**Membership:** (a) *Member:* An organisation or an individual offering consulting services with no significant financial interest in the product of the service. *(b) Conditions of membership:* Applicants for membership shall furnish evidence of professional and technical competence.

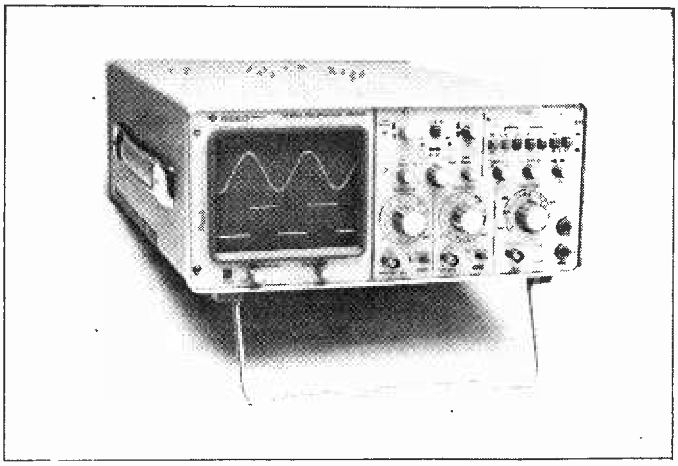
The ethic which has been adopted by the Association is basically similar to that of the existing professional associations. It ensures that the advice proferred by its members is not influenced by financial interests in the products and that any commercial involvement is, in any event, limited to a small proportion of the member's activity. Members will always declare the nature of this involvement when appropriate.

# NEW PRODUCTS

WW 301



WW302



WW 303

## Portable computer access

Access to a remote computer from any location with a telephone line and a tv set is possible with Tele-Zip. Costing £550, Tele-Zip comprises keyboard, acoustic modem and tv modulator in a suitcase housing.

Conceived by Data Dynamics, it is a follow-on from their Zip range of computer terminals: coming from a UK company these do not have the limitations of the simpler US terminals which because of their fixed one-chip basis can't accommodate changes like 50Hz mains, the Datel service, or the £ sign. "We put in a microprocessor" said a spokesman at a recent press launch "not for its low cost, but to give us flexibility." Some of the obvious areas of use are education, seat booking, remote diagnosis, computing, selling.

Details from Data Dynamics, Data House, Springfield Road, Hayes, Middx.
**WW 301**

## Insulation strippers

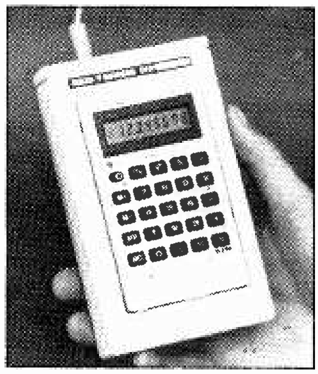
Cable strippers designed to cope with coaxial cables are announced by Hellermann. Two blades are used to sever both sheath and dielectric, leaving inner conductors free at a length suitable for termination. The depth of cut is adjustable and, in three models, the strippers will take cables of between 3 and 13mm o.d. Blades are replaceable. Hellermann Electric, Pennycross Close, Plymouth, Devon.
**WW 302**

## 15MHz oscilloscope

Two 15MHz channels of 2mV/cm sensitivity and a maximum time-base speed of 100ns/cm are the characteristics of the Gould Advance OS255. All the usual triggering modes are provided, and there is a 1V calibration signal, a timebase output and directly coupled intensity modulation. The 10 × 8cm tube is on the left, completely separated from all but tube controls, so that a right-handed operator does not tend to obscure the screen while using either sweep or amplifier controls. A left-handed user might find the layout less convenient. Weighing 6kg, the instrument is easily portable. Gould Instrument Division, Roebuck Road, Hainault, Essex.
**WW 303**

## Integrator

Varying direct voltages up to 25mV are integrated with time and displayed numerically on the MV1 millivolt integrator. It can therefore be used to integrate or average any varying quantity



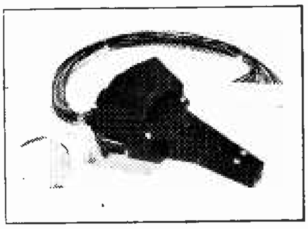
which can be transduced to a voltage, such as temperature, liquid flow or power over a period from minutes to months. An eight-digit display is provided and the instrument is battery-powered. Delta-T Devices, 128 Low Road, Burwell, Cambridge.
**WW304**

## Keypad

KB44E is a hexadecimal coded keypad using low-profile reed-switch keys. Encoding is by c.m.o.s. circuitry, which will accept supplies between 3 and 15V and uses little power, and the coding is the ISO R943 4-bit character set. Two-key rollover, n-key lockout and bounce protection is provided. Dimensions are 108 × 108 × 28mm with keys depressed. F.R. Electronics Ltd, Wimborne, Dorset.
**WW 305**

## Print head

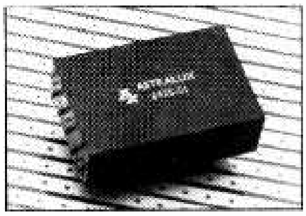
Suited for use in o.e.m. printers, the Roxburgh 820 printer head is a seven-needle type, printing on a 7 ×5 dot matrix. Characters are 2.87mm in height and are printed at the rate of 100 characters per second. Paper can be either



standard with an ink ribbon or pressure sensitive, the input being sufficient to imprint three copies plus the top printing. The drive pulse to each needle solenoid is 400μs, of 24V and 3A. Mean life before failure is claimed to be 25 million characters. Roxburgh Electronics Ltd, 22 Winchelsea Road, Rye, East Sussex.
**WW 306**

## Solid-state relays

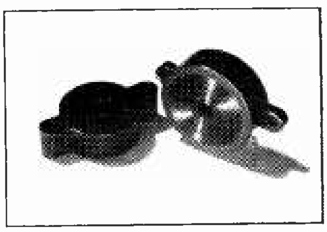
In a package measuring 42 × 15 × 26mm, the Astralux 6000 series of solid-state relays can switch up to 15A at 600V pk. A variety of ratings is available, the 1A version being designed for printed-board mounting, larger types for chassis or heatsinks. Isolation between input and output is quoted as 2.5kV or 3.5kV r.m.s., depending on the model, and the



input voltage range is 3-24V d.c. at an impedance of 2 kilohms. Astralux Dynamics Ltd, Brightlingsea, Colchester, Essex.
**WW 307**

## Alarms

Piezoceramic warning 'bleepers' from Pedoka are said to produce a clear, loud sound for small devices such as telephone, alarm clocks and the like. Model PKB5-3BO, which requires 9V at 9mA



d.c., emits a 2.8kHz note of 99dB at a distance of 30cm. Pedoka Ltd, 28-29 White Lion Street, London N.1.
**WW 308**

## High speed interface

The CD40115D is a 22 pin high speed silicon-on-sapphire i.c. designed to provide a two way interface between c.m.o.s. and t.t.l. systems. The 8-bit device offers 5 to 12V or 12 to 5V level conversion with a typical propagation delay of 10ns and 30ns for c.m.o.s. to t.t.l. and vice versa. T.t.l. sink current is specified as 30mA, and no external pull-up resistors are required on the t.t.l. input. Apart from the level-conversion mode, a high impedance tri-state mode can be selected. RCA Solid State, Sunbury-on-Thames, Middlesex TW16 7HW.
**WW 309**

## Cutter

The general-purpose cutters from Vero, type AB050, are claimed to be at home with materials ranging from tin plate to cardboard, handling printed-board material with ease. The blades are of stainless steel, with plastic grips, and a spring opens the cutters. Price is £3.50 from Vero Systems (Electronic) Ltd, 362 Spring Road, Sholing, Southampton, Hants.
**WW 310**

## Small digital multimeter

An unusual digital multimeter from Heuer weighs less than 3oz, including its probe and batteries. The size of the main unit, with l.c., 3½-digit display, is 4 × 1.6 × 0.5in, not much bigger than the probe, and provides for the measurement of alternating and direct voltage and current to 1kV, 2A and 20MΩ. The unit offers true r.m.s. measurement and there are extra probes for high current, voltage and temperature investigation. Heuer Time Ltd, Argyle House, 29/31 Euston Road, London N.W.1.
**WW 311**

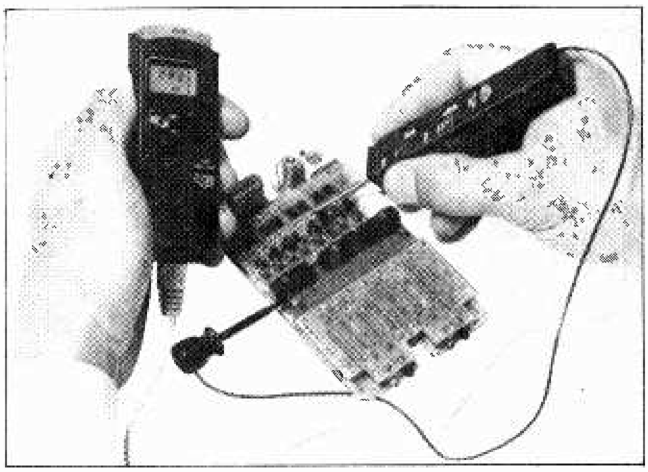
## Capacitance box

Capacitor substitution box from Time Electronics, the Type 9000, covers the range 100pF to 10μF in five decades, with a mid-scale tolerance of ±1%. Colour-coded edge switches are provided and stray capacitance is less than 50pF. The companion resistor box, the 8000, inserts resistance of 1 ohm to 100 megohms in eight decades at between 0.1% and 1% tolerance. Contact resistance is less than 0.25 ohms. Electroplan Ltd, P.O. Box 19, Orchard Road, Royston, Herts.
**WW 312**

## 100MHz synthesizer sig. gen.

Clive Green of Quartzlock, and of Green Electronic & Communication Equipment Ltd, says he has made a "British synthesizer breakthrough" with the model 360 signal generator. Most signal generators stop at 5MHz, he says, are non-programmable and have analogue controls that need to be correlated with meter readings. This one goes up to 100MHz (200MHz with doubler) and down to 100Hz, with b.c.d. programming, all-digital control settings with very low modulation distortion even at high modulation level (1% is claimed). Simultaneous a.m. and f.m. is possible — an advantage perhaps for potential use with a.m. stereo systems. Resolution is between one part in $10^5$ and $10^6$, accuracy one in $10^7$ with a stability of 3 parts in $10^9$ per day.

Price is £3,300 and according to Green is better and more reliable than its competition at £10,000. Now he's started selling "quietly", with trial quantities to people like the MoD, P.O., Plessey, Clive Green clearly feels he's got a winner. "After 20 years in the instrument business" he told us "you get a feel for what is needed". He reckons the market potential is enormous — second only to that for oscilloscopes. Which should please his backers, Peak Investments (with whom he believes he has a good deal, because unlike his previous arrangements, with ICFC for example, finance is recouped in relation to sales, and not at fixed intervals). Quartzlock Sales Ltd, Newnham Industrial Estate, Plymouth PL7 4LU.
**WW 313**



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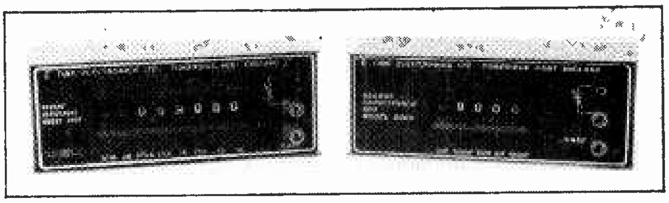

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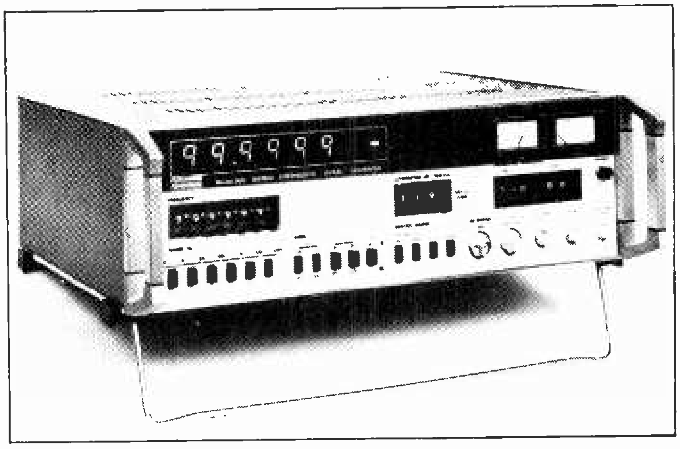



**WW 313**


## Digits out — hands in

As an exercise in turning a necessity into a fashion, the digital watch (meaning the kind with a row of numbers instead of hands) is perhaps the most successful since the Cornish pasty. A set of binary information is not the most convenient possible drive signal for a pair of hands, and the size of a watch and the energy available in a small battery makes moving parts unattractive. The easiest way to display the states of a collection of digital circuits is in numerical form, so this is what is usually done. Now, speaking personally, I can't get on at all well with a watch which brutally tells me that it is 09.43:51. It makes me perform mental arithmetic and at just before quarter to ten in the morning a friendly old clock face is much more reassuring. I freely admit that I'm at fault here — lots of people get a deal of pleasure in telling me the time to the nearest second, even though most of these watches exhibit spurious second displays which can be 60 seconds or more in error. No, I know I'm the odd one out: I still keep thinking that a two-bob piece is 20 pence.

I'm evidently not the only one, though, because Texas have just brought out an electronic watch which has the usual type of digital works but a liquid-crystal pair of hands and a set of hour points for dyed-in-the-wool reactionaries like me. Rich d.-i.-t.-w. reactionaries, mind you, since it costs around £200. Until the customary drop in price that we have come to expect takes place, I'll press on with my mechanical marvel, which is only about an order less accurate and a lot more comfortable than a row of numbers.

## Music of humanity

A lot of clever people — scientists, engineers, religious leaders and people said to be world thinkers, whatever they are — are going to hold a symposium on Humanity. I know this because a handout on the subject settled briefly on my desk the other day, in between an announcement of another £5M turke . . . turnkey contract and a claim that the latest ultimate amplifier is soon to be with us. Apart from its subject, the feature of the symposium which renders it out of the ordinary is that the delegates will be in London, Los Angeles and Toronto, all at the same time. They intend to talk to each other by way of satellite television link, and can refer to a computer in New York which possesses the data relevant to the symposium.

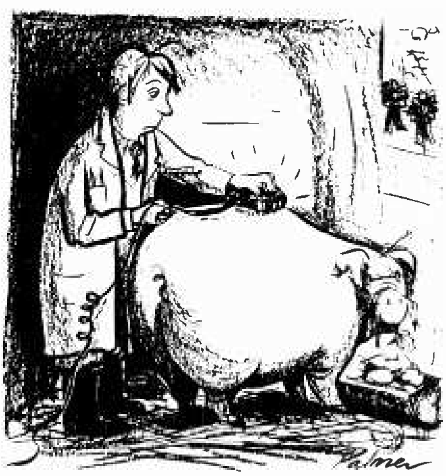
Now, this is all very well and no one has a greater respect for technical wizardry than I have, but isn't this carrying a fascination with gadgetry a bit far? If the langugage of this handout is any guide, and I do hope it isn't, the whole thing is going to be somewhat less than "transparent", if I can make use of one of the newer communications expressions. The medium, in fact, could well become the message, to borrow further. *(Or "massage", as McLuhan said later – Ed.)*

We are assured, for example, that the delegates will be able to "communicate via satellite video link with each of the other centres as well as accessing a computer conferencing system and database held in New York". It goes on to refer to "media co-ordination" and to offer the delegates "experiential events". It could be that I'm just an out of date reactionary, but it doesn't sound a lot like humanity to me. Bit too Orwellian for my taste.

I am, however, greatly encouraged to discover that the calibre of the people involved in the symposium is such that they will be able to offer their views on "the future of mankind as it is now". With tricks like that up their sleeves, who needs the gadgetry?

## Out of the ivory tower

You need a strong stomach for this job. Particularly if you've led a sheltered life, as I have. Electronic engineers have traditionally held the view that life beyond the output socket was a nasty business, properly left to those who professed an affinity with the seedier kinds of endeavour, such as heavy engineering. 'Industrial electronics', it used to be felt, was all right for those of us who didn't mind hob-nobbing with vulgar, spanner-brandishing mechanical people, but not really to be recommended.




Then, of course, we were discovered. The world and his wife decided that electronics was the 'in' subject and we all had to accustom ourselves to designing equipment for foundries, weighing machines, farms, rolling mills and all manner of extremely unscientific undertakings, from docking supertankers to measuring the thickness of pig fat. The people at Bell and Howell have now, it appears, reached their lowest point. They can surely progress no further in this matter of vulgarization. They have announced, with every appearance of being proud of themselves, that they are involved in measuring the depth of sludge in a water authority sludge digester. I do not feel impelled to dwell on the more unsavoury aspects of this exercise, but I do ask myself where it will all end.

## So who's perfect?

As the man who once shrieked 'Don't touch that!' a fraction of a second *after* the bonnet lid had fallen on my head, my timing would appear to be as immaculate as ever. Purely in an effort to be helpful, I offered my views on the spelling of the word program(me) recently, pointing out that the Concise Oxford preferred programme. Well, not only has the above dictionary turned its coat, but the new edition of "Hart's Rules" also shows clear evidence of having been got at. Computers, from now on, will work with programs (ugh!) according to these two respected works, though one will still buy a programme at the Festival Hall. *Wireless World* will not rock the boat: although the single-m spelling seems a wilful perversity, which cannot be recognized in speech unless it is pronounced in the American way, it will now be used in the context of computers.

Professional arguers need not worry, though. There are still lots of words to haggle over. Perhaps the next one could be connexion, which is spelt both ways in *Wireless World*, but only because the rest of them here don't know any better and think that connection is the way to do it. Quite wrong, of course . . .

## The game of the name

The Post Office seem to be having hard luck in choosing a name for their viewdata system. First of all "Viewdata" couldn't be registered as a trade name because it described pretty accurately what the system did (what a crazy world we live in!) so they chose Prestel. It now turns out that Prestel is also the name of a firm in Milan which specializes in field strength measurements and of a book publisher in Munich — both, as you'll note, concerned with the game of communication.

**NEW PRODUCT BULLETIN**

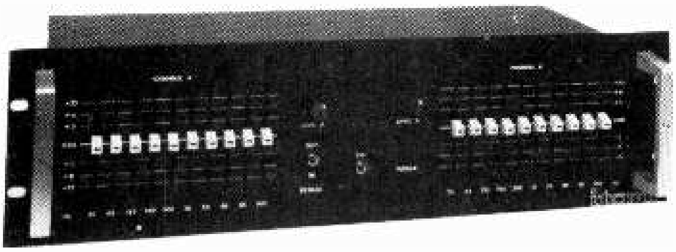
**ITA**

## ORBAN from USA

Dual channel multispring reverb unit. Each channel features four springs — far smoother than single spring systems. "Twang" and "boing" are virtually eliminated by incorporating a floating threshold limiter. Bass, mid-range EQ and bandwidth controls. The best compact reverb unit available.

## ITAM 882

New Stereo Mixer, built to a specification not a price! Ultra low noise —128dB. 8 inputs + 8 direct outputs, 2 outputs with VU meters. 2 limiters. XLR mic inputs (balanced). 3 band EQ + mid sweep.
**£395 + VAT**



## ITAM Graphic Equalizer

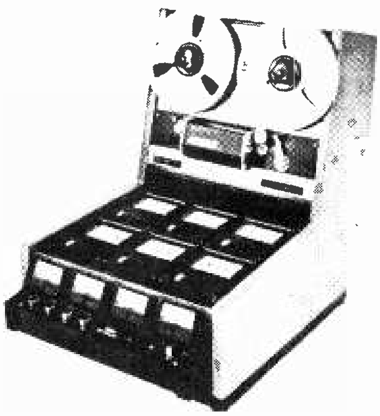
A fully professional graphic equalizer at a reasonable price. Stereo, with 10 bands per channel, 19 inch rack mounting. £280 + VAT.

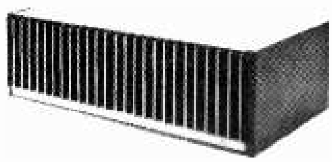
## AMPEX ATR-700

Now every studio can afford legendary Ampex performances and reliability. Fully professional specification including balanced inputs/outputs, Cannon connectors, variable tape speed, sel sync. The price will fit this year's budget, not next year's! Sole distribution by ITA.

## OTARI DP4050 OCF IN CASSETTE DUPLICATOR

Now with 3¾ + 7½ master capability and Ferrite heads. Duplicates 6 cassettes each run at 8 times speed. Over 80 stereo C60 per hour. Unquestionably the finest in cassette copier available from the world's largest duplicator manufacturer.





## QUAD

The new 405 power amplifier is now in stock. 100 watts per channel — simply the best, for £££'s less! Immediate Delivery!

**ITA**

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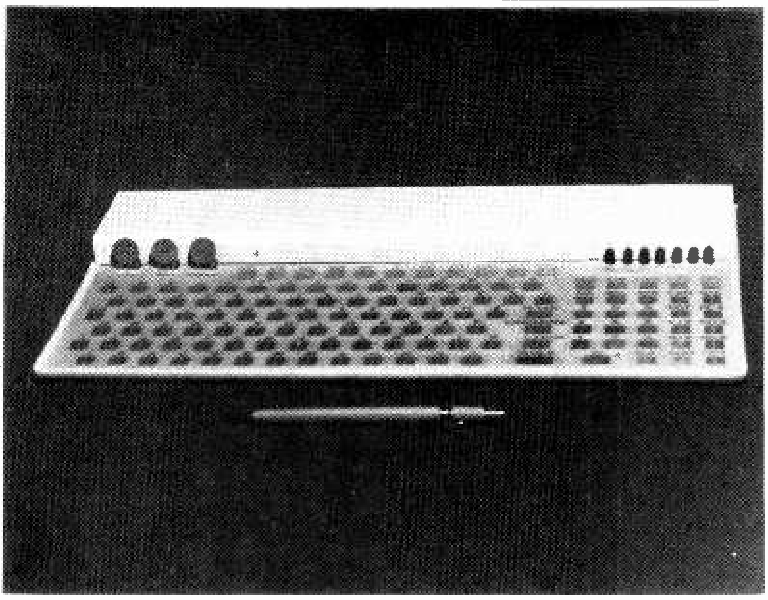
FRANCE: Son Professionnel, 2 Rue des Tennerolles, 92210 Saint Cloud (Paris). Tel: 602 6815.

WW—106 FOR FURTHER DETAILS

# STAR DEVICES

STAR DEVICES



## NOW AVAILABLE

## ASCII ENCODED TOUCH KEYBOARD

The Standard Unit offers the following features.

- * 7 bit parallel ASCII encoded output.
- * Positive and negative strobe edges.
- * MOS - DTL - TTL compatible outputs.
- * Each output will drive 4 TTL loads.
- * Full ASCII set - 128 characters - Upper and lower case.
- * LED's to show ASCII coding of selected character.
- * Audio tactile feedback with volume / tone control.
- * Character input rate adjustable from 0.1 to 1 second.
- * Touch sensitivity control.
- * Automatic character repeat.
- * Modified two key rollover and N key lockout.
- * Automatic scan facility - Will automatically scan through and output each character in the ASCII set. Useful for testing and setting up systems.
- * Requires 5 Volts at only 200 mA. See Option 'D'.
- * Gold plated edge connector 0.1" pitch. Mating connector provided.
- * Calculator type numeric cluster with expanded Ø pad.
- * Expanded pads for carriage return, horizontal tab, line feed and space.
- * Low profile case. Non-slip feet.
- * Comprehensive handbook and keyboard cleaning device supplied.
- * One year guarantee.
- * Assembled, burnt in and fully tested.
- * Designed and manufactured in the United Kingdom.

**£37-50**

**Inclusive of VAT, post & packing.**

| | |
|---|---|
| Dimensions | 14.1 x 7.3 x 1.2 inches<br>358 x 185.4 x 30.5 m.m. |
| Weight | 16 ounces.<br>454 grammes. |
| Colour | Blue base with grey case and surround. |
| Operating | Temperature range 0° - 50° C. |

Star Devices (QWERTY) Limited,
P.O. Box 21,
Newbury,
Berkshire,
United Kingdom.

Patents Pending. Copyright © 1978.

Optional Extras.

| | | | |
|---|---|---|---|
| A. | Serial output conforming to RS 232 / V24 | .. .. | £ 5-00 |
| A1. | Internal Baud rate generator. State on order Baud rate required. | .. .. | £ 4-00 |
| A2. | Internal generation of ± 12 Volts for use with Option 'A'. | .. .. | £ 6-00 |
| B. | Parity check bit (bit 8). Both 'Odd' and 'Even' brought out to edge connector. can be incorporated in Option 'A' or 'C'. | .. .. | £ 3-00 |
| C. | 20 mA Current loop output. | .. .. | £ 4-00 |
| D. | 'On-Board' 5 Volt regulator. Requiring D.C. input of 7 to 12 Volts. | .. .. | £ 3-00 |
| E. | Earphone socket + plug in personal earphone. Ideal when several units are being used in close proximity to each other-in schools etc. | .. .. | £ 2-00 |
| F. | Active Low outputs. | .. .. | £ 3-00 |
| G. | 30 Volt open collector outputs-Active High. | .. .. | £ 3-00 |
| H. | 30 Volt open collector outputs-Active Low. | .. .. | £ 3-00 |

* * * * * * * * * * * * * * * * * * * * *

Consult factory for other requirements.

* * * * * * * * * * * * * * * * * * * * *

Options can be incorporated in the keyboard after purchasing by returning the keyboard to the factory and stating which Option(s) are required. Include remittance for Option(s) at prices then currently advertised plus £ 5-00 handling charge.

* * * * * * * * * * * * * * * * * * * * *

Note. With Option A (RS 232) the Baud rate and ± 12 Volts can be supplied to the keyboard by the user.

* * * * * * * * * * * * * * * * * * * * *

The following Baud rates are preferred :- 50, 75, 100, 110, 134.5, 150, 200, 300, 400, 600, 1200,2400, 4800, 9600.

Please circle Option(s) required with your keyboard.

A - A1 - A2 - B - C - D - E - F - G - H.

Baud rate for Option A1 ____________

Cheque / P.O. enclosed for £ ____________
Indicate total order value.

Made payable to :-
Star Devices Limited.

Name ________________________________

Address ______________________________

______________________________________

Please Print

Prices inclusive of VAT, post and packing.

Star Devices (QWERTY) Ltd.,
P.O. Box 21,
Newbury,
Berks.

I understand that if I am not satisfied with my keyboard in every way, I may return it in good condition, within ten days for a full cash refund.

# THINK OF A SHAPE


S 500D—dual channel
up to 500W/RMS per
channel DE-20 KHZ

## Whatever it is, the H|H electronic 'S' range of power amplifiers will handle it

The H|H 'S' range is designed to handle heavy industrial usage in the fields of vibrator driving, variable frequency power supplies and servo motor systems.

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Dual Channel
19" rack mount 3½" high
500w R.M.S. into 2.5 ohms per channel
900w R.M.S. in bridge mode
DC—20 KHZ at full power
0.005% harmonic distortion (typical)
At 300 W.R.M.S. into 4 ohms at 1 KHZ
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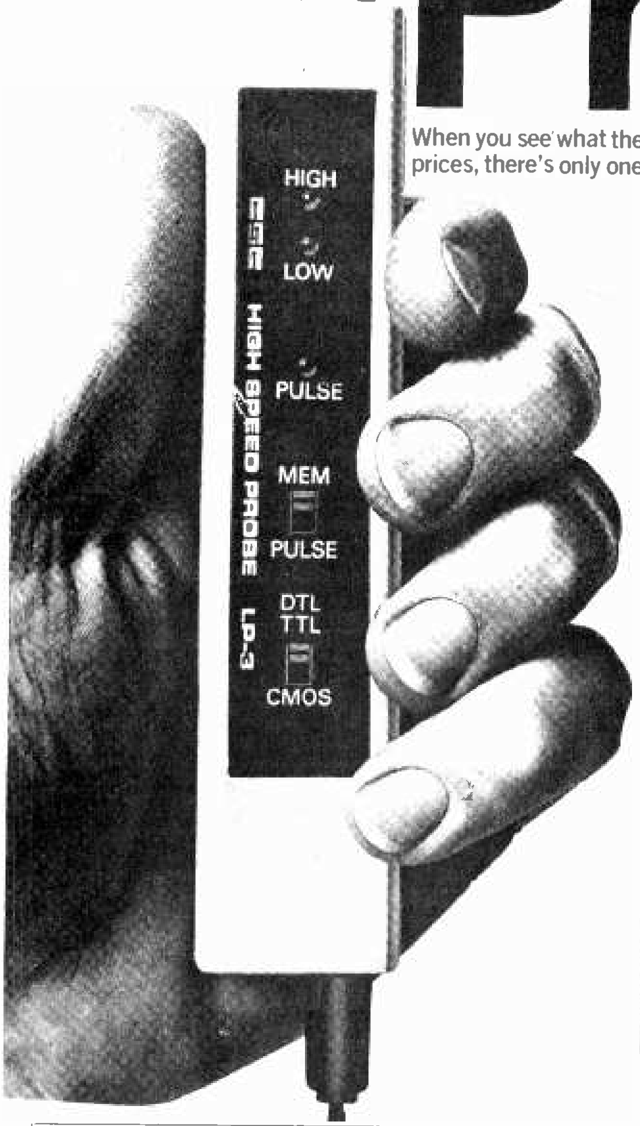
# The Logic Probes




**When you see what these new CSC logic probes can do, in such a small size, and at such small prices, there's only one word for it:—**

## Amazing!

**LP-1** Unit Price £31.00 · Post & Package £1 50 · VAT £2 60 · **Total £35.10.**
Clip the leads to the power supply of the circuit under test, touch the probe tip to any pin, pad or component and you're in business. The 'HIGH' and 'LOW' LEDs show logic states 1 or 0, if neither come on you've got open circuit, tri-state, signal out of tolerance (or no power!)
The 'PULSE' LED flashes once for any pulse 50n sec or longer, and flashes regularly at 3Hz for high frequency trains. Then, while 'PULSE' is flashing, 'HIGH' will come on alone to show duty-cycles over 85%, 'LOW' alone to show less than 15%, and with both on together duty-cycles can be estimated between 15% and 85% by relative brightness.
In the MEMORY mode, the leading edge (positive- or negative-going) of any pulse will latch a flip-flop on and keep the PULSE LED lit as long as power is applied to the probe. You can catch events that are hard to see even with a high quality scope!
LP-1 is switch-selectable for DTL TTL and HTL/CMOS circuits

**LP-2** Unit Price £18 00 · Post & Package £1 25 · VAT £1 54 · **Total £20.79.**
Economy version of LP-1, with the same HTL/CMOS and DTL/TTL capability 'HIGH' or 'LOW' LEDs function as in LP-1, 'PULSE' catches pulses as short as 300nsec and shows pulse trains as 10Hz blink. When pulsing, 'HIGH' comes on to show duty-cycles above 70%, 'LOW' shows below 30%, both on together show between 30% and 70%. 300,000 Ohm input impedance protects your circuit under test, and the low price brings the advantages of our quick, easy LOGIC PROBE technique to anyone interested in logic circuitry.

**LP-3** Unit Price £49 00 · Post & Package £1 50 · VAT £4 04 · **Total £54.54.**
Super high speed version, captures pulses as short as 10nsec, and monitors pulse trains as rapid as 50MHz. That's better performance than many oscilloscopes! And no bulky instruments, no set-up time. At frequencies up to 1.5MHz you can estimate duty-cycles by the High/Low relative intensity, as with LP-1. DTL/TTL and HTL/CMOS are switch-selectable, of course, plus 'MEM' memory mode to latch on to any pulse, pulse train or passing transient. LP 3 is the ideal trouble shooter for your fastest logic circuits, and like all CSC probes is well-designed, handy and easy to use, robust, reliable and individually tested before it leaves the factory

**And the new pulser DP-1** Unit Price £51.00 · Post & Package £1 50 · VAT £4 20 · **Total £56.70.**
The Digital Pulser another new idea from CSC. The DP-1 registers the polarity of any pin, pad or component and then, when you touch the 'PULSE' button, delivers a single no-bounce pulse to swing the logic state the other way. Or if you hold the button down for more than a second, the DP 1 shoots out pulse after pulse at 100Hz. The single LED blinks for each single pulse, or glows during a pulse train. If your circuit is a very fast one, you can open the clock line and take it through its function step by step, at single pulse rate or at 100 per second. Clever! And a very reasonable price

**How to order.** Telephone 0799-21682 and give us your Access, Barclaycard or American Express number, and your order will be in the post that night. Or, write your order, enclosing cheque or postal order, or stating credit card number and expiry date (Don't post the card!) Alternatively, ask for our latest catalogue, showing all CSC products for the engineer and the home hobbyist
*(Prices are for UK only. For Europe add 10%, outside Europe add 12½% to total prices)*

| Specification | LP-1 | LP-2 | LP-3 | DP-1 |
|---|---|---|---|---|
| Input Impedance | 100,000Ω | 300,000Ω | 500,000Ω | Output Tri State |
| Minimum Detectable Pulse | 50ns | 300ns | 10ns | Autopolarity Pulse Sensing |
| Max Input Signal (Freq.) | 10MHz | 1.5MHz | 50MHz | Sink and Source 100ma |
| Pulse Detector (LED) | High Speed Train or Single Event | High Speed Train or Single Event | High Speed Train or Single Event | Pulse Train 100pps |
| Pulse Memory | Pulse or Level Transition Detected and Stored | None | Pulse or Level Transition Detected and Stored | LED indicator flashes in Single Pulse Stays lit on Pulse Train |

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| Model No. | Contacts | Price, each |
|---|---|---|
| 217L | 170 | £3.25 |
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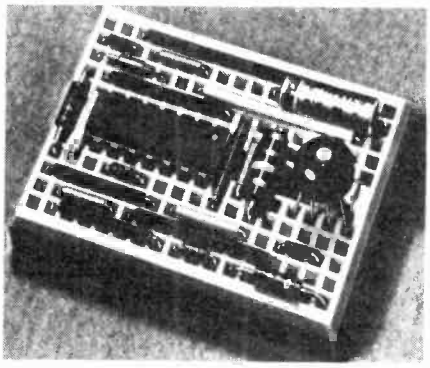
| 264R | 512 | £6.65 |
| 264L | 640 | £8.32 |

(All prices include packing, postage and VAT)



## Lektrokit IC Test Clips

**FROM £3.08 inc p & p and VAT**

Eleven models, from TC-8 to TC-40 to fit all DIP sizes. Prices from £3.08 for the TC-14, £3.25 for the TC-16, etc.

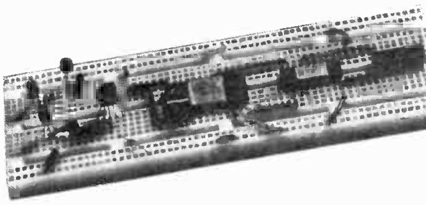
Test clip grips IC's without slipping or shorting between pins—makes testing IC's on boards easier, aids removing and inserting DIP's without damage. Each IC pin can be brought up to a convenient contact post for test leads or probe connections.

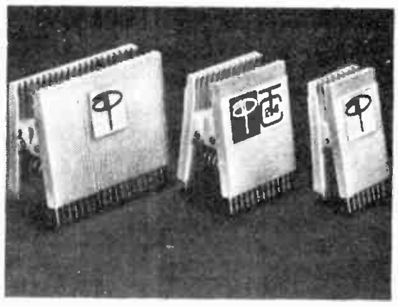
## Lektrokit Super Strip SS2

**ONLY £11.05 inc p & p and VAT**

Super Strip accepts ALL DIP's— as many as nine 14-pin at a time— and/or TO-5's and discrete components. With interconnections of any solid wire up to 20 AWG.

Super Strip has 840 contact points, combining a power/signal distribution system with a matrix of 640 contacts in groups of 5. Distribution system has eight bus-bars, each with 25 contact points.





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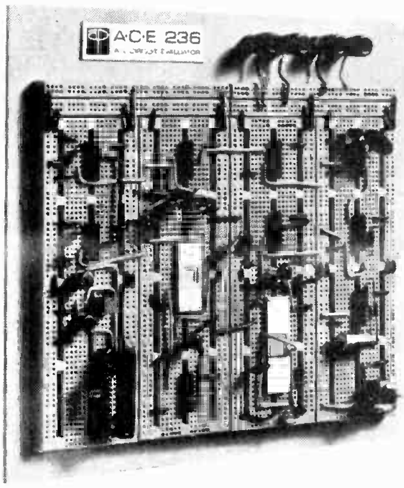
With ACE, you just plug in components and make connections with ordinary 22-gauge solid wire. No soldering. You can build any working project *complete*, as fast as you could lay out a circuit diagram before.

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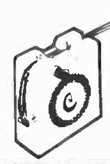
**HOBBY WRAP**
Model BW 630

Battery Wire-Wrapping Tool Complete with Bit and Sleeve. NEW

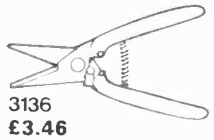
**WIRE-WRAPPING TOOL**
For .025" (0,63mm) sq. post "MODIFIED" wrap, positive indexing, anti-overwrapping device.

| | | |
|---|---|---|
| A | For AWG 30 | BW-630 |
| B | For AWG 26-28 | BW-2628 |
| C | Bit for AWG 30 | BT-30 |
| D | Bit for AWG 26-28 | BT-2628 |

**A £26.75. B £31.95. C £2.82. D £7.44**



**3 IN 1 WIRE DISPENSER**
New wire dispenser cuts and strips three different colours of wire. Quick and easy to use pocket size.
**£4.07**
Wire Size: 30 AWG.
50 ft. Red, Blue, White
Kynar insulated.



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Cuts everything. Leather, wire, plastic, tin-plate, cardboard. Stainless steel blades.
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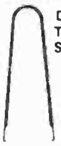
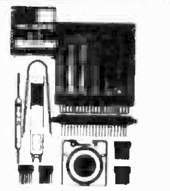
The EX-1 Extractor is ideally suited for hobby enthusiast or lab engineer. Featuring one piece spring steel construction. It will extract all LSI, MSI and SSI devices of from 8 to 24 pins.
Extractor Tool EX-1.



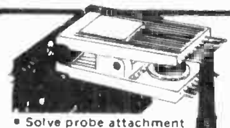
**DIP/IC INSERTION TOOL WITH PIN STRAIGHTENER**
**£2.79**
INS-1416



**WIRE-WRAPPING KIT**
Contains: Hobby Wrap Tool WSU-30 M, Wire Dispenser WD-30-B, (2) 14 DIP's, (2) 16 DIP's, Hobby Board H-PCB-1, DIP/IC Insertion Tool INS-1416 and DIP/IC Extractor Tool EX-1.

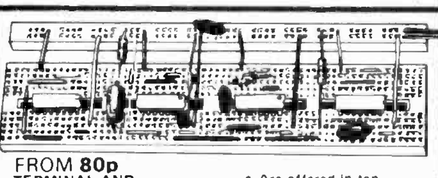
| | |
|---|---|
| Wire-Wrapping Kit | WK-4B (Blue) |

**£19.22**



**IC TEST CLIPS £2.97**
**FOR DUAL-IN-LINE PACKAGES**
- Provide full access to integrated circuit DIP leads.
- Remove DIP's damage free.
- Available in sizes to accommodate all DIP's; TC-14 fits 14-pin DIP's etc.

- Solve probe attachment problems.
- Simplify prototype and production testing, field service work, and quality control.



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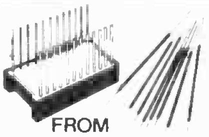
**TERMINAL AND DISTRIBUTION STRIPS**
Bread boarding building blocks with universal matrices of solderless plug-in tiepoints.
- Facilitate quick, solderless circuit build-up and check-out on universal .1" x .1" matrix.
- Are offered in ten configurations.
- Accept all components with leads up to .032" diameter.
- Require no special patch cords.
- Includes integral non-shorting instant mounting backing.

**HOBBY WRAP TOOL**
Wire-wrapping, stripping, unwrapping tool for AWG 30 on .025 (0,63mm) Square Post.

| | | |
|---|---|---|
| Regular Wrap | A | WSU-30 |
| Modified Wrap | B | WSU-30M |

**A £4.74 B £5.07**



**DIP SOCKET**
Dual-in-line package, 3 level wire-wrapping, phosphor bronze contact, gold plated pins .025 (0,63mm) sq., .100 (2,54mm) centre spacing.

| | |
|---|---|
| 14 Pin Dip Socket | 14 Dip |
| 16 Pin Dip Socket | 16 Dip |

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**RIBBON CABLE ASSEMBLY £2.92**

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| With 14 Pin Dip Plug - 4" Long | DE 14-4 |
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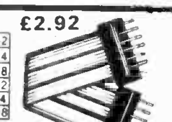
| With 16 Pin Dip Plug - 2" Long | DE 16-2 |
| With 16 Pin Dip Plug - 4" Long | DE 16-4 |
| With 16 Pin Dip Plug - 8" Long | DE 16-8 |



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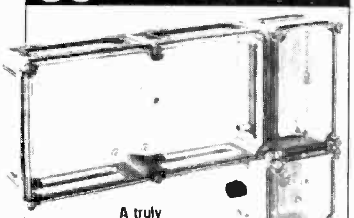

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Encase solves your waterproof and dustproof problems and because of its chemical resistance is ideal in the process industries. The polycarbonate is virtually unbreakable. Covers—clear PC. Case—glass filled PC. Gaskets/screws incl. gland plates (hinges available).

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|---|---|---|---|---|
| ENC A | 190 | 190 | 130 | 9.48 |
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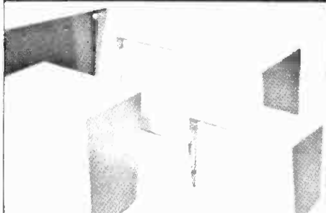
| ENC C | 380 | 190 | 130 | 15.40 |
| ENC D | 280 | 280 | 130 | 16.03 |
| ENC E | 380 | 280 | 130 | 20.51 |
| ENC F | 560 | 280 | 130 | 28.51 |
| ENC G | 560 | 350 | 130 | 39.29 |

## WH CONTIL

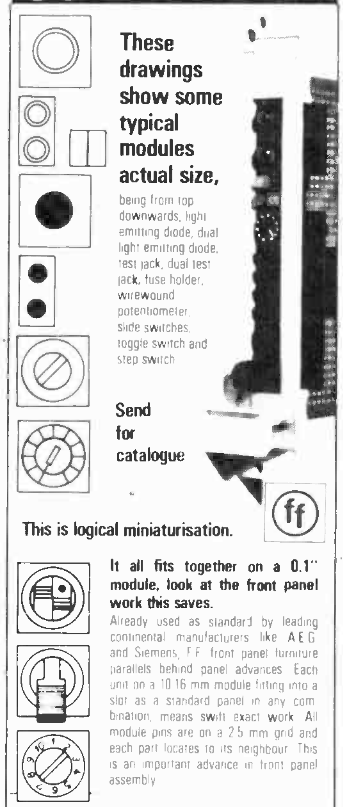


**West Hyde's best selling case, strong, rigid and smart**

| | L | B | H | |
|---|---|---|---|---|
| CON 755 | 178 | 127 | 127 | 8.68 |
| CON 975 | 229 | 178 | 127 | 10.30 |
| CON 867 | 203 | 152 | 178 | 10.30 |
| CON 127 | 305 | 178 | 178 | 11.86 |
| CON 161 | 406 | 305 | 178 | 16.36 |
| CON 191 | 489 | 267 | 26 | 22.53 |
| CON 1910 | 489 | 381 | 267 | 28.36 |

Best selling range of Textured blue acrylic steel eyebrow cases. Front panels white or PVC/aluminium, also unpainted up to size 1277.

## WH FRONT FURNITURE



**These drawings show some typical modules actual size,**
being from top downwards, light emitting diode, dual light emitting diode, test jack, dual test jack, fuse holder, wirewound potentiometer, slide switches, toggle switch and step switch.

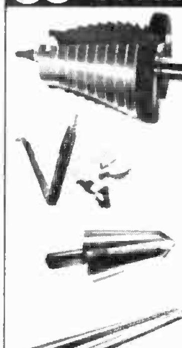
**Send for catalogue**

ff

**This is logical miniaturisation.**

**It all fits together on a 0.1" module, look at the front panel work this saves.**
Already used as standard by leading continental manufacturers like AEG and Siemens, FF front panel furniture parallels behind panel advances. Each unit on a 10.16 mm module fitting into a slot as a standard panel in any combination, means swift exact work. All module pins are on a 2.5 mm grid and each part locates to its neighbour. This is an important advance in front panel assembly.

## WH CUTTING TOOLS



**Bradrad drills and deburrs, thin or thick, plastic or steel.**
£17.80
6–36mm or ¼"–1½"

**Adel nibbling tool cuts virtually any shaped hole.**
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**Conecut powered reamer.**
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**Reamers for plastic or metal.**
3–12mm £8.25
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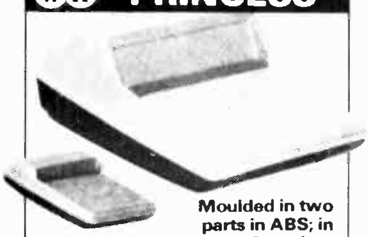
## WH PRINCESS



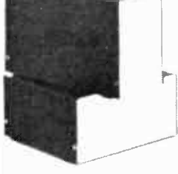
**Moulded in two parts in ABS; in four sizes**

1. The largest for keyboards displays etc.
2. Prestige display of data inputs, large calculators.
3. Still ample room for keyboard and visual display or meters.
4. Elegant hand held keyboards take a Eurocard.

**Colour: black case base and either a black or tan top.**

| | | | |
|---|---|---|---|
| PR1 | £16.50 | PR2 | £12.90 |
| PR3 | £7.00 | PR4 | £3.90 |

## WH SAMOS



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Equipment can be assembled in the lower half, which is flanged for rigidity, completed, tested then the top cover is sprung into place.

Moulded plug in feet included.

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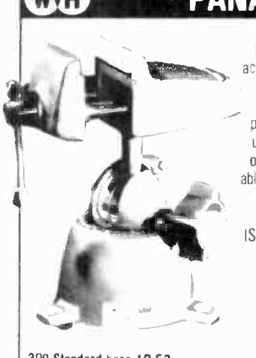
| S2 | 100 | 100 | 50 | 1.56 | S6 | 150 | 125 | 75 | 2.63 |
| S3 | 150 | 100 | 50 | 1.74 | S7 | 200 | 125 | 75 | 2.92 |
| S4 | 50 | 125 | 75 | 1.96 | | | | | |

## WH PANAVICE



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| 7480 | 0.45 | 74174 | 0.89 | 74LS73 | 0.30 | 74LS298 | 1.60 | 4067 | 3.50 | | |
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| 7482 | 0.80 | 74176 | 0.88 | 74LS75 | 0.45 | 74LS353 | 1.05 | 4069 | 0.17 | | |
| 7483 | 0.72 | 74177 | 0.88 | 74LS76 | 0.32 | 74LS365 | 0.50 | 4070 | 0.17 | | |
| 7484 | 0.90 | 74178 | 1.20 | 74LS78 | 0.32 | 74LS366 | 0.50 | 4071 | 0.17 | | |
| 7485 | 0.88 | 74179 | 1.10 | 74LS83 | 0.78 | 74LS367 | 0.50 | 4072 | 0.17 | | |
| 7486 | 0.26 | 74180 | 0.90 | 74LS85 | 0.90 | 74LS368 | 0.50 | 4073 | 0.17 | | |
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| 7493 | 0.40 | 74186 | 7.20 | 74LS109 | 0.36 | 4002 | 0.16 | 4081 | 0.17 | | |
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The unit is designed to decode not only UHJ but virtually all other 'quadrophonic' systems (Not CD4), including the new BBC HJ 10 input selections.
The decoder is linear throughout and does not rely on listener fatiguing logic enhancement techniques. Both 2 or 3 input signals and 4 or 6 output signals are provided in this most versatile unit. Complete with mains power supply, wooden cabinet, panel, knobs, etc.

Complete kit, including licence fee **£45.00** + VAT
or ready built and tested **£61.50** + VAT

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# INTRUDER 1 RADAR ALARM

**With Home Office Type approval**

As in "Wireless World", designed by Mike Hosking, 240V ac mains operated and disguised as a hardbacked book. Detection range up to 30 feet.

Complete exclusive designer approved kit **£46.00** + VAT
or ready built and tested, **£54.00** + VAT

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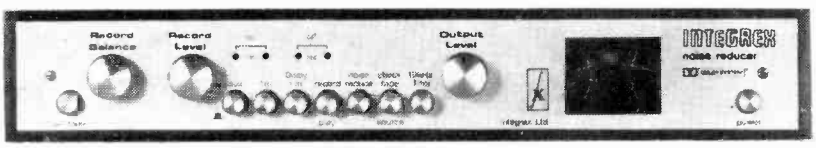
# *Wireless World* Dolby(TM) noise reducer

*Trademark of Dolby Laboratories Inc.*




**Typical performance**

Noise reduction better than 9dB weighted.
Clipping level 16.5dB above Dolby level (measured at 1% third harmonic content)

Harmonic distortion 0.1% at Dolby level typically 0.05% over most of band, rising to a maximum of 0.12%

Signal-to-noise ratio: 75dB (20Hz to 20kHz, signal at Dolby level) at Monitor output

Dynamic Range >90db

30mV sensitivity.

Featuring:

- switching for both encoding (low-level h.f. compression) and decoding
- a switchable f.m. stereo multiplex and bias filter.
- provision for decoding Dolby f.m. radio transmissions (as in USA).
- no equipment needed for alignment.
- suitability for both open-reel and cassette tape machines.
- check tape switch for encoded monitoring in three-head machines.

Complete Kit **PRICE: £39.90** + VAT

Also available ready built and tested .......... **Price £54.00** + VAT

Calibration tapes are available for open-reel use and for cassette (specify which) .......... **Price £2.20** + VAT *

Single channel plug-in Dolby(TM) PROCESSOR BOARDS (92 x 87mm) with gold plated contacts are available with all components .......... **Price £8.20** + VAT

Single channel board with selected fet .......... **Price £2.50** + VAT

Gold Plated edge connector .......... **Price £1.50** + VAT *

Selected FETs **60p** each + VAT, **100p** + VAT for two, **£1.90** + VAT for four

Please add VAT @ 12½% unless marked thus*, when 8% applies (or current rates)

We guarantee full after-sales technical and servicing facilities on all our kits, have you checked that these services are available from other suppliers?

*Please send SAE for complete lists and specifications*

# INTEGREX LTD.

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

# INTEGREX

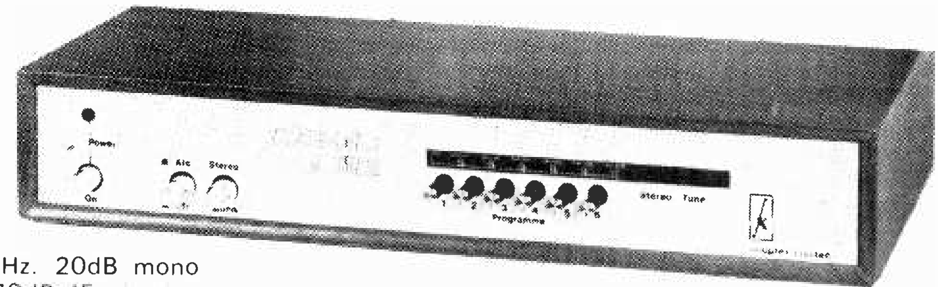
## S-2020TA STEREO TUNER/AMPLIFIER KIT

SOLID MAHOGANY CABINET


***A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.***

**Brief Spec.** Amplifier Low field Toroidal transformer, Mag, input, Tape In/Out facility (for noise reduction unit, etc.), THD less than 0.1% at 20W into 8 ohms. Power on/off FET transient protection. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section uses 3302 FET module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.2μV. THD 0.3%. Pre-decoder 'birdy' filter. **PRICE: £58.95**+VAT

## NELSON-JONES MK. I STEREO FM TUNER KIT



***A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.***

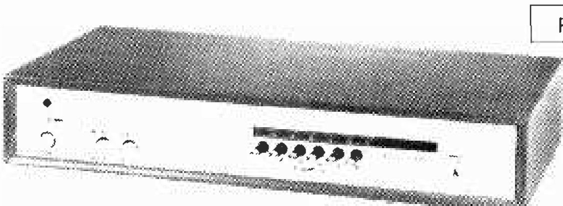
**Brief Spec.** Tuning range 88—104MHz. 20dB mono quieting @ 0.75μV. Image rejection — 70dB. IF rejection — 85dB. THD typically 0.4%.
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.

*Compare this spec. with tuners costing twice the price.*

**Mono £32.40**+VAT
**With ICPL Decoder £36.67**+VAT
**With Portus-Haywood Decoder £39.20**+VAT

Please send for details of the Nelson-Jones Mk. II Kit as in this month's W.W.

## STEREO MODULE TUNER KIT



***A low-cost Stereo Tuner based on the 3302 FET RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC Variable INTERSTATION MUTE. PLL stereo decoder IC. Pre-decoder 'birdy' filter Push-button tuning***

Sens. 30dB S/N mono @ 1.2μV
THD typically 0.3%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

**PRICE: Stereo £31.95**+VAT

## S-2020A AMPLIFIER KIT

***Developed in our laboratories from the highly successful "TEXAN" design. PC mounting potentiometers, switches, sockets and fuses are used for ease of assembly and to minimize wiring Power 'on/off' FET transient protection.***

**Typ Spec.** 24+24W r.m.s. into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

**PRICE: £33.95**+VAT

**ALL THE ABOVE KITS ARE SUPPLIED COMPLETE WITH ALL METALWORK, SOCKETS, FUSES, NUTS AND BOLTS, KNOBS, FRONT PANELS, SOLID MAHOGANY CABINETS AND COMPREHENSIVE INSTRUCTIONS**

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| **BASIC NELSON-JONES TUNER KIT** | £14.28+VAT | **PHASE-LOCKED IC DECODER KIT** | £4.47+VAT |
| **BASIC MODULE TUNER KIT (stereo)** | £16.75+VAT | **PUSH-BUTTON UNIT** | £5.00+VAT |

**PORTUS-HAYWOOD PHASE-LOCKED STEREO DECODER KIT** ..................... £8.00+VAT

**TRANSISTORISED 3cm RADAR AMPLIFIER SWITCH:** with 24v waveguide switch, .9 x .4cm ins. with crystal CV.2355 and spark gap VX.1046. **£16.20** + £1.00 post.

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**RACAL RA-17 RECEIVER** 500KHz—30mHz, s/hand, good condition, **£365.00** (including VAT 12½%).

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**CRYSTAL TEST SET TYPE 193:** Used for checking crystals in freq. range 3,000-10,000kHz. Mains 230v 50hz. Measures crystal current under oscillatory conditions and the equivalent resistance. Crystal freq. can be tested in conjunction with a freq. meter. **£27.00,** carr. £2.00.
**ELECTROLYTIC CAPACITOR REFORMING UNIT NO. 1.** 230v a.c. input 0-100mfd 6 to 450 volts in 10 ranges complete with leads and plus. **£15.00.** Carriage £3.00.
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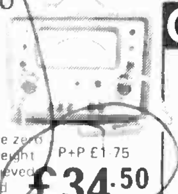

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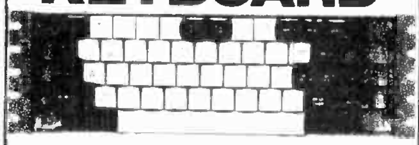

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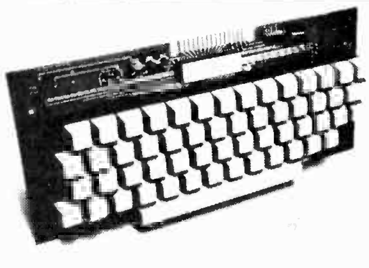

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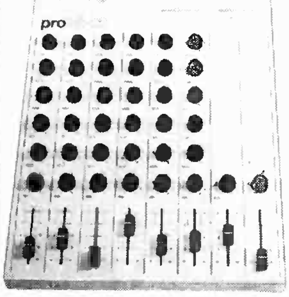


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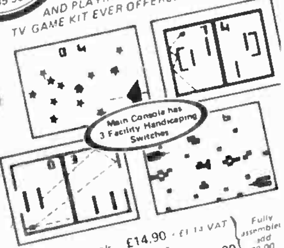


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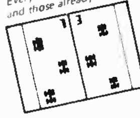


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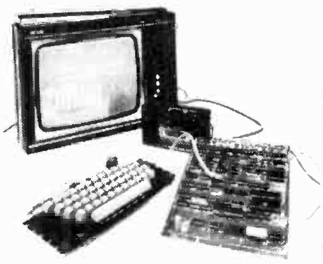

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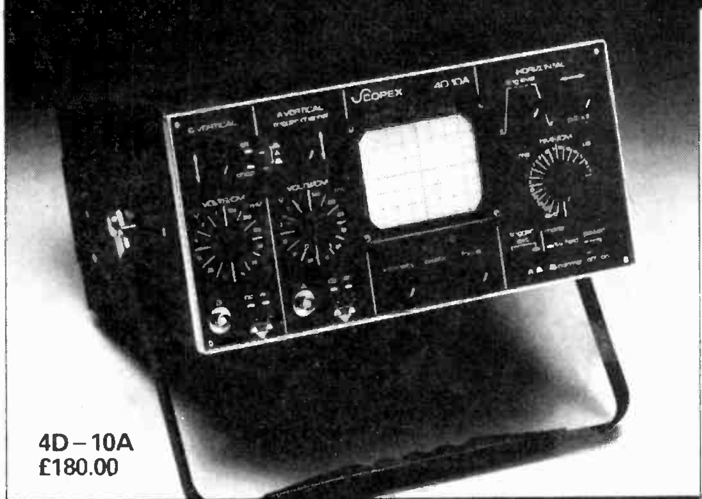


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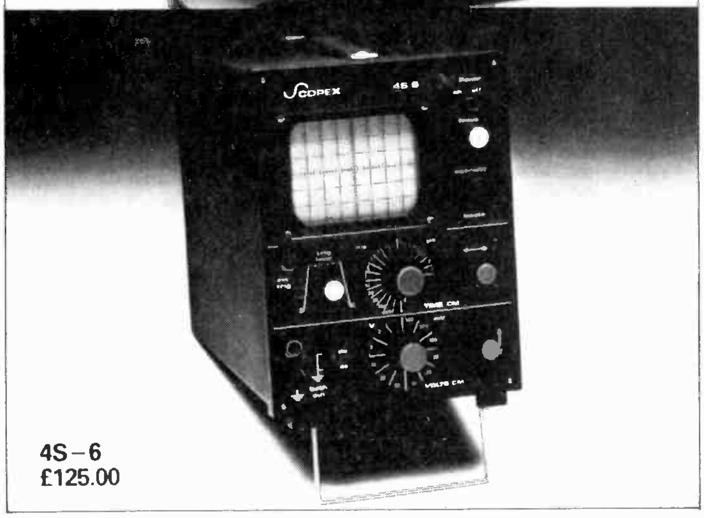


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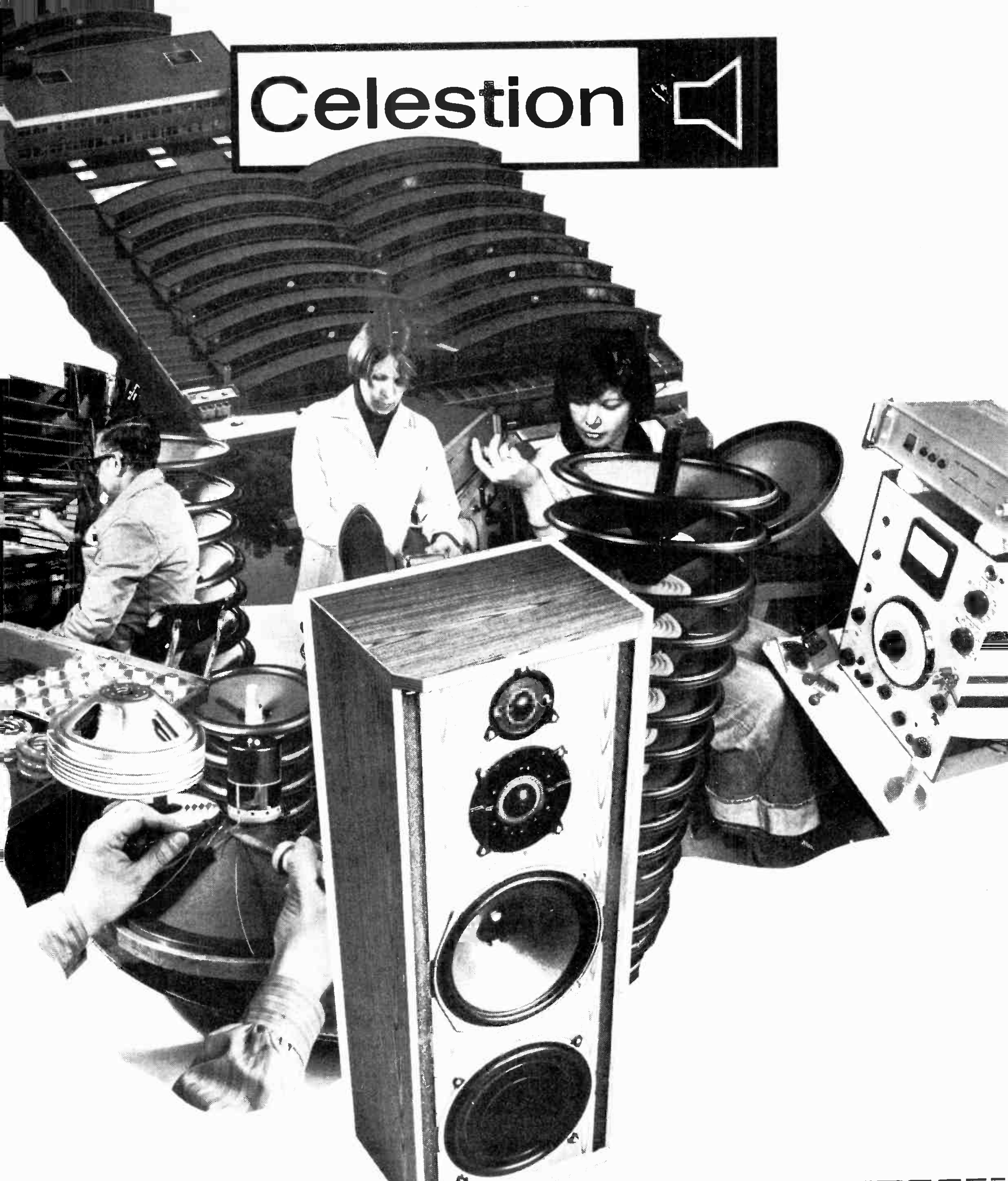
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No 1 20v 3A **£3** pp 75p. No 2 27v 1A **£1.50** pp 50p. No 3 12v 1½A and 24v ½A. 2 separate windings **£1.50** pp 50p. No 4 12v 1A **£1** pp 50p. No 5 20v 1A **£1.50** pp 50p. No 6 55v ½A and 6.3v ½A **£1.50** pp 50p. No 7 24v 1A shrouded type **£1.50** pp 50p. No 8 13v 3A and 15v 1A 2 separate windings 'C' core type **£3.50** pp £1. No 9 15v 1.2A 6.3v 4.5A 250v 80M/A. 3 separate windings **£3.50** pp £1. No 10 27v 1.8A 9v 1.8A 3v 1.8A 3 separate windings **£3.50** pp £1. No 11 13-0-13v 1A **£2.50** pp 50p.

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| MFD | Volts | Price |
|---|---|---|
| Q25 | 1500vAC | **50p** |
| Q75 | 440vAC | **50p** |
| 1 | 470vAC | **60p** |
| 1.25 | 360vAC | **65p** |
| 2 | 400vC | **75p** |
| 2.4 | 360vAC | **75p** |
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| 2.7+0.1 | 700vAC | **£1.25** |
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| 3.5 | 250vAC | **£1.00** |
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| 15 | 250vAC | **£1.75** |

PP up to 2.5MFD **25p,** 2.7 to 15MFD **50p** + 8% on total

**STANDARD PLUG-IN RELAYS 7 AMP CONTACTS BY FAMOUS MAKERS WELL BELOW LIST PRICE**

| COIL VOLTAGE | CONTACTS | PINS | PRICE |
|---|---|---|---|
| 110v AC | 2 CO | 8 | **65p** |
| 100v AC | 2 CO | 8 | **65p** |
| 48v AC | 2 CO | 8 | **50p** |
| 30v DC | 2 CO | 8 | **75p** |
| 24v DC | 3 CO | 11 | **85p** |
| 24v DC | 2 CO | 8 | **85p** |
| 24v DC | 1 CO | 8 | **65p** |
| 12v AC | 3 CO | 11 | **95p** |
| 12v AC | 2 CO | 8 | **85p** |
| 12v DC | 3 CO | 11 | **95p** |
| 10v DC | 3 CO | 11 | **95p** |

**STANDARD OPEN TYPE 7 AMP CONTACTS**

| COIL VOLTAGE | CONTACT | PRICE |
|---|---|---|
| 240v AC | 3 CO | **85p** |
| 240v AC | 2 CO | **75p** |
| 240v AC | 1 CO | **65p** |
| 110v AC | 3 CO | **65p** |
| 110v AC | 2 CO | **65p** |
| 50v AC | 3 CO | **65p** |
| 48v DC | 3 CO | **50p** |
| 24v DC | 2 CO | **75p** |
| 12v DC | 2 CO | **75p** |
| 10v DC | 3 CO | **85p** |

PP 10p per relay. Please add VAT 8% on total.

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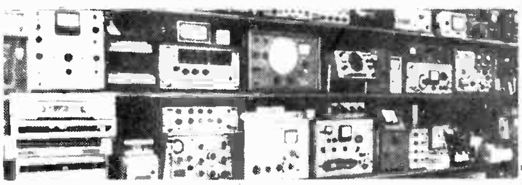

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| ECH81 | 0.45 |
| ECH84 | 0.95 |
| ECL80 | 0.60 |
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| ECL83 | 1.20 |
| ECL85 | 0.65 |
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| EF41 | 0.75 |
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| EF83 | 1.50 |
| EF85 | 0.45 |
| EF86 | 0.55 |
| EF91 | 0.65 |
| EF92 | 0.75 |
| EF95 | 0.45 |
| EF183 | 0.65 |
| EF184 | 1.60 |
| EFB04 | 2.00 |
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| EH90 | 0.60 |
| EL32 | 0.60 |
| EL34 | 2.20 |
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| | |
|---|---|
| EL81 | 1.05 |
| EL82 | 0.80 |
| EL84 | 0.60 |
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| EL91 | 1.60 |
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| EM81 | 0.60 |
| EM84 | 0.40 |
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| EY81 | 0.45 |
| EY86/87 | 0.55 |
| EY38 | 0.55 |
| EZ80 | 0.45 |
| EZ81 | 0.60 |
| GY501 | 0.90 |
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| GZ34 | 2.00 |
| GZ37 | 2.50 |
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| OB2 | 0.60 |
| PABC80 | 0.40 |
| PC85 | 0.50 |
| PC86 | 0.85 |
| PC88 | 0.75 |
| PC900 | 1.25 |
| PCC84 | 0.45 |
| PCC89 | 0.55 |
| PCC189 | 0.65 |
| PCF80 | 0.80 |
| PCF82 | 0.40 |
| PCF84 | 0.65 |
| PCF86 | 0.65 |
| PCF200 | 0.90 |
| PCF201 | 0.90 |
| PCF801 | 0.55 |
| PCF802 | 0.65 |
| PCF805 | 1.80 |
| PCF806 | 0.85 |
| PCF808 | 1.80 |
| PCH200 | 0.80 |
| PCL81 | 0.60 |
| PCL82 | 0.65 |
| PCL84 | 0.70 |
| PCL86 | 0.70 |
| PCL805/85 | 0.75 |
| PD500 | 2.25 |
| PFL200 | 1.35 |
| PL36 | 0.80 |
| PL81 | 0.75 |
| PL82 | 0.50 |
| PL83 | 0.50 |
| PL84 | 0.50 |
| PL504 | 1.40 |
| PL508 | 1.30 |
| PL509 | 2.40 |
| PL802 | 2.80 |
| PL80 | 1.80 |

| | |
|---|---|
| PY33 | 0.60 |
| PY80 | 0.60 |
| PYB1/800 | 0.55 |
| PY82 | 0.45 |
| PY83 | 0.50 |
| PY88 | 0.65 |
| PY500 | 1.35 |
| PY859 | 5.75 |
| PY801 | 0.60 |
| QQV03-10 | 2.50 |
| QQV03-12 | 2.50 |
| QQV06-40A | 14.00 |
| QV03-12 | 2.00 |
| SC1/400 | 4.00 |
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| SP61 | 0.85 |
| TT21 | 7.50 |
| U25 | 1.00 |
| U26 | 0.85 |
| U27 | 1.00 |
| U191 | 0.75 |
| U281 | 0.50 |
| U301 | 0.50 |
| U801 | 0.80 |
| UABC80 | 0.80 |
| UAF42 | 0.65 |
| UBF80 | 0.55 |
| UBF89 | 0.50 |
| UBL1 | 1.00 |
| UBL21 | 0.75 |
| UCC84 | 0.80 |
| UCC85 | 0.60 |
| UCF80 | 0.80 |
| UCH81 | 0.60 |
| UCL82 | 0.75 |
| UF41 | 0.80 |
| UF80 | 0.45 |
| UF85 | 0.40 |
| UL41 | 0.75 |
| UL84 | 0.75 |
| UM80 | 0.60 |
| UM84 | 0.40 |
| UY82 | 0.55 |
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| VR105/30 | 1.80 |
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| 1U4 | 0.60 |
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| 5V4G | 0.65 |
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| 5Z4G | 0.70 |
| 5Z4GT | 0.75 |
| 6AB7 | 0.60 |
| 6AC7 | 0.60 |
| 6AH6 | 0.70 |
| 6AK5 | 0.55 |
| 6AK8 | 0.40 |
| 6AL5 | 0.40 |
| 6AL5D | 0.65 |
| 6AM5 | 1.60 |
| 6AM6 | 0.65 |
| 6AN8 | 0.85 |
| 6AQ5 | 1.30 |
| 6AQ5W | 0.85 |
| 6AS6 | 0.60 |
| 6AT6 | 0.75 |
| 6AU6 | 0.40 |
| 6AV6 | 0.50 |
| 6AX4GT | 0.80 |
| 6AX5GT | 1.00 |
| 6B7 | 0.75 |
| 6BA6 | 0.40 |
| 6BE6 | 0.50 |
| 6BG6G | 1.00 |
| 6BJ6 | 1.10 |
| 6BQ7A | 0.60 |
| 6BR7 | 2.30 |
| 6BW6 | 2.80 |
| 6BW7 | 1.00 |
| 6C4 | 0.40 |
| 6C6 | 0.55 |
| 6CH6 | 3.00 |
| 6CL6 | 0.75 |
| 6CY5 | 0.90 |
| 6D6 | 0.50 |
| 6EA8 | 0.80 |
| 6F6GB | 0.90 |
| 6F8G | 0.75 |
| 6F12 | 0.65 |
| 6F14 | 0.80 |
| 6F15 | 0.60 |
| 6F17 | 1.00 |
| 6F24 | 0.90 |
| 6F33 | 4.20 |
| 6M6 | 4.20 |
| 6J4WA | 1.75 |
| 6J5 | 0.75 |
| 6J5GT | 0.55 |
| 6J6 | 0.50 |
| 6J7 | 0.75 |
| 6J7G | 0.50 |
| 6K7 | 0.70 |
| 6K7G | 0.35 |
| 6K8GT | 0.55 |

| | |
|---|---|
| 6L6M | 1.90 |
| 6L6GT | 0.90 |
| 6L7G | 0.65 |
| 6L18 | 0.60 |
| 6LD20 | 0.50 |
| 6Q7G | 0.70 |
| 6SA7 | 0.55 |
| 6SG7 | 0.75 |
| 6SJ7 | 0.70 |
| 6SJ7GT | 0.50 |
| 6SK7 | 0.60 |
| 6SL7GT | 0.75 |
| 6SN7GT | 0.75 |
| 6SQ7 | 0.75 |
| 6V6GT | 0.75 |
| 6X4 | 0.60 |
| 6X5GT | 0.55 |
| 6Y6G | 0.95 |
| 6Z4 | 0.65 |
| 6-30L2 | 0.90 |
| 7B7 | 0.80 |
| 7V4 | 0.80 |
| 9D2 | 0.60 |
| 9D6 | 0.75 |
| 10C2 | 0.60 |
| 10F18 | 0.60 |
| 10P13 | 0.60 |
| 11E2 | 11.00 |
| 12A6 | 0.60 |
| 12AT6 | 0.45 |
| 12AT7 | 0.55 |
| 12AU7 | 0.50 |
| 12AV6 | 0.70 |
| 12AX7 | 0.60 |
| 12BA6 | 0.50 |
| 12BE6 | 0.60 |
| 12BM7 | 0.60 |
| 12C8 | 0.55 |
| 12E1 | 4.25 |
| 1215GT | 0.40 |
| 12K7GT | 0.60 |
| 12KBGT | 0.70 |
| 12Q7GT | 0.70 |
| 12SC7 | 0.55 |
| 12SH7 | 0.70 |
| 12SJ7 | 0.55 |
| 12SQ7 | 0.55 |
| 12Y4 | 0.40 |
| 13D6 | 0.60 |
| 14S7 | 1.00 |
| 19AQ5 | 0.75 |
| 19G3 | 10.00 |
| 19G6 | 6.00 |
| 19H5 | 17.00 |
| 20D1 | 0.60 |
| 20F2 | 0.60 |
| 20L1 | 1.00 |
| 20P1 | 0.40 |
| 20P3 | 0.80 |
| 20P4 | 1.10 |
| 20P5 | 1.00 |

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|---|---|
| 25L6GT | 0.80 |
| 25Z4G | 0.70 |
| 30C15 | 1.00 |
| 30C17 | 1.10 |
| 30C18 | see PCF805 |
| 30F5 | 1.00 |
| 30F12 | 1.20 |
| 30FL12 | 1.20 |
| 30FL14 | 1.00 |
| 30L15 | 1.00 |
| 30L17 | 1.00 |
| 30P12 | 1.00 |
| 30PL1 | 1.00 |
| 30PL13 | 1.10 |
| 30PL14 | 1.10 |
| 35L6GT | 0.80 |
| 35W4 | 0.60 |
| 35Z4GT | 0.70 |
| 50C5 | 0.70 |
| 50CD6G | 1.20 |
| 75 | 1.00 |
| 75C1 | 0.80 |
| 76 | 0.80 |
| 78 | 0.75 |
| 80 | 0.75 |
| 85A2 | 2.20 |
| 723A/B | 11.00 |
| 803 | 6.00 |
| 805 | 18.00 |
| 807 | 1.00 |
| 813 | 10.60 |
| 829B | 11.00 |
| 832A | 4.60 |
| 866A | 2.80 |
| 931A | 6.00 |
| 954 | 0.50 |
| 955 | 0.50 |
| 956 | 0.60 |
| 957 | 0.90 |
| 1625 | 1.00 |
| 1629 | 0.70 |
| 2051 | 1.00 |
| 5763 | 2.00 |
| 5842 | 5.50 |
| 5933 | 3.00 |
| 6057 | 0.85 |
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| 6064 | 0.85 |
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**10 CORE CABLE** 10 x 7/76 (10 colours) P.V.C.
O.D. 7m.m. 10m—£2. 50m—£8.50. 100m—£16. P&P 2p per metre.
**12 CORE SCREENED CABLE** 12 x 14/76 with outer screen—P.V.C. covered. O.D. 9m.m.
10m—£4. 50m—£18.50. 100m—£35. P&P 2p per metre.
**16 PAIR RIBBON CABLE** 16x2 core P.V.C.
Double sheathed forming 2in wide strip.
10m—£3; 50m—£13.50; 100m—£25. P&P 2p per metre.
**200 way TELEPHONE CABLE** o.d. 12m.m. £1 per metre. P.P. 40p
**E.H.T. MODULES** (resin encapsulated, in metal box)
i/p 240x.50hz. o/p 13.7 kv. @ 7 watts (150x95x72m.m.) £10 P.P. £1
**STABILISED POWER SUPPLIES** input 120/240v. 50hz
5-14 volts @ 6amp (pre-set) with manual £20 P.P. £2
12-17 volts @ 6amp. variable £20 P.P. £2
**P.C. EDGE CONNECTORS**
32 way (.1 pitch) finished end 49p P&P 10p
56 way (.1 pitch) cuttable 65p P&P 15p
64 way (.1 pitch) cuttable 75p P&P 15p
64 way gold plated pins 90p P&P 15p
Mounting pillars for 56/64 way 15p per pair.
**'DRYFIT' RE-CHARGEABLE BATTERIES** (Lead/Acid)
Ex. Equip. Good condition. tested.
6v @ .9 A.H. £1.25 P&P 35p
6v @ 2.6 A.H. £2.50 P&P 50p
6v @ 6 A.H. £3.50 P&P 75p
6v @ 7.5 A.H. £5.00 P&P 75p

## J. B. PATTRICK
**191/193 London Road**
**Romford, Essex RM7 9DJ**
**Romford 44473**

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**SINCLAIR PRODUCTS***
Microvision TV **£172.** PDM35 **£27.25,** mains adaptor **£3.24,** case **£3.25.** DM235 **£47.50.** Rechargeable battery units **£7.95.** Adaptor/charger **£3.70.** Case **£8.50.** Cambridge prog calculator **£13.15,** prog. library **£2.95,** mains adaptor **£3.20.** Enterprise programmable calculator **£20.95.**

**S-DECS AND T-DECS***
S-Dec **£3.39.** T-DeC **£4.44.** μ-DeCA **£4.52.** μ-DeCB **£6.73.** 16 dil adaptors **£2.14.**

**CONTINENTAL SPECIALITIES***
EXP300 **£6.21.** EXP350 **£3.40.** EXP600 **£6.80.** EXP650 **£3.89.** EXP4B **£2.48.** PB6 **£9.94.**

**TV GAMES**
Send s.a.e. for data. AY-3-8500 — chip **£4.95.** Kit **£4.** Tank battles — chip **£6.90.** Kit **£7.05.** Stunt cycle — chip **£6.90.** Kit **£5.60.** AY-3-8600 + kit **£12.50.** Rifle kit **£4.95.**

**MAINS TRANSFORMERS**
6-0-6V 100ma **79p.** 1½a **£2.35.** 6.3V 1½a **£1.89.** 9-0-9V 75ma **79p.** 1a **£1.99.** 2a **£2.60.** 12 0-12V 50ma **79p.** 100ma **90p.** 1a **£2.49.** 13V ½a **95p.**

**JC12; JC20 AND JC40 AMPLIFIERS**
A range of integrated circuit audio amplifiers supplied with free data and printed circuits. JC12 6 watts **£1.60.** JC20 10 watts **£2.95.** JC40 20 watts **£3.95.** Send s.a.e. for data.

**PRINTED CIRCUIT MATERIALS**
50 sq ins pcb **40p.** 1 lb FeC1 **£1.05.** Dalo pens **73p.** Laminate cutter **75p.** Small drill bit **20p.**

**BATTERY ELIMINATORS**
**3-way model** 6/7½/9V 300ma **£2.95.** **100ma radio models** with press stud connectors, 9V **£3.35,** 6V **£3.35,** 9V + 9V **£4.50,** 6V + 6V **£4.50.**

**BATTERY ELIMINATOR KITS**
Send sae for data. **100ma radio types** with press stud connectors. 4½V **£1.80,** 6V **£1.80,** 9V **£1.80,** 4½ + 4½V **£2.50,** 6 + 6V **£4.50,** 9 + 9V **£4.50.** **Stabilized 8-way types** 3/4½/6/7½/9/12/15/18V 100ma **£3.20,** 1 Amp **£6.40.** **Stabilised power kits** 2-18V 100ma **£3.60,** 2-30V 1A **£6.95,** 2-30V 2A **£10.95.** **Car converter** input 12V dc output 6/7½/9V 1A stabilized **£1.95.**

**BI-PAK AUDIO MODULES**
S450 tuner **£23.51.** AL60 **£4.86.** PA100 **£16.71.** SPM80 **£4.47.** BMT80 **£5.95.** Stereo 30 **£20.12.**

**COMPONENTS**
Send for full list. 1N4148 **1.4p.** 741 **15p.** Plastic equivs BC107, BC109, BCY72 **4.7p.** BCY71 **4.9p.** ¼w resistors E12 10R to 10M **0.9p.** 16V electrolytics **.47,** 1, 2, 5, 10, 22mf **5p.** 100mf **6p,** 1000mf **10p.** Polyesters 250V 015, .068, .1mf **1½p.** Ceramics 50V E6 22pf to 33n **1.7p.** Polystyrenes 63V E12 15pf to 10n **2.5p.** Zeners 400MW E24 2V7 to 33V **6.1p** presets 0.1W 100 to 4M7 **6.8p.**

## SWANLEY ELECTRONICS
**DEPT. WW, 32 Goldsel Road, Swanley, Kent.**
Mail order only. Postage 30p extra. Prices include VAT. Official credit orders welcome.

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## STEREO DISC AMPLIFIER 2

FOR BROADCASTING, DISC MONITORING AND TRANSFER WITH THE HIGHEST QUALITY. Stereo Disc Amplifier 2 is a self-contained mains powered unit which accepts cartridge inputs and produces balanced line level outputs. Permanent rumble filtering and switched scratch filtering are included.

1KHz @ 6mV set for 0dBV.7 output, loaded 600 ohms.

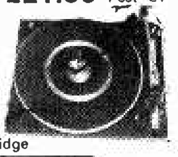
**Total Harmonic Distortion**
Output + 10dBV.7 — 30 Hz — 20KHz below noise.
Output + 20dBV.7 — 1KHz—88dB, 0.004%, 30Hz-20KHz—82dB, 0.008%
**Static Intermodulation Distortion** 50Hz + 7KHz, 4:1
Output + 10dBV.7 — −90dB, 0.003% limit of measurement;
**Dynamic Intermodulation Distortion** 3.18KHz square wave (single pole −3dB @ 100KHz) + 15KHz sine wave, 4:1. Relative to 15KHz component
Pre-emphasised input 1V pk-pk — −70dB, 0.03% limit of measurement
**Cartridge impedance interaction on frequency response.**
High inductance cartridge, 1H — Less than 0.2dB
**Clipping Point Complementary to RIAA Curve,** 1KHz clips at + 24dBV.7 output
30Hz-20KHz — Within 1dB
Clipping determined by onset of peaky distortion products or THD exceeding −80dB
**Differential Phase Shift between left and right channels**
50Hz-20KHz — Within 0.5
Worst error at LF and HF filter turnovers. — Within 5
**Crosstalk** — 1KHz — 76dB, 30Hz-20KHz, — 60dB

## SURREY ELECTRONICS
**The Forge, Lucks Green, Cranleigh, Surrey GU6 7BG (STD 04866) 5997**

**WW—090 FOR FURTHER DETAILS**

# U.K. RETURN OF POST MAIL ORDER SERVICE, ALSO WORLDWIDE EXPORT SERVICE

## BSR HI-FI AUTOCHANGER
**STEREO AND MONO £21.50** Post £1



Plays 12, 10 or 7 records Auto or Manual. A high quality unit backed by BSR reliability with 12 months' guarantee. A.C 200/250V Size 13½-11¼in 3 speeds. Above motor board 3¾in Below motor board 2½in with Sonotone V100 magnetic cartridge

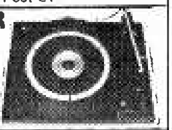
**NEW BSR SINGLE PLAYER £19.95**
Model P182 3-speeds flared aluminium turntable. Post £1 "S" shaped arm, cueing device, stereo ceramic cartridge

B.S.R. Budget Autochanger with stereo cartridge, plays all size records **£14.95**

## HEAVY METAL PLINTHS
With P.V.C. Cover. Cut out for most BSR or Garrard decks. Silver grey finish **£6.50** Post £1 50
Model "A" Size 12½ x 14¾ x 7½in
Model "B" Size 16 x 13¾ x 7in **£7.50**

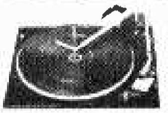
**TINTED PLASTIC COVERS ONLY**
Sizes 14½ x 12½ x 4¼in **£3.** 17½ x 14 x 4in **£4.50.** 16¼ x 14 x 4in. **£4.** 15¼ x 13½ x 4in. **£3.75.** 15 x 13½ x 3in. **£3.50.** 17¼ x 9½ x 3½in **£3.** 14½ x 14¾ x 2½in. Rosewood sides **£4.**
Ideal for record decks, tape decks, etc Post £1

## BSR SINGLE PLAYER



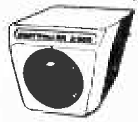
Ideal replacement or disco deck with cueing device and stereo ceramic cartridge 3 speeds Large turntable, modern design
**£17.50** Post £1

## GARRARD HI-FI AUTO CHANGER Model 2025



3-speed stereo cartridge Cueing devices **£14.95** Post £1

## SMITH'S CLOCKWORK 15 AMP TIME SWITCH



**0-6 HOURS £3.30** Post 35p
Single pole two-way Surface mounting with fixing screws. Will replace existing wall switch to give light for return home garage, automatic anti-burglar lights, etc Variable knob Turn on or off at full or intermediate settings. Brand new

## ELAC HI-FI SPEAKER 8in. TWIN CONE

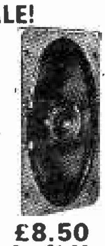

Large ceramic magnet 50-16,000 c/s Bass resonance 40 c/s
8 ohm impedance
10 watts. RMS. **£5.95** Post 35p

## VOLUME CONTROLS
5kΩ to 2MΩ LOG or LIN L/S **35p.** D P **60p.** STEREO L/S **85p.** D.P **£1.** Edge 5K S P. Transistor **45p.**

## 80 Ohm Coax 8p yd.
FRINGE LOW LOSS **15p** yd Ideal 625 and colour PLUGS **10p.** SOCKETS **10p.** LINE SOCKETS **18p.** OUTLET BOXES **50p.** 300 ohm FEEDER **5p** yd

## ELAC 9 × 5in HI-FI SPEAKER TYPE 59RM **£3.45**
Post 35p
This famous unit now available. 10 watts. 8 ohm

## E.M.I. 13½ x 8in. SPEAKER SALE!



With tweeter and crossover. 10 watt. 3 or 8 ohm **£7.95** Post 45p
Ditto 15 watts. 8 ohm **£10.50** Post 65p
With tweeter and crossover. 20 watt **£11.50** Post 75p
8 or 15 ohm 20 to 20,000 c.p.s Post 75p

**Suitable Bookshelf Cabinet £8.50**
Teak finish. For EMI 13 x 8 speakers. Post £1.00

**THE "INSTANT" BULK TAPE ERASER**

Suitable for cassettes, and all sizes of tape reels. A.C. mains 200/250V Leaflet S.A.E.
Will also demagnetise small tools **£4.95**
**Head Demagnetiser. Only £4.75** Post 50p

**RELAYS.** 12V D.C. **95p.** 6V D.C. **85p.** 240V A.C **95p.**
**BLANK ALUMINIUM CHASSIS.** 6 x 4—**95p;** 8 x 6—**£1.40;** 10 x 7—**£1.55;** 12 x 8—**£1.70;** 14 x 9—**£1.90;** 16 x 6—**£1.85;** 16 x 10—**£2.20. ANGLE ALI.** 6 x ¾ x ¾in—**15p.**
**ALUMINIUM PANELS.** 6 x 4—**24p;** 8 x 6—**38p;** 14 x 3—**40p;** 10 x 7—**54p;** 12 x 8—**70p;** 12 x 5—**44p;** 16 x 6—**70p;** 14 x 9—**94p;** 12 x 12—**£1;** 16 x 10—**£1.16.**
**ALI BOXES IN STOCK. MANY SIZES**
**VARICAP FM TUNER HEAD** with circuit & connections **£4.95.** Some technical knowledge required
**TAG STRIP** 28-way **12p.**
**TAPE OSCILLATOR COIL.** Valve type, **35p.**
**BRIDGE RECTIFIER** 200V PIV ½ amp **50p.** 8 amp **£2.50.**
**TOGGLE SWITCHES** S P **30p.** D.P.S.T. **40p.** D.P.D.T **50p.**
**MANY OTHER TOGGLES IN STOCK**
**PICK-UP CARTRIDGES** ACOS. GP91 **£1.50.** GP95 **£2.50.** SONOTONE stereo **£2.00. ADASTRA** magnetic **£6.**
**WIRE-WOUND RESISTORS** 5 watt, 10 watt, 15 watt **15p ea.**

## R.C.S. SOUND TO LIGHT KIT Mk. 2
Kit of parts to build a 3 channel sound to light unit 1,000 watts per channel. Suitable for home use. Easy to build Full instructions supplied. Cabinet **£4** extra. Will operate from 200MV to 100 watt signal. **£17** Post 35p

## R.C.S. LOW VOLTAGE STABILISED POWER PACK KITS
All parts and instructions with Zener diode, printed circuit rectifiers and double wound mains transformer. Input 200/240V a.c. Output voltages available, 6 or 7.5 or 9 or 12V d.c. up to 100mA or less. Size 3 x 2½ x 1½in. Please state voltage required. **£2.95** Post 45p

## R.C.S. POWER PACK KIT
12 VOLT, 750mA. Complete with printed circuit board and assembly instructions. **£3.35** Post 30p
12 VOLT 300mA KIT. **£3.15.**

## R.C.S. "MINOR" 10 watt AMPLIFIER KIT
This kit is suitable for record players, guitars, tape playback, electronic instruments or small P.A. systems. Two versions available Mono, **£12.50;** Stereo, **£20.** Post 45p. Specification 10W per channel; input 100mV; size 9½ x 3 x 2in. approx. S.A.E details. Full instructions supplied. A.C. mains powered.

**R.C.S. DRILL SPEED CONTROLLER/LIGHT DIMMER KIT.**
Easy to build kit **£3.25**
Will control up to 400 watts AC mains Post 35p

**R.C.S. STEREO PRE-AMP KIT.** All parts to build this pre-amp Inputs for high, medium or low imp per channel, with volume control and P.C. Board **£2.95**
Can be ganged to make multi-way stereo mixers Post 35p

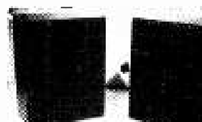
**MAINS TRANSFORMERS** ALL POST 75p

| | |
|---|---|
| 250-0-250V 70mA 6.5V, 2A | £3.45 |
| 250-0-250V 80mA 6 3V 3 5A, 6 3V 1A | £4.60 |
| 350-0 350V 80mA, 6 3V 3 5A, 6 3V 1A | £5.80 |
| 300-0-300V 120mA, 2×6 3V 2A C T, 5V 2A | £8.50 |
| 220V 45mA, 6 3V 2A | £1.75 |
| HEATED TRANS 6 3V ½ amp | £1.00 |
| Ditto 3 amp | £1.75 |
| GENERAL PURPOSE LOW VOLTAGE Tapped outputs | |
| 2 amp 3, 4, 5, 6 8, 9 10, 12, 15, 18, 25 and 30V | £5.30 |
| 1 amp 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 | £5.30 |
| 2 amp 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 | £8.50 |
| 3 amp 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 | £11.00 |
| 5 amp, 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 | £14.50 |

| | | | |
|---|---|---|---|
| 12V, 100mA | £1.00 | 20V, 40V, 60V 1 amp | £3.50 |
| 12V, 750mA | £1.30 | 12V, 300mA | £1.00 |
| 10-0-10V 2amp | £2.45 | 10V, 30V, 40V, 2 amp | £2.75 |
| 30V, 5 amp and 17V-0-17V, 2 amp | £3.45 | 40V 2 amp | £2.95 |
| | | 20V 1 amp | £2.20 |
| 0 5, 8 10, 16V, ½ amp | £1.95 | 20V-0-20V, 1 amp | £2.95 |
| 9V, 3 amp | £2.75 | 30V-0-30V, 2 amp | £7.00 |
| 25-0-25V 2 amp | £3.50 | 2 of 18V, 6 amp, each | £9.00 |
| 30V, 2 amp | £3.00 | 12-0-12V, 2 amp | £2.95 |
| 30V, 1½ amp | £2.75 | 9V, ¼ amp | £1.30 |

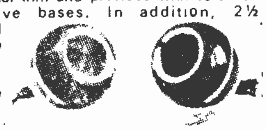
AUTO TRANSFORMERS, 115V to 230V or 230V to 115V 150W **£5.00**
250W **£6.00.** 400W **£7.00** 500W **£8.00**
FULL WAVE BRIDGE CHARGER RECTIFIERS
6 or 12V outputs 2 amp **75p.** 4 amp. **£1.25**
CHARGER TRANSFORMERS 1½ amp **£3.50**
4 amp **£6.80**
12V, 1½ amp Half Wave Selenium Rectifier **25p**

## COMPACT SPEAKERS



Teak or White
13 × 10 × 6in. approx.
50 to 14,000 cps.
10 watts rms. 4 or 8 ohms.
**£16 pair** Post £1.30

## EXTENSION SPEAKERS £3.95 ea.
Globe shaped cases in high gloss mouldings of red or green, are finished with chrome frontal trim and provided with screw-on rubber inset protective bases. In addition, 2½ metres of strong lead already fitted with phono plug is supplied.



Full Range
Frequency Response
Impedance 8 ohms
Power Peak 5 watts

**LOW VOLTAGE ELECTROLYTICS**
1, 2, 4, 5, 8, 16, 25, 30, 50, 100, 200mF 15V **10p.**
500mF 12V **15p;** 25V **20p;** 50V **30p;**
1000mF 12V **17p;** 25V **35p;** 50V **47p;** 100V **70p.**
2000mF 6V **25p;** 25V **42p;** 420mF/500V **£1.30.**
2500mF 50V **62p;** 3000mF 25V **47p;** 50V **65p.**
3900mF 100V **£1.60.** 4700mF 63V **£1.20.** 2700mF/76V **£1.**
5000mF 6V **25p;** 12V **42p;** 35V **85p.** 5600mF/76V **£1.75**

**HIGH VOLTAGE ELECTROLYTICS**

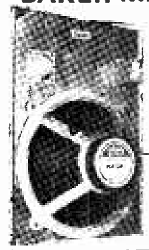
| | | | |
|---|---|---|---|
| 8/350V **22p** | 8+8/450V **50p** | 50+50/300V **50p** | |
| 16/350V **30p** | 8+16/450V **50p** | 32+32/450V **75p** | |
| 32/500V **75p** | 16+16/450V **50p** | 100+100/275V **65p** | |
| 50/350V **50p** | 32+32/350V **50p** | 150+200/275V **70p** | |

**MANY OTHER ELECTROLYTICS IN STOCK**

**SHORT WAVE** 100pF air spaced gangable tuner, **95p.**
**TRIMMERS** 10pF, 30pF, 50pF, **5p.** 100pF, 150pF, **15p.**
**CERAMIC,** 1pF to 0.01mF, **5p.** Silver Mica 2 to 5000pF, **5p.**
**PAPER** 350V-0.1 **7p;** 0 5 **13p;** 1mF 150V **20p;** 2mF 150V **20p;** 500V-0 001 to 0.05 **12p;** 0 1 **15p;** 0.25 **25p;** 0.47 **35p.**
**MICRO SWITCH SINGLE POLE CHANGEOVER 20p.**
**SUB-MIN MICRO SWITCH, 25p.** Single pole change over.
**TWIN GANG,** 385 + 385pF **50p;** 500pF standard **75p.** 365 + 365 + 25 + 25pF. Slow motion drive **65p.**
120pF **TWIN GANG, 50p;** 365pF **TWIN GANG, 50p.**
**NEON PANEL INDICATORS 250V.** Amber or red **30p.**
**RESISTORS.** 10Ω to 10M. ¼W, ½W, 1W, 20% **2p;** 2W, **10p.**
**HIGH STABILITY.** ½W 2% 10 ohms to 1 meg., **12p.**
Ditto 5%. Preferred values 10 ohms to 10 meg., **5p.**

## ELECTRO MAGNETIC PENDULUM MECHANISM 95p Post 30p.
1 5V d c operation over 300 hours continuous on SP2 battery, fully adjustable swing and speed. Ideal displays, teaching electro magnetism or for metronome, strobe, etc

## BAKER MAJOR 12" £16.88



Post £1.00
30-14,500 c/s, 12in. double cone woofer and tweeter cone together with a BAKER ceramic magnet assembly having a flux density of 14,000 gauss and a total flux of 145 000 Maxwells Bass resonance 40 c/s. Rated 25W. NOTE 4 or 8 or 16 ohms must be stated

Module kit. 30-17,000 c/s with tweeter, crossover baffle and instructions **£20.52** Post £1 60 each
Please state 4 or 8 or 16 ohms

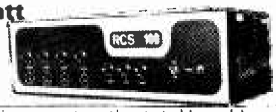
**BAKER "BIG-SOUND" SPEAKERS.** Post £1 each.

| 'Group 25' | 'Group 35' | 'Group 50/15' |
|---|---|---|
| 12in 30W **£12.96** | 12in. 40W **£15.12** | 15in 75W **£36.72** |
| 4 or 8 or 16 ohm | 4 or 8 or 16 ohm | 8 or 16 ohm |

**BAKER LOUDSPEAKER, 12 INCH. 60 WATT. GROUP 50/12,** 4 OR 8 OR 16 OHM HIGH POWER. FULL RANGE PROFESSIONAL QUALITY. RESPONSE 30-16,000 CPS MASSIVE CERAMIC MAGNET WITH ALUMINIUM PRESENCE CENTRE DOME. **£22.68** Post £1.60

**TEAK VENEERED HI-FI SPEAKERS AND CABINETS**
For 13x8in. or 8in. speaker **£8.50** Post £1
For 6½in. speaker and tweeter 12x8x6in. **£5.95** Post 75p
Many other cabinets in stock. Phone your requirements.
**SPEAKER COVERING MATERIALS.** Samples Large S.A.E.
**LOUDSPEAKER CABINET WADDING** 18in wide **20p** ft.

## R.C.S. 100 watt VALVE AMPLIFIER CHASSIS

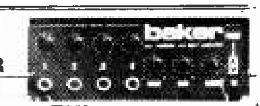



Four inputs. Four way mixing, master volume, treble and bass controls. Suits all speakers. This professional quality amplifier chassis is suitable for all groups, disco, P A., where high quality power is required. 5 speaker outputs. A/C mains operated. Slave output socket. Produced by demand for a quality valve amplifier. 100V line output to order. Send for leaflet.
Suitable carrying cab **£16.50** Price **£99** carr £6.00

Horn tweeters 2-16kc/s. 10W 8 ohm or 16 ohm **£3.60.**
Audax Tweeters 3-18kc/s. 50W 8 ohm **£7.50.**
**CROSSOVERS. TWO-WAY** 3000 c/s 3 or 8 or 15 ohm **£1.90.** 3-way 950 cps/3000 cps. **£2.20.**
**LOUDSPEAKERS P.M. 3 OHM** 7x4in. **£1.50;** 6½in., **£1.95;** 8x5in., **£1.90;** 8in., **£2.50.**
**SPECIAL OFFER:** 80 ohm, 2¼in., 2¾in., 35 ohm, 3in., 25 ohm, 2½in., 3in., 5x3in., 7x4in., 8 ohm, 2½in., 3in., 3½in., 5in., 15 ohm, 3½in. dia, 6x4in., 7x4in, 5x3in., 3 ohm., 2½in, 2¾in., 3½in., 5in. dia. **£1.50 each.**
**PHILIPS LOUDSPEAKER,** 8in., 4 ohms, 4 watts, **£1.95**
**RICHARD ALLAN TWIN CONE LOUDSPEAKERS**
8in. diameter 4W **£2.50.** 10in. diameter 5W **£2.95;** 12in. diameter 6W **£3.50.** 3/8/15 ohms, please state.
**MOTOROLA PIEZO ELECTRIC HORN TWEETER. £7.95**
Handles up to 100 watts. No crossover required.

**BLACK PLASTIC CONSTRUCTION BOX** with brushed aluminium facia. Sturdy job. Size 6¼ x 4¾ x 2in. **£1.50**

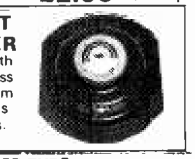
## BAKER 150 WATT PROFESSIONAL MIXER AMPLIFIER




All purpose transistorised
Ideal for Groups, Disco and P.A. 4 inputs speech and music. 4 way mixing. Output 4 8/16 ohms. A C Mains Separate treble and bass controls Master volume control
50 watt model **£59** **£85** £1 50 carr.

**LOW VOLTAGE POWER PACK for MODELS.**
Ready made. Famous make. Will supply 10 volts D.C. at 400mA. With terminals and mains lead. **£2.95** Post 50p

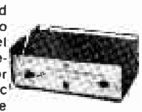
## GOODMANS COMPACT 12-INCH BASS WOOFER



Standard 12in. diameter fixing with cut sides 12 x 10. 14 000 Gauss magnet 20 watts R.M S. 4 ohm imp. Bass resonance = 30 c.p.s Frequency response 30-8000 c.p s.
**£9.95 each** Post £1

**ALUMINIUM HEAT SINKS. FINNED TYPE.**
Sizes 5 × 4 × 1 **95p.** 6½ × 2 × 2¼ **65p.**
**JACK PLUGS. Plastic 25p; Metal 30p.**
**JACK PLUGS Stereo Plastic 30p; Metal 35p.**
**JACK SOCKETS. Open 20p; Closed 25p.**
**JACK SOCKETS Stereo Open 25p; Closed 30p.**
**FREE SOCKETS — Cable end 30p.**
**2.5mm and 3.5mm JACK SOCKETS 15p.**
**2.5mm and 3.5mm JACK PLUGS 15p.**
**DIN TYPE CONNECTORS**
**Sockets 3-pin, 5-pin 10p. Free Sockets 3-pin, 5-pin 25p.**
**Plugs 3-pin 20p; 5-pin 25p.**
**PHONO PLUGS and SOCKETS ea. 10p.**
**Free Socket for cable end ea. 15p.**
**Screened Phono Plugs ea. 15p.**
**TV CONVERGENCE POTS 15p each**
Values = 5, 7, 10, 20, 50, 100, 200, 250, 470, 2000 ohms.

**MONO PRE-AMPLIFIER.** Mains operated solid state pre-amplifier unit designed to complement amplifiers without low level phono and tape input stages. This free-standing cabinet incorporates circuitry for automatic R.I.A.A equalisation on magnetic phono input and N.A B. equalisation for tape heads. **£4.50** Post 50p



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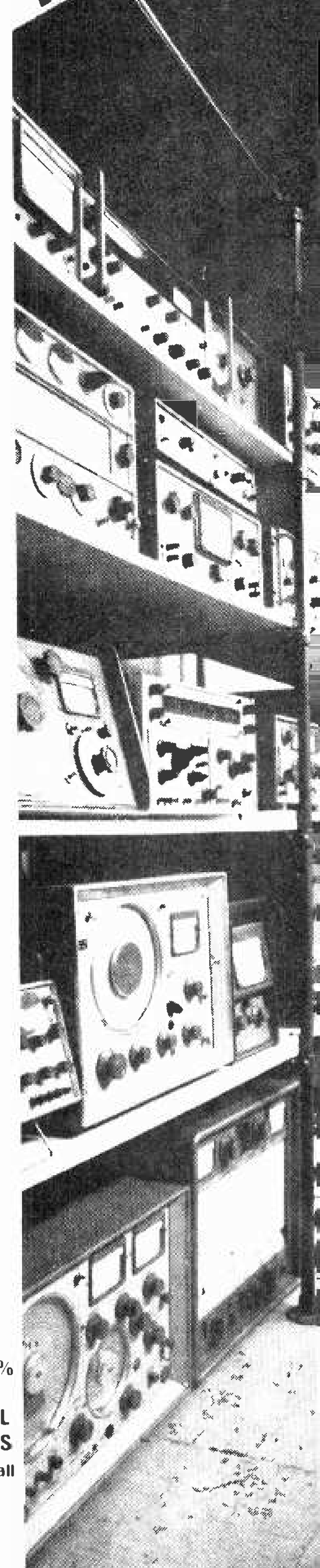
# Electronic Brokers Ltd

## The Test Equipment People

**Calibrated & Guaranteed 12 Months**



## AC Voltmeters & Electronic Multimeters

### ADVANCE
**VM77E Transistorised Voltmeter** 10Hz-6Mz 1mV-300V I/P Z 10M Ohms **£130.00**

### AIRMEC
**301A RF Valve Voltmeter** 100Hz-900MHz 300µV-300V **£330.00**

### BOONTON
**91H RF Valve Voltmeter** 20KHz-1200MHz. 100µV-300V **£415.00**

### BRADLEY
**112RF Millivoltmeter** 3mV-300mV 1-300MHz Battery operated **£375.00**

### BRUEL & KJAER
**2409 Electronic Voltmeter** 2Hz-200KHz 10mV-1000V True RMS **£245.00**

### HEWLETT PACKARD
**400F AC Voltmeter** 20Hz-4MHz 100µV-300V **£235.00**
**411A RF Millivoltmeter** 500KHz-1GHz 10mV-10V **£395.00**

### PHILIPS
**PM.2503 Electronic Multimeter** AC/DC Voltage and Current **£90.00**

### ROHDE & SCHWARZ
**U.R.V. RF Voltmeter** 1KHz-2400MHz with 50 Ohms insertion unit 20mV-10V **£235.00**

### SIGN
**AM324 AC Voltmeter** 15Hz-500Khz 1mV-300V **£60.00**

## Analogue Multimeters

### AVO
**Model 7** **£40.00**
**Model 8** **£55.00**
**Test Set No. 1** **£65.00**
**Precision Avo** **£45.00**
Leads, Prods, clips for Avo's **£4.95**

### PHILIPS
**PM 2412** AC/DC Volts & amps 40K Ohms/V **£60.00**

## Analysers

### BRUEL & KJAER
**2112 AF Spectrometer** 22Hz-45KHz **£650.00**

### HEWLETT PACKARD
**332A Distortion Analyser** 5Hz-600kHz 0.1%-100% also AM detector **£495.00**
**333A Distortion Analyser** 5Hz-600kHz 0.1%-100% also Auto Null **£515.00**

### RACAL
**409 Modulation Meter** 3-1500MHz AM & FM **£345.00**

### ROGERS/SIGN
**DM.344 Distortion Meter** 20Hz-20KHz **£230.00**

### TEKTRONIX
**1L5 Spectrum Analyser Plug In** 10Hz-1MHz **£850.00**
**1L10 Spectrum Analyser Plug In** 1-36MHz **£750.00**
**1L30 Spectrum Analyser Plug In** 925MHz-10.5GHz **£1200.00**
**1L40 Spectrum Analyser Plug In** 1.5-12.4GHz **£1275.00**

### T.E.S.
**D.566B Distortion Meter** 10Hz-1MHz 0.03 to 100% **£305.00**

### MARCONI INSTRUMENTS
**T.F. 791D Deviation Meter** 4-1024MHz Dev 10Hz-125KHz **£195.00**

## Attenuators

### GENERAL RADIO
**874 GA Variable Attentuator** 100MHz-4GHz 0.120dB 50 Ohms **£120.00**

### MARCONI INSTRUMENTS
**TF.1073A Series Step Attenuator** DC-100MHz 0-100dB 50 or 75 Ohms **£75.00**
**TF.2162 Step Attenuator** DC-1MHz 0-111dB 600 Ohms. **£120.00**

### ROHDE & SCHWARZ
**RBD Attenuator BN 33662/60** DC-600MHz. 20dB 60 Ohms **£40.00**
**DPR Step Attenuator BN 18042/60** DC-300MHz 0-100dB 60 Ohms **£90.00**

### ROHDE & SCHWARZ
**RBD UHF Attenuator BN33661/50** DC-2.4GHz. 10dB. 50 Ohms **£55.00**

## Bridges

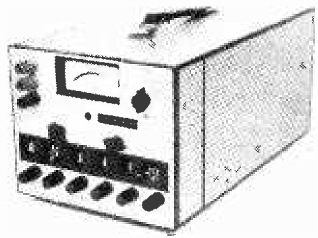
### MARCONI INSTRUMENTS
**TF.2701 In Situ Universal Bridge** **£395.00**
**TF.1245 'Q' Meter Supplied with TF.1246 Oscillator** 40KHz-50MHz **£625.00**

### WAYNE KERR
**B.221 (CT.530) Univ. Bridge** 0.1% accuracy **£275.00**
**Q.221 Low Impedance Adaptor** for use with B.221 **£75.00**
**B.521 (CT.375) Univ. Bridge** 1% accuracy **£120.00**

## Calibration Equipment

### HEWLETT PACKARD
**740B DC Voltage Source & Differential Voltmeter** **£850.00**
**741B DC Voltage Source & AC/DC Differential Voltmeter** **£975.00**

### FLUKE
**931B True RMS Differential Voltmeter** 10Hz-1MHz 0.01V-1100V **£1,050.00**
**883AB. AC/DC Differential Voltmeter** 1mV-1100V **£975.00**



### TEKTRONIX
**184 Time Mark Generator** **£275.00**
**191 Constant Amplitude Generator** **£375.00**
**2901 Time Mark Generator** **£400.00**
**2101 5nS Pulse Generator** **£525.00**

## Digital Counters

### ADVANCE
**TC.14 Frequency Counter** DC-250MHz 9 digit **£295.00**
**TC.15 + TC.15P1 Counter & Plug In** DC-500MHz 9 digit 10mV sensitivity **£495.00**
**TC.16 Frequency Counter** 5Hz-80MHz **£110.00**
**TC.17 or TC.17A Time Counter** Freq period Period Average. Pulse width count DC-80MHz **£195.00**
**TC.21 Time Counter** Freq Time. Period. Count Pulse width 2Hz-10MHz **£195.00**
**TC.22 Time Counter** DC-100MHz **£275.00**

### FLUKE
**1900A opt. 01** 5Hz-80MHz 25mV Sensitivity with battery option **£215.00**
**1941A Industrial Counter/Totaliser** 5Hz-40MHz **£120.00**
**1980A Communications Counter** 5Hz-515MHz 15mV sensitivity 6 digit. Battery operated **£295.00**

### PHILIPS
**PM.6612 Timer Counter** 10Hz-80MHz 9 digit display **£405.00**
**PM.6615 Timer Counter** 10Hz-1GHz 10mV sensitivity **£795.00**
**PM.6620 Timer Counter** DC-45MHz 50mV sensitivity **£395.00**
**PM.6625 Timer Counter** DC-1GHz Sensitivity 20mV LF I/P 10mV RF I/P 9 digit **£1,010.00**
**PM.6661 Frequency Counter** 10Hz-80MHz 20mV sensitivity 8 digit **£185.00**

### PHILIPS
**PM.6630A Timer Counter** DC-160MHz 8 digit Display **£600.00**
**PM.6645 Frequency Counter** 30Hz-512MHz 5mV sensitivity **£710.00**

### RACAL
**836 Timer Counter** DC-32MHz **£250.00**

A copy of our trading conditions is available on request

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**49-53 Pancras Road, London NW1 2QB**
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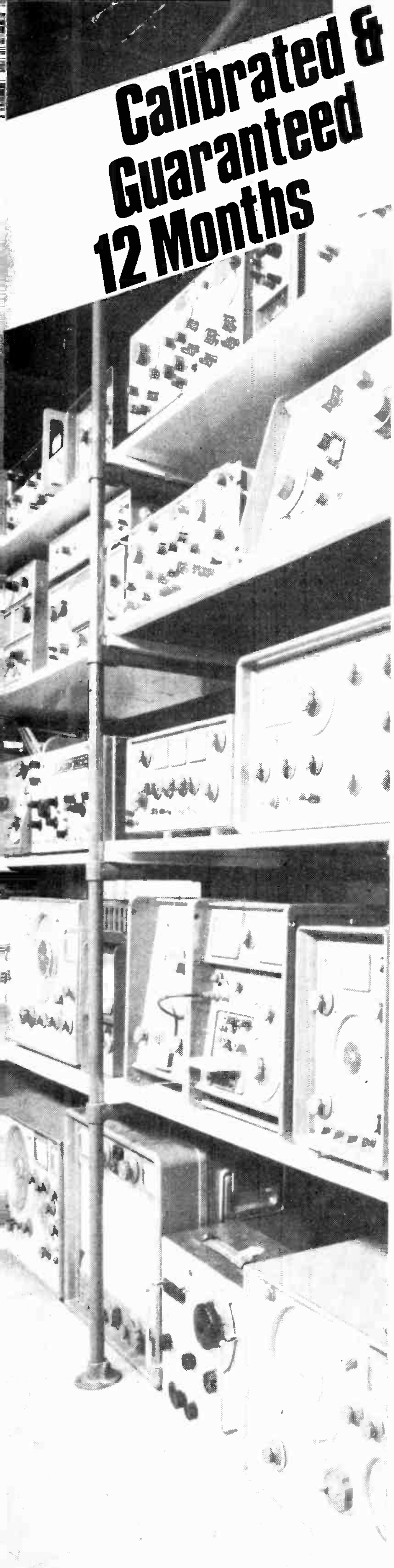



# Electronic

49-53 Pancras Road, London NW1 2QB
Tel: 01-837 7781

## Digital Voltmeters & Multimeters

### ADVANCE
**DMM2 Digital Multimeter** 3½ digit £95.00
**DRM6 True R.M.S. DVM** 4½ digit, scale 1999, 10mV-1KV 10μV resolution Frequency range DC-1MHz £295.00

### HEWLETT PACKARD
**3490A DM** 5½ digit, scale length 120000 AC Volts 1V-1kV 10μV resolution. DC Volts 100mV-1kV, 1μV resolution. Resistance 100 Ohms-10M Ohms, 1M Ohms resolution. Full auto-ranging and variable sample rate. Self check facility £595.00
**34702A DMM C/W 34740A Display** 4½ digit AC/DC & Ohms £295.00

### PHILIPS
**PM2424 DMM** 4 digit £300.00
**PM.2443 DC DVM** 4½ digit, scale length 19999 £430.00
**PM2513 D.M.M. 3½ digit** £90.00
**PM.2513A DMM** 3½ digit, scale length 1999 £95.00
**PM.2522 DMM** 3½ digit £175.00

### S.E. LABORATORIES
**SM210 DC DVM** 4 digit, scale length 9999 100mV-1kV 10μV resolution £365.00
**SM214 AC-DC DVM** 5½ digit, scale length 10999 SC-DC Volts 1 1V-1 1kV 10μV resolution £400.00

### SCHLUMBERGER
**A243 Digital Voltmeter** 5½ digit, 1μV resolution Autoranging DC & AC (mean) & Ohms £675.00

### SOLARTRON
7040 D.M.M. 4½ digit c/w Battery Pack £265.00

## Miscellaneous

### E.N.I.
500L R.F. Amplifier 2-500MHZ 20Db gain 300mW o/p £315.00

### FLUKE
412B H.V. Power Supply 0-2100V Resolution 5mV o/p current 5-40mA £365.00

### WAVETEK
755 Programmable Digital Phase Meter 40Hz-2MHz 0-360 £750.00

## Miscellaneous R.F. Accessories

### HEWLETT PACKARD
**1100A Delay Line** £75.00
**8431A Pass Band Filter** 2-4GHz 50 Ohms £75.00
**8436A Pass Band Filter** 8-12 4GHz 50 Ohms £75.00
**8732A Pin Modulator** 1 8-4 5GHz 50 Ohms £100.00
**8734B Pin Modulator** 7 0-12 4GHz 50 Ohms £100.00

### ROHDE & SCHWARZ
**ZDP Reflectometer** 300-4 200MHz 50 Ohms £70.00
**ZPW Directional Coupler** 380-1000MHz 50 Ohms £75.00

## Oscilloscopes

### COSSOR
**CDU 150 Dual Trace Oscilloscope** DC-35MHz 5mV20V/div Full delayed sweep Long persistence CRT £450.00
**4000 Dual Trace Oscilloscope** DC-50 MHz 5mV-10V/div Full delayed sweep Unused £495.00

### DYNAMCO
**7100 Dual Trace Portable Oscilloscope with 1Y2 and 1X2 modules** DC-30 MHz 10mV-20V/div Full delayed sweep £350.00
**7500 Dual Trace Portable Oscilloscope** DC-40MHz 10mV-20V/div Full delayed sweep Unused £495.00

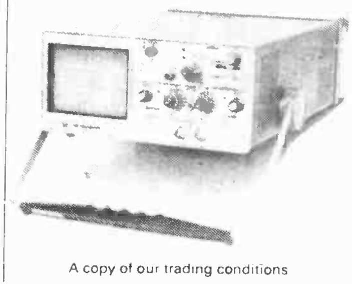
### TEKTRONIX
661 Sampling Scope c/w 5T3 and 4S1 Dual Trace and accs. £585.00
CA Plug In for 530, 540 and 580 series £60.00

### HEWLETT PACKARD
**184B Storage Scope** Rack style, variable persistance, c/w 1808A Dual Channel Vertical Amp, DC75MHz 1825 Time base and Delay Generator, UNUSED CONDITION — BARGAIN £1,600.00

### PHILIPS
**PM.3240 Dual Trace Portable Oscilloscope** DC-50MHz 5mV-2V/div Full delayed sweep From £950.00
**PM3010 Miniature Scope** DC5MHz Dual Trace Battery/Mains operation Light-weight 1.8 Kg £325.00
**PM3230 Dual Beam Scope** DC-10MHz 20mV/div, TV frame and Sync separator £155.00
**PM3260E Portable Scope** DC-120MHz 5mV/div Delayed Sweep Dual Trace £1,300.00

### SOLARTRON
**CD.1400 Dual Trace Oscilloscope with 2 off CX1441 and 1 off CX1443 modules.** DC-15MHz 10mV-50V/div 0 5μS-0 5S div £180.00-£205.00

### TEKTRONIX
**531A Bench Oscilloscope** with Dial trace vertical Plug-In unit CA DC-13 5MHz Sensitivity 50mV-20V div £290.00
**647A Bench Oscilloscope** with Dual trade vertical Plug in unit 10A2A and delayed time base plug-in unit 11B2A DC-100MHz Sensitivity 10mV-20V/div £1,200.00
**585A Bench Oscilloscope** with Dual trace vertical Plug-in unit 82 DC-80MHz Sensitivity 10mV-50V/div £775.00
**547 Bench Oscilloscope** with dial trace vertical Plug-in unit 1A1 DC-50MHz Sensitivity 5mV-20V/div £775.00
**545B Bench Oscilloscope** with Dual trace vertical Plug-in unit CA DC-24MHz Sensitivity 50mV to 20V/div £425.00
**432 Portable Scope** Dual Trace DC125MHz 1mV/Div SUPERB CONDITION QUANTITIES AVAILABLE £495.00



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**543B Bench Oscilloscopes** with Dual trace vertical Plug-in unit CA £350.00
**575 Transistor Curve Tracer** £400.00
**556 Dual Beam Scope (Mainframe)** DC-50MHz dependent on choice of Plug-ins £325.00
**555 Dual Beam Scope (Mainframe)** DC-33MHz wide choice of Plug-ins £300.00

## Oscilloscope Probes

### PROBES
**EB90 X1 Probe Kit** DC-20MHz 1 5 mtr cable 40pF I/P cap 500V DC max working BRAND NEW £9.00
**EB91 X10 Probe Kit** DC-80MHz 1 2 mtr cable I/P Z 10M Ohms paralleled by 10 8pF Compensation 15-50pF BRAND NEW £11.00
**EB95 X1 and X10 Switched Probe Kit.** DC-15MHz in X1 DC-80MHz in X10 I/P Z 10M Ohms paralleled by 10 8pF in X10. 1 2 mtr cable BRAND NEW £15.00

### GREENPAR
**GE81500/2 X1, X10 Probe Kit.** DC-200MHz 10M Ohms I/P resistance Compensation 15-50pF UNUSED £27.00

## Power Meters

### HEWLETT PACKARD
**430C RF Power Meter with 477B Thermistor Mount** 10MHz-10GHz 100mW £225.00

### MARCONI INSTRUMENTS
**TF 893A AF Power Meter** 20Hz-35KHz 1mW-10W I/P Z 2 5 Ohms-20K Ohms £185.00
**TF.1020A Series RF Power Meter** DC-250MHz 50 100W FS or 150-300W FS I/P Z 75 Ohms on 50-100W model, 50 Ohms on 150-300W model From £105.00

### T.E.S.
**MU964 AF Power Meter** 20Hz-50KHz 1mW-10W I/P Z 2 5 Ohms-20K Ohms £175.00

## Pulse Generators

### ADVANCE
**PG.52B Modular Pulse Generator** 0 1Hz-30MHz c/w 2 x P3 3 x P2, P4 P5, P1 £700.00
**PG59 Dual Output Pulse Generator** (CT600) 1Hz-10MHz £595.00

### PHILIPS
**PM5704 TTL Pulse Generator with P.S.U.** 0 1Hz-10MHz TTL O/P will drive up to 30 gates £250.00
**PM5712 Pulse Generator** 1Hz 50MHz Variable delay width single or double pulse Base line offset £525.00
**PM5715 Pulse Generator** Similar spec to PM5712 but with variable rise and fall times £575.00
**PM5770 Pulse Generator** 1Hz-100MHz Variable delay width rise and fall time Single or double pulse, base line offset £790.00
**PM5775 Pulse Generator** 1Hz-100MHz Variable delay width rise and fall time Single or double pulse base line offset £800.00
**PM5776 Pulse Generator** Same spec as PM5775 but dual O/P £900.00

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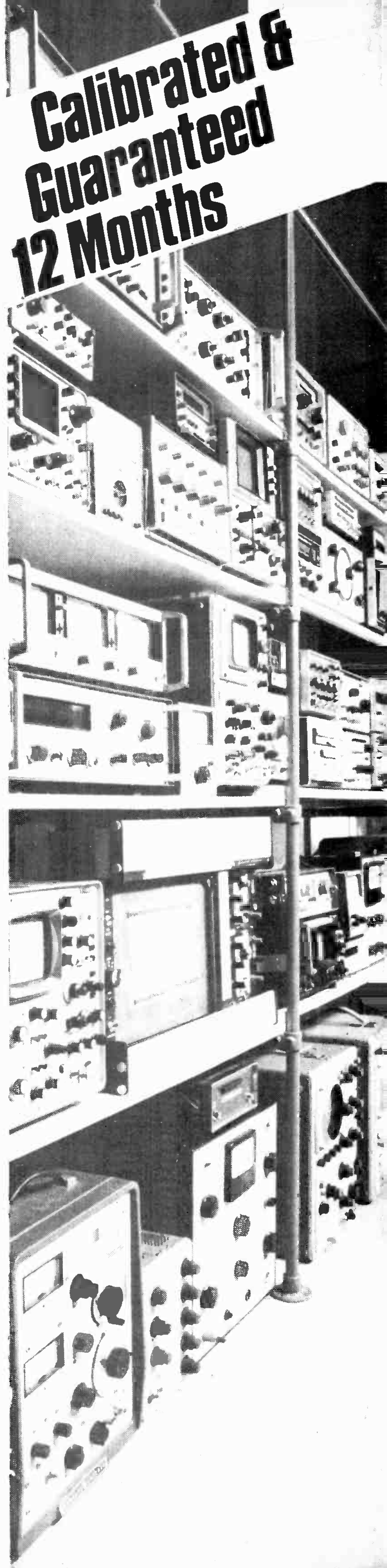


## Radio Receivers

### EDDYSTONE

**730/1A Communication Receiver** 480KHz-30MHz in 5 ranges. BFO, noise limiting, AF filter, AVC, RF/gain, S Meter £175.00

**730/4 Communications Receiver** 480KH-30MHz, 5 Bands, BFO, noise limiting, AVC, RF gain, AF filter. UNUSED CONDITION £275.00

**880 Communications Receiver** 500kHz-30.5MHz in 1MHz wavebands. BFO, AGC, RF-IF gain, noise limiting, AF filter, S Meter £325.00

### RACAL

**RA117E Communications Receiver** 1-30MHz MHz and KHz tuned separately. Selectivity 100Hz-13kHz in 6 ranges. BFO, AVC, Noise limiter, RF/IF gain, S meter £375.00

## Recorders

### ADVANCE

**Omniscribe 5000 Strip Chart Recorder** 1 and 2 pen models available. Please contact us for full details on modules and main frames From £200.00

### HOUSTON INSTRUMENTS

**6520 YT Recorder** £450.00

### PHILIPS

**PM8110 Mini Single Channel Chart Recorder** Sensitivity 10mV-10V full span. Chart width 12cm. Chartspeed 5 and 20mm/min £300.00

### RECORD

**3" Paper Width Recorder** with 500 µA sensitivity FS. Left-hand zero. 1 and 6 per hour chart speed £75.00

### YOKAGAWA

**3047 Two Channel Chart Recorder** Scan width 250mm. Sensitivity 0.5mV-100V. Speeds 60cm/min to 2cm/hr £530.00

## Signal Sources

### ADVANCE

**H1E LF Sine/Square Oscillator** 15Hz-50kHz Sine Square £75.00

**J2E L.F. Oscillator** 15Hz-50kHz £90.00

**J3 L.F. Oscillator** 10Hz-100kHz £150.00

**J4 L.F. Oscillator** 10Hz-100kHz £135.00

**SG67A Wide Range Oscillator** 1Hz-1MHz sine or square wave £95.00

**SG68A Low Distortion Oscillator** 1.5Hz-150kHz. Battery operated. Distortion less than 0.01% £150.00

### FLUKE

**6160A/DX** Synthesised Signal Generator 4-30MHz. 1Hz resolution £675.00

### HEWLETT PACKARD

**202H AM/FM Signal Generator** 54-216MHz From £495.00

**608D VHF Signal Generator** 10-420MHz From £495.00

**612A U.H.F. Signal Generator** 540-1230MHz From £950.00

**616A U.H.F. Signal Generator** 1.8-4.2GHz £550.00

**626A S.H.F. Signal Generator** 10-15.5GHz £500.00

**608E A.M. Signal Generator** 10-480MHz £675.00

### MARCONI INSTRUMENTS

**TF.801D/1 AM Signal Generator** 10kHz-470Mhz £400.00

**TF.995A/5 AM/FM Signal Generator** 1.5MHz-220MHz £380.00

**TF995B/2 AM/FM Signal Generator** 200KHz-220MHz £675.00

**TF1060 AM Signal Generator** 450-1250Mhz. From £400.00

**TF1066B/6 AM/FM Signal Generator** 10-470MHz £675.00

**TF1101 R-C Oscillator** 20Hz-200kHz. 1mV-20V into 600 Ohms. Metered O/P £125.00

**TF1370A R-C Oscillator** 10Hz-10MHz £245.00

**TF2000 AF Oscillator** 20Hz-20kHz £325.00

**TF2002 AM Signal Generator** 10kHz-72MHz £675.00

**TF.2005R Two Tone AF Signal Source** £350.00

**TF2100 AF Oscillator** 20Hz-20kHz £150.00

### MUIRHEAD

**D890A L.F. Decade Oscillator** 1Hz-111.1kHz £260.00

### PHILIPS

**PM5125 Sine/Square Oscillator** 10Hz-1MHz £145.00

**PM5167 Function Generator** 1MHz-10MHz. Sine, square, + pulse, ramp, triangle, single shot with variable phase £875

**PM5105 LF Oscillator** 10Hz-100kHz £156.00

**PM5324 AM/FM Signal Generator** 100KHz-110MHz £450.00

**PM5326 AM/FM Signal Generator** 100KHz-125MHz Digital Readout £695.00

### ROHDE & SCHWARZ

**SBF Wide Band Oscillator BN40861** 10Hz-10MHz £230.00

**SMCB S.H.F. Signal Generator** 1700-5000MHz £450.00

**SMCC S.H.F. Signal Generator** 4400-8300MHz £500.00

**SMLR Power Signal Generator BN41001** 100kHz-30MHz £350.00

### TELECOMMUNICATIONS

**SG5U Battery Operated F.M. Signal Generator** 400-480MHz £390.00

### SIGN ELECTRONICS

**S324 Low Distortion Oscillator** 6Hz-60kHz Battery operated £90.00

## Sweep Generators

### KAY

**154C Sweeper Main Frame with PM7650B Plug-in Unit** 50KHz-110MHz £450.00

### MARCONI INSTRUMENTS

**TF1099 MF Sweep Generator** 100KHz-20MHz £175.00

### ROHDE & SCHWARZ

**Polyscop SWOB I Wideband Sweeper and Display** 0.5-400MHz £1,000.00

**SWH LF Sweep Generator** 50MHz £250.00

### TELONIC

**SM2000 Sweeper Main Frame with E-3M RF Plug-in Unit** 530MHz-3.12GHz £600.00

**SM2000 Sweeper Main Frame with LA-1M Plug-in** 0.20kHz £200.00

**S-6 Plug-in Unit for SM2000 Main Frame** 600-1200MHz £250.00

**S-4M Plug-In Unit for SM2000 Main Frame** 150-500MHz £200.00

**L-6M Plug-In Unit for SM2000 Main Frame** 50-120MHz £200.00

**HD-1A Sweep Generator** 400-900MHz £400.00

**SD-3 Sweep Generator** 4.25-930MHz £450.00

## Test Sets

### MARCONI INSTRUMENTS

**TF.2332 AF Transmission Test Set** 20Hz-20kHz £425.00

**TF.2333 MF Transmission Test Set** 30Hz-560kHz £600.00

**TF.2343 Quantization Distortion Tester** £400.00

### S.T.C.

**74262B White Noise Test Set** 12kHz-4.5MHz £600.00

### WANDEL & GOLTERMAN

**3PS-1 Band Pass Filter** Centre frequencies 70, 534, 1248, 3886 and 12150 Hz £175.00

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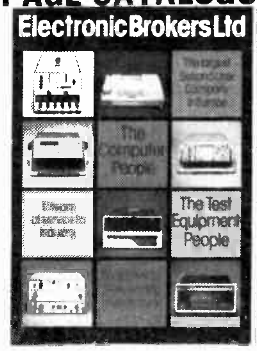


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| Frequency Response. | 50 — 18 000 Hz |
| Polar Pattern: | Hypercardioid |
| Output Level. | 0,9mV/PA ≙ —60 dbm |
| EIA Sensitivity Rating. | — 153 dbm |
| Electrical Impedance | 200 ohms |
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Excellent anti-feedback characteristic over the whole frequency range.

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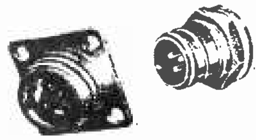

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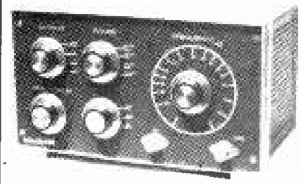

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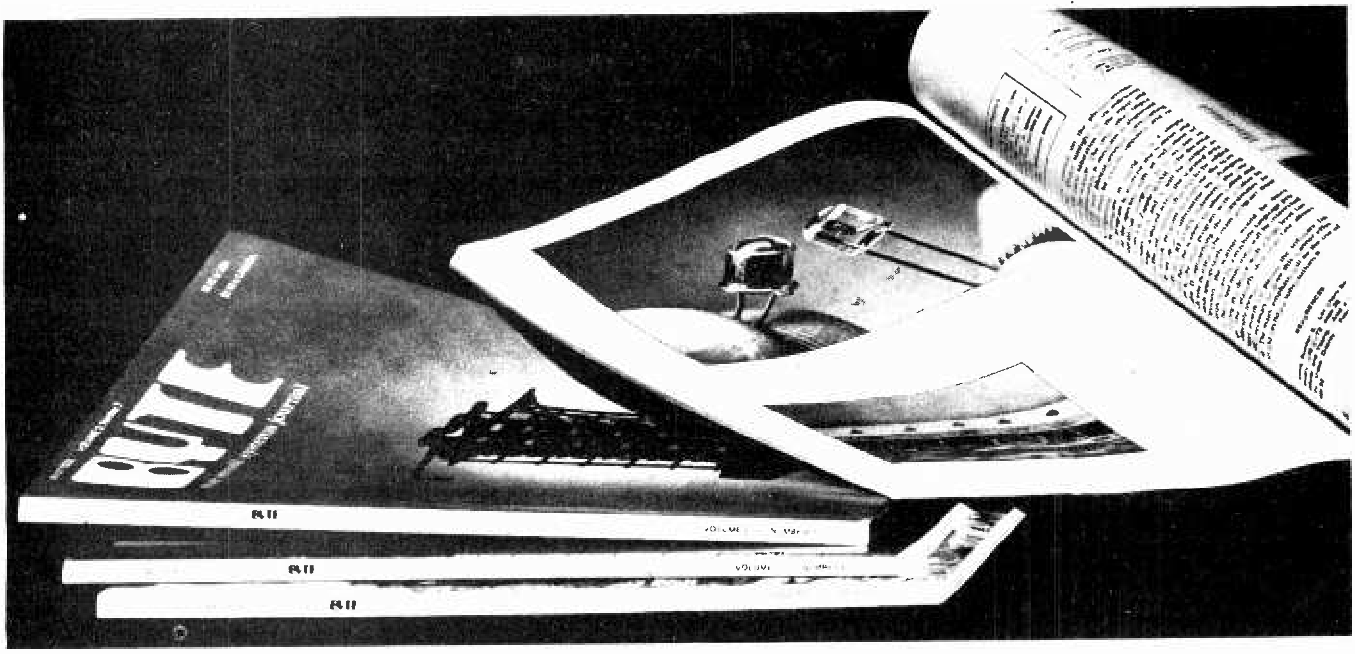

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**DISPLAYED APPOINTMENTS VACANT:** £8.50 per single col. centimetre (min. 3cm).
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For further information, please telephone Andree Trionfi on Freefone 2281 or write to her at the following address:
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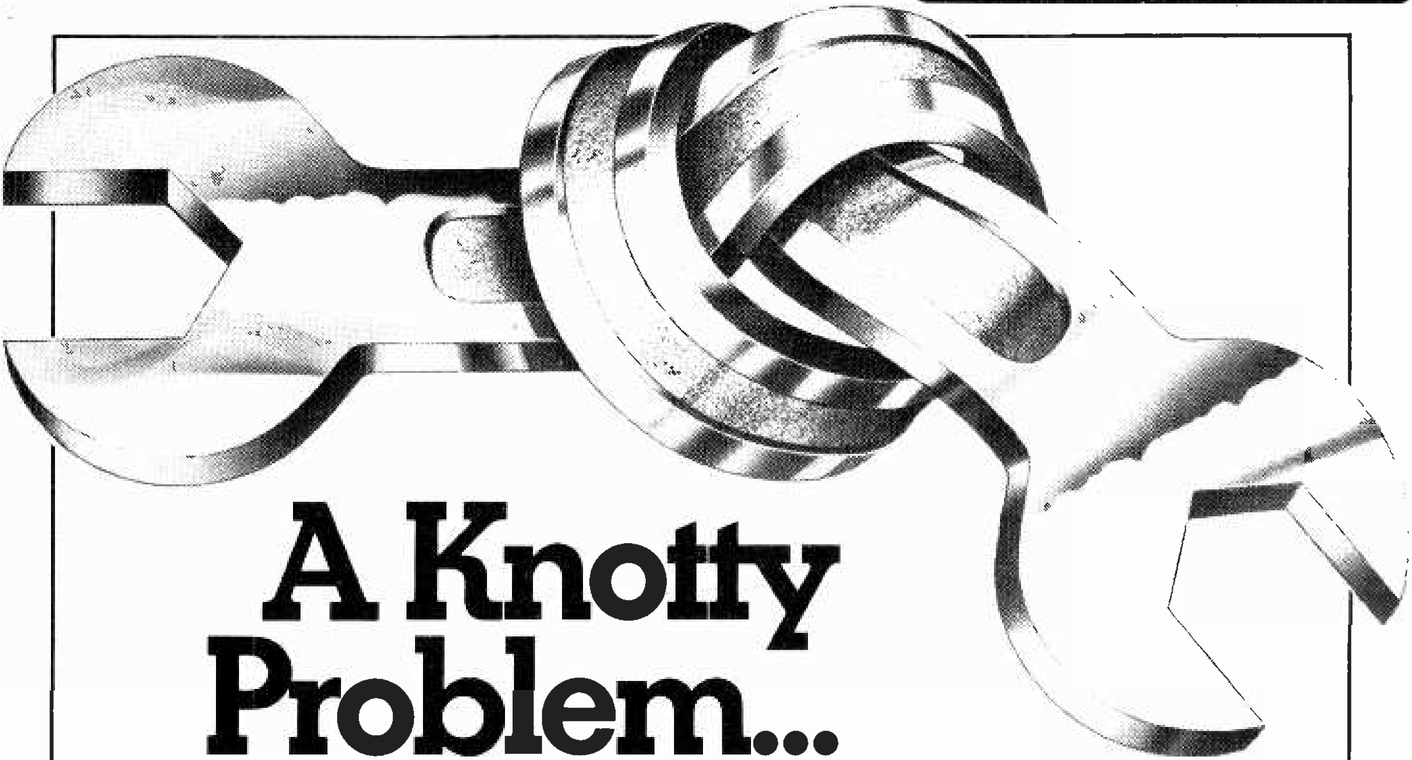

# A Knotty Problem...
# for Electronics Engineers

We get knotty problems with the tools of our trade too, although these are more likely to be the oscilloscope and digital testmeter than the spanner. The use of elaborate test equipment to maintain the high technical standards of our Radio and Television Broadcasting Services calls for a skill and understanding that comes only with our meticulous training.

If you would like to help us to run our Radio and Television Service including those radio services broadcasting to millions of overseas listeners, then why not get in touch because there are immediate vacancies for engineers in the London area, at various regional centres and at transmitting and monitoring stations.

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**For further details and an application form write to: The Engineering Recruitment Officer, BBC, Broadcasting House, London W1A 1AA, quoting reference number 78.E.(4077) ELWW**

BBC

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Please forward further details of current Engineer vacancies and an application form.
I am qualified in Electronics Engineering/Physics with: Degree ☐ HND ☐ HNC ☐ C&G F.T.C. ☐
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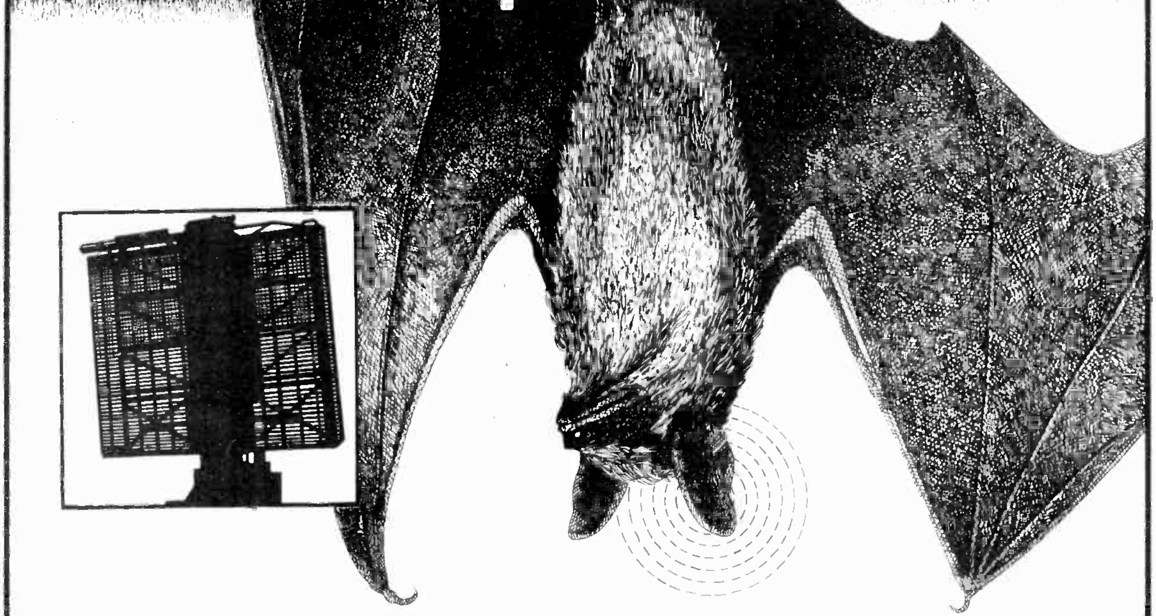

If nature had the research and development facilities that STL take for granted, the Bat would have adaptive antennas, as well as a precise navigation system.

The one thing we don't take for granted are our R & D people. Because when you're working on projects like satellite navigation systems, adaptive microwave antennas and novel radar concepts the future's very much in your hands.

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## A senior maintenance engineer is required for the repair and calibration of professional equipment used in the execution of research programmes at the laboratory

This involves the maintenance of oscilloscopes, pulse generators, counters, digital voltmeter, precision high power magnet controller and analysers of various kinds. Experience in fault finding on some of the equipment is necessary.

It is hoped to gradually extend the maintenance capability to include microprocessors, computers and associated peripherals.

Please send for an application form to M. L. Malpass, Personnel Manager, Philips Research Laboratories, Cross Oak Lane, Redhill, Surrey, quoting reference 113.

Research Laboratories

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(8697)

THE UNIVERSITY OF ASTON IN BIRMINGHAM

# SENIOR ELECTRONICS TECHNICIAN

Applications, from persons over 21 years of age, are invited for the post of Senior Electronics Technician, attached to a laboratory concerned with research and teaching in Visual Science and Electrodiagnostics. Duties include operation, maintenance, development and construction of a wide variety of apparatus for electrodiagnostic and psycho-physical studies, in a well equipped workshop/laboratory environment.

Applicants should have a sound knowledge of modern analogue and digital techniques and practical ability in prototype wiring and general workshop practice.

Appointment will be at Grade 6 on the salary scale £3,654 to £4,365.

Application forms available from **Mr. C. J. Simpson, Staffing Department, The University of Aston in Birmingham, Gosta Green, Birmingham B4 7ET, quoting reference L/891/W.W.** (8686)

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We expect the right people, aged 25+, will be qualified to at least full Technical C & G or HNC level with a minimum of 5 years' industrial experience at circuit or component level under their belt.

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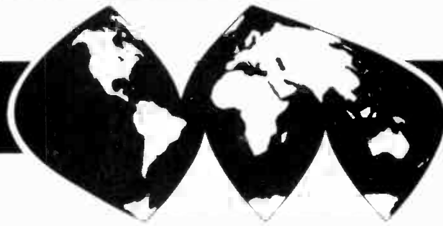

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## SENIOR TEST ENGINEERS, TEST ENGINEERS AND TEST TECHNICIANS

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(8662)

M E L

**UNIVERSITY OF WARWICK**

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## TECHNICIAN GRADE 5

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Salary according to qualifications and experience, will be on the scale £3,210 x 5 increments to £3,747 p.a. plus £465 London Weighting Allowance

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(8699)

# Appointments

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Department of Chemistry

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Required for Electronic Instrumentation work in the Laboratories. This will involve the maintenance, fault-finding, servicing of amplifiers, servo-systems, analogue and digital circuits as supplied to spectroscopic and other scientific equipment. There will also be the opportunity for development, modification and construction of special equipment for research purposes.

Candidates should hold HNC, Advanced City & Guilds or recognised apprenticeship, or an equivalent qualification, preferably in electronics, and have 8 years' experience inclusive of the training period.

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UNIVERSITY OF BRISTOL

**ELECTRONICS TECHNICIANS**
Grade 5

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Salary in the range £3186-£3720 for a 37½-hour week (scale under review).

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You should have the necessary qualifications plus at least two years' general experience in industrial electronic engineering. A good knowledge of analogue and digital circuitry would be an advantage.

Your skills and knowledge will be used to assist the company to achieve its existing and future aims in design, development and manufacture. Work where your skills are appreciated and rewarded.

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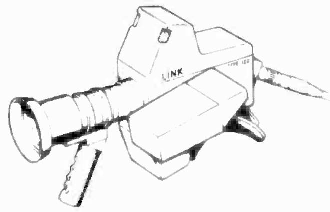

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**SALARY** Above average, according to ability and not a rigid grade structure.

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**LINK** ELECTRONICS North Way Andover Hampshire England Telephone Andover (0264) 61345

(8701)

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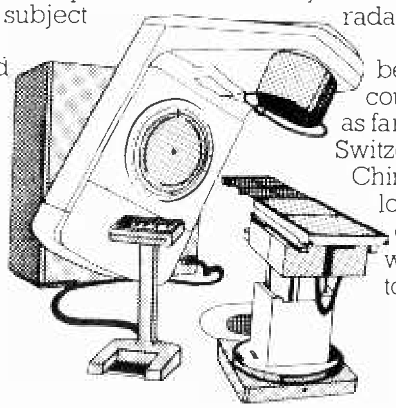
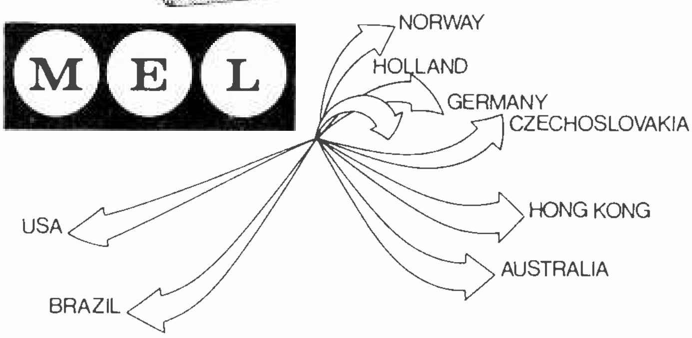
Male or female, you will need to be qualified to HNC level with a good knowledge of semi-conductor and digital circuitry and ideally with experience of modern high power radar and computer systems.



Based in Crawley, Sussex midway between London and Brighton you could become involved in projects as far afield as the USA, Austria, Switzerland, Yugoslavia, Holland, China, Brazil and Norway. So if you are looking for the opportunity to carry out worthwhile medical installation work on a worldwide basis, get in touch – NOW.

Contact John Shuttleworth,
Personnel Officer,
M.E.L., Manor Royal, Crawley, Sussex.
Telephone: Crawley 28787 ext 219

M E L




(8661)

## LANCHESTER POLYTECHNIC
Coventry

### TEMPORARY PSYCHOLOGY TECHNICIAN (1 YEAR)

The successful applicant will be required to undertake such duties as the setting up of equipment for student lab classes, servicing and repairing equipment, designing and constructing new equipment and apparatus to meet the needs of staff and student projects and the making of Video Programmes. The person appointed may also be called upon to assist in other areas and duties within the Technical Unit.

HNC in Electrical/Electronic Engineering or equivalent, with at least five years' practical experience in at least one of the following is desirable: Audio Recording/Reproduction, CCTV/Video Colour and Monochrome Systems, Digital Control and Analogue Systems.

Applicants should have the ability to work on their own initiative. Previous experience in this field would be an advantage.

For application form and further particulars please apply in writing enclosing a foolscap stamped and addressed envelope to the **Personnel Officer, Lanchester Polytechnic, Priory Street, Coventry CV1 5FB, returnable by 3rd December, 1978.**

(8673)

## SENIOR ANALOGUE AND RF DESIGN ENGINEERS

Experienced on linear analogue circuits, including LF, HF, VHF, UHF and Power Supply.
Qualifications: Degree in Engineering or HNC plus 5-10 years' experience.

## SUPPORT ENGINEER (ANALOGUE)

Experienced in beadboard testing and prototype development.
Qualifications: HNC or ONC plus three years' minimum experience.

*Telephone or write to:*
**W. Phillips, Personnel Manager**
**McMICHAEL LIMITED**
**Wexham Road**
**Slough SL2 5EL**
**Telephone: Slough 24541**

(8672)

# Component Evaluation Engineers

Rank Xerox, one of the leading names in communications and information handling systems have, at Welwyn Garden City, a modern facility where research, technological development, product design and the study of advanced manufacturing developments can proceed side by side. To assist us in our product development programme we now need additional electronics engineers for evaluation and testing of new components.

The work will cover all issues related to electronic components and their standards including liaison with manufacturing units and vendors to ensure that electronic components are correctly applied, sourced and tested.

Applicants, male or female, should hold a degree or HNC/HND in Electronic Engineering and have at least 3 years' experience in the electronics component field – particularly in component manufacture.

We offer a wide range of fringe benefits, including very generous pension, life assurance and sickness benefits and where necessary relocation expenses.

For action please contact Jim Collingham, on Milton Keynes 316611 for an application form and company information, or write to him at Rank Xerox, Engineering Group, Linford Wood, Milton Keynes, MK14 6LA. In the evening and at weekends an answering service is available on Milton Keynes 312870.

(8675)

RANK XEROX
ENGINEERING GROUP

THE POLYTECHNIC OF CENTRAL LONDON
SCHOOL OF COMMUNICATION

## ASSISTANT MAINTENANCE ENGINEER

The Radio and Television Studios of the School of Communication have a vacancy for an assistant maintenance engineer. The post will be involved in the maintenance of a wide range of broadcast quality equipment, and applicants should have an HNC or Final City and Guilds.

**Salary £2,998-£4,669 on TO 1 scale.**

Further details and application form from the **Establishment Officer, PCL, 309 Regent Street, W1R 8AL.**

(8707)

NORTHERN JOINT POLICE COMMITTEE

## RADIO TECHNICIANS

**Salary Scale: Grade 'D' £3,933 to £4,461 per annum plus £312 supplement**

**Grade 'C' £3,420 to £3,834 per annum plus £312 supplement**

Applications are invited from suitably qualified persons, who are at least twenty-one years of age and in good physical health, for two posts of Radio Technician based at Police Headquarters, Perth Road, Inverness. A clean current driving licence is essential.

Job Specification and Application Form can be obtained from the Personnel Officer, Police Headquarters, Perth Road, Inverness, and should be returned to the above Department not later than three weeks from the date of this advertisement.

## HNC/C&G RADIO & TV ELECTRONICS ENGINEER

required for developing electronics workshop. Responsible position involving training young people.

Permanent job. Good wage.

**Kilburn Skills Training Workshop, N.W.10. Tel. 069 5489 (Daytime).**

(8741)

# Calibration Engineer

Opportunity occurs for an Engineer with experience in radio frequency measuring techniques to perform calibration of radio interference measuring receivers and ancillary equipment. The requirements will extend to running the calibration facilities for the EMC Laboratory and also providing an external calibration service. Preferred qualifications HNC/HND, but lower qualifications would be acceptable for applicants with relevant experience.

Vacancies also exist for qualified Engineers or Physicists to work on problems of electromagnetic interference in ships, military vehicles and aircraft. Experience in rf techniques is desirable but not essential and recently qualified applicants with an interest in radio frequency techniques, communications, etc., are invited to apply.

These positions offer excellent opportunity for career development at competitive salaries and with an attractive range of fringe benefits.

Male or female applicants please apply for an application form to the **Personnel Manager, Electrical Research Association Ltd., Cleeve Road, Leatherhead, Surrey KT22 7SA. Leatherhead 73933.**

(8676)

ERA

UNIVERSITY OF ABERDEEN
TELEVISION SERVICE

# TELEVISION ENGINEER

Applications are invited for the post of Television Engineer in the University's Television Service, which operates in colour to broadcast standards.

Applicants should be television engineers with experience of maintenance of colour television display, origination or recording equipment. Work will be at Service's studio centre, the colour mobile unit and at the Medical School. Normal colour vision is a requirement of this post.

Salary on Other Related Staff Interim Scale 1B £3384-£5604 with appropriate placing. (The "Agreed Scale" (£3463-£5830) will be fully implemented on 1.10.1979). Figures quoted are exclusive of any National "cost of living" increases that may be agreed.

Further particulars from **The Secretary, The University, Aberdeen, with whom applications (two copies) should be lodged by 8th December, 1978.**

(8677)

**RADIO COMMUNICATION ENGINEERS AND RADIO PAGING ENGINEERS NEEDED**
**£4,900 AND £4,400**
**(Remuneration inclusive of bonuses)**

Applications are invited for the above positions. Due to continuing expansion we need engineers at our London depot and also our new branch at Harrow, Middx. We are London's largest independent radio telephone company, and would be interested in hearing from you if you have knowledge of mobile V.H.F. equipment.

Contact Mike Rawlings or Bill Clarke, on 01-328 5344.

London
**Communications**
(Equipment) Ltd
30 Boundary Road, London NW8    01 328 5344

(8547)

**CAPITAL APPTS.**

**FREE LISTS**
101 Design/Development and Test Jobs
Permanent and Contract
**To £6,000**

9 Windmill St.   London, W.1.

**637 5551 day; 636 9659 eve.**

**AUDIO VISUAL SERVICE ENGINEERS**

mainly for 16mm sound projectors. Also trainees. Salary negotiable.
**BURGESS LANE & CO. LTD.**
**Thornton Works, Thornton Avenue, Chiswick, London, W.4**
**Tel: 994 5752 and 5953**

(8700)

# Service and Test Engineers

As aircraft and electronics equipments become more sophisticated and our servicing programme expands, the need for experienced Service and Test Engineers increases.

At Stanmore, we are involved in the provision of spares and the repair, maintenance and overhaul of a variety of British and American airborne electronic equipment.

We need Engineers who can successfully maintain the high standards and efficiency required both in the aircraft and the workshop.

It's skilled work, calling for sound practical experience of radio and electronics theory, ranging from audio to microwave and including the use of advanced test equipment for fault diagnosis. Training in this field will be given to suitable, less experienced engineers.

The Company offers excellent salaries and benefits together with first-class working conditions in well-equipped workshops. This Unit is conveniently situated in pleasant surroundings within easy reach of the A1 and M1.

**MARCONI AVIONICS**
A GEC-Marconi Electronics Company

If the job sounds interesting and you'd like to put us to the test, write with details of experience to:
Mrs. E. Wagg
Marconi Avionics Ltd.
22-26 Dalston Gardens, Stanmore, Middlesex
HA7 1BZ.
Tel: 01-204 3322

(8710)

## BRISTOW HELICOPTERS

**The Largest International Helicopter Group**

Due to continuing expansion we have the following vacancies

### AVIONIC PROJECT ENGINEER

Based at Redhill Aerodrome the successful applicant will be to CAA 'X' licence standard or will have an ONC/HNC in electrical engineering and be familiar with CAA requirements. A broad general knowledge of aircraft avionics is required preferably with some drawing office experience. Initiative and the adaptability to work in a team are essential qualities for this position.

### RADIO, ELECTRICAL/INSTRUMENT AUTOPILOT, COMPASS ENGS.

With or without CAA licences to work initially on U.K. operations. Prospects for future overseas work are good in certain of these trades.

### BATTERY SHOP TECHNICIAN

To repair and maintain Lead-Acid and Nickel-Cadmium aircraft batteries to CAA/FAA standards. Training would be given to applicants with a suitable background without specific battery shop experience.

**Apply to: Administration Officer — Engineers**
**Redhill Aerodrome, Redhill, Surrey**

(8695)

**COMPUTING TECHNIQUES LTD.**

## CHIEF TEST ENGINEER to £7,500

We are looking for a Senior Electronics Test Engineer, who is technically well qualified and keen to run his own department. The successful candidate will be responsible for building up our existing test department, maintaining quality assurance standards, liaison with the design department, design of test equipment and test procedures and the recruitment of additional staff.

Applicants as well as enjoying working with the latest generation of logic families, microprocessors and operation amplifiers, should be qualified at least to H.N.C. standard in Electronics and have a proven track record in a high technology environment.

## SERVICE/COMMISSIONING ENGINEER to £6,000

A vacancy exists for a dynamic self-motivated Service/Commissioning Engineer to be responsible for customer after-sales service of our range of analogue and hybrid computers, data loggers and industrial data acquisition and control equipment.

The successful applicant will already have a good working knowledge of both analogue and digital electronics, gained either in a similar position or within an electronics test environment, preferably with qualifications to H.N.C. standard.

The post is based at Billingshurst but with frequent visits throughout the U.K. and overseas.

## TEST ENGINEERS

[illegible] vacancies at various [illegible] within our test department and are keen to interview engineers looking for the opportunity to work with state-of-the-art devices.

(8654)

# RADIO TECHNICIANS

# WORK IN COMMUNICATIONS R&D AND ADD TO YOUR SKILLS

At the Government Communications Headquarters we carry out research and development in radio communications and their security, including related computer applications. Practically every type of system is under investigation, including long-range radio, satellite, microwave and telephony.

Your job as a Radio Technician will concern you in developing, constructing, installing, commissioning, testing, and maintaining our equipment. In performing these tasks you will become familiar with a wide range of processing equipment in the audio to microwave range, involving modern logic techniques, microprocessors, and computer systems. Such work will take you to the frontiers of technology on a broad front and widen your area of expertise — positive career assets whatever the future brings.

Training is comprehensive: special courses, both in-house and with manufacturers, will develop particular aspects of your knowledge and you will be encouraged to take advantage of appropriate day release facilities.

You could travel — we are based in Cheltenham but we have other centres in the UK, all of which require resident Radio Technicians and can call for others to make working visits. There will also be some opportunities for short trips abroad, or for longer periods of service overseas.

You should be at least 19 years of age, hold (or expect to obtain) the City and Guilds Telecommunications Technician Certificate Part I (Intermediate), or its equivalent, and have a sound knowledge of the principles of telecommunications and radio, together with experience of maintenance and the use of test equipment. If you are or have been in HM Forces your Service trade may allow us to dispense with the need for formal qualifications.

You start on £2927 at 19, up to £3700 if you are 25 or over, rising to £4252, and promotion will put you on the road to posts carrying substantially more. There are also opportunities for overtime and on-call work paying good rates.

Get full details from our **Recruitment Officer, Robby Robinson, on Cheltenham (0242) 21491, Ext. 2269, or write to him at GCHQ (Ref. WW12), Oakley, Priors Road, Cheltenham, Glos GL52 5AJ.** If you seem suitable, we'll invite you to interview in Cheltenham — at our expense of course.

(8508)

# Audio Engineer

The above vacancy has arisen with the Electronics Department of The Decca Record Company in New Malden, Surrey.

The work of the department is concerned with the design and maintenance of electronic audio equipment used by the Quality Control Department in testing of long-playing records.

Applicants, male or female, should be aged over 20 and must have audio experience. Preference will be given to those with a relevant City and Guilds or O.N.C. qualification.

The position carries a competitive salary and excellent general conditions of employment. Additional benefits include subsidised lunches, discounts on Company Products and Sports and Social Club.

**Write or phone the Personnel Officer, The Decca Record Company Limited, Burlington House, Burlington Road, New Malden, Surrey. Telephone: 01-942 2464.**

8003

**DECCA**

*The Queen's Award for Export Achievement to Decca Ltd 1976.*

Zoom Television Limited

# An opportunity for Video Engineers

Zoom Television is Europe's foremost distributor of video hardware, cassette and tape equipment, offering comprehensive video-production facilities to programme makers and users operating in the non-broadcast area.

To meet the demands of an expanding market we seek experienced video engineers who are self-starters and able to work without close supervision in a challenging environment.

Salary is negotiable, and a company car provided. As a member of the Plantation Holdings Group of Companies, career prospects and conditions of service are excellent.

**For more details contact Steve Woolhouse at: IVER (0753) 654044**

**Zoom Television Limited, Pinewood Studios, Iver Heath, Buckinghamshire.**

(8666)

## Engineers/Programmers/Designers/Hardware Quality Consultants

# Did you know you could fly?

## Small to medium systems development

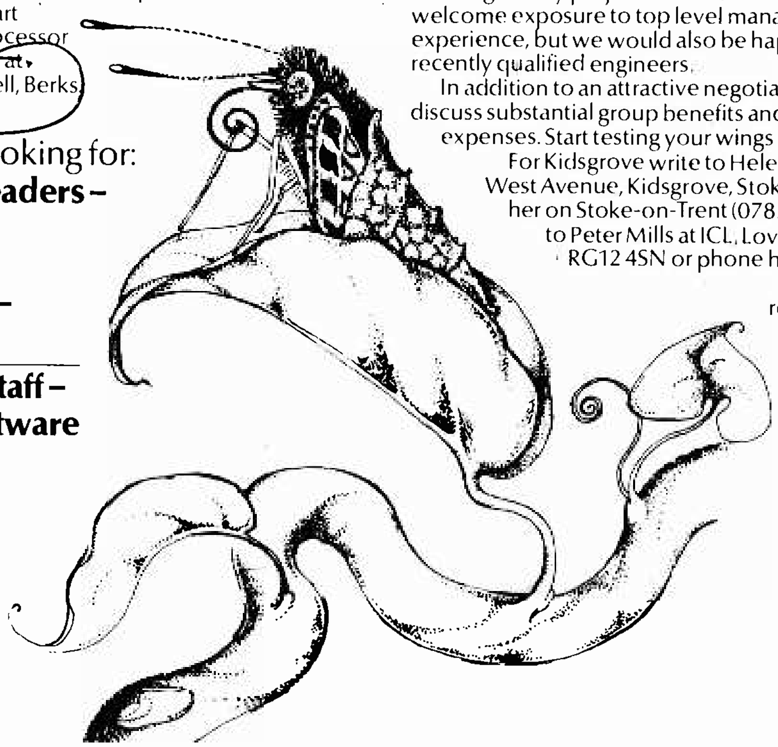
### Salaries up to £8000

Slow motion careers tend to take off fast at ICL. We need – and know how to reward – top calibre staff capable of utilising the latest state-of-the-art technology, including microprocessor techniques. We have vacancies at, Kidsgrove, N. Staffs and Bracknell, Berks.

In particular we are looking for:

**Engineering Team Leaders – Logic Designers – Circuit Designers – Microprogrammers –** Kidsgrove/Bracknell

**Systems Validation Staff – Engineering Test Software Programmers – Assembly Level Programmers – Hardware Quality Consultants –** Bracknell



Whatever their respective disciplines, they'll be people who enjoy working on key projects in a vital area of development and they'll welcome exposure to top level management. We value experience, but we would also be happy to consider ambitious, recently qualified engineers.

In addition to an attractive negotiable salary, we'll want to discuss substantial group benefits and generous relocation expenses. Start testing your wings today.

For Kidsgrove write to Helen Ralston at ICL, Westfields, West Avenue, Kidsgrove, Stoke-on-Trent ST7 1TL, or phone her on Stoke-on-Trent (0782) 29681. For Bracknell write to Peter Mills at ICL, Lovelace Road, Bracknell, Berks RG12 4SN or phone him on Bracknell (0344) 24842. When writing please quote reference WW1018. You may reverse the charges when phoning.

**International Computers**

think computers – think ICL

ICL

(8706)

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ITN

## SENIOR ENGINEER — TELECINE

**Salary: £6499 p.a.**

Independent Television News has a vacancy for a Senior Engineer in the ITN facilities centre in Central London. Applicants should have several years' experience of operating and maintaining Telecine machines.

The work covers a wide variety of programmes, including news, commercials and feature material.

Contributory pension scheme and free life insurance.

**Please telephone the Personnel Office on 01-637 3244 for an application form quoting reference 30316.** (8680)

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ELECTROSONIC

## PROJECT ENGINEERS/ MANAGERS

1978

Electrosonics Ltd., a world leader in the fields of audio visual, lighting and theatre systems require to augment their existing project management team.

We are seeking engineers of proven ability in one or more of the above fields who will welcome the freedom and responsibility of controlling their own projects from concept to completion.

Many of our projects cover a wide range of technologies from heavy current to electronics to microprocessors.

Applicants should ideally have a higher academic qualification, but more important is a sound background and the will to succeed in our expanding company.

Salary circa £5,000 per annum + in most cases a company car.

An **ELECTRONICS ENGINEER** with professional qualifications, preferably in one or more of the following

Microprocessors, digital, analogue or audio circuitry

The applicant should have a commercial approach to design/development and be able to carry a project from initial design to final production including essential test equipment and full documentation.

Applications in writing giving a résumé of career to date should be addressed to

**R. L. C. Stinton, C.Eng., M.I.E.E.**
**Projects Controller**
**ELECTROSONICS LIMITED**
**815 Woolwich Road, London SE7 8LT**
**Telephone 01-855 1101**

(8404)

# Communicate with Racal

## Have you considered a career in Technical Publicity?

### Engineers and Technicians

Opportunities have arisen in our Publicity Department at Wokingham for engineers, technicians and technical authors (male/female) who possess a sound electronics background to move into technical publicity by joining a team involved in the production of written copy for a wide range of sales literature and technical articles. It would be an advantage if applicants possessed some experience in either data communications, electronic instrumentation or radio communications.

Successful applicants, who should possess a confident personality and the ability to express themselves clearly will have the opportunity to participate in a technical writing course.

The work is varied, stimulating and progressive as would be expected with a highly successful Group whose annual turnover is running at a rate in excess of £200,000,000. A certain amount of travel will be involved for which a clean driving licence is essential. Excellent prospects exist for promotion to more senior positions.

The Company offers excellent salaries, a contributory superannuation and free life assurance scheme, and over four weeks' annual holiday.

Please apply in writing giving brief details of age, experience and qualifications to

Manager Group Personnel Services, Racal Group Services Limited, Western Road, Bracknell, Berkshire RG12 1RG

RACAL

(8670)

# LABORATORY TECHNICIANS

BBC Engineering Designs Department requires technicians for Central London laboratories to assist engineers with the development, construction and testing of sound and television broadcasting equipment.

Vacancies exist both for people with experience of this type of work and for trainees.

**LABORATORY TECHNICIANS**
Successful candidates will probably be in their 20's and have a keen interest in, and a minimum of two years' practical experience of, electronics. They will have at least ONC or City & Guilds Part 2 or equivalent. Salary according to qualifications and experience in the range £3,440 - £3,775 rising to £4,575.

**JUNIOR LABORATORY TECHNICIANS**
Successful candidates will probably be aged 18-20 and have a keen interest in electronics. They will either be recently qualified to ONC or City & Guilds Part 2 (T4) standard or have started the final year of such a course. Salary according to qualifications in the range £3,130 - £3,370. Excellent opportunities for promotion.

Requests for application forms to **The Engineering Recruitment Officer, BBC, Broadcasting House, London W1A 1AA,** quoting Reference Number 78.E.2385/WW, and enclosing a self addressed envelope at least 9" x 4" or telephone 01-580 4468. Ext. 2675. Closing date for completed application forms is 14 days after publication.

(8671)

BBC

**CENTRAL ELECTRICITY RESEARCH LABORATORIES**

**Kelvin Avenue, Leatherhead, Surrey, KT22 7SE**

# Assistant Technical Officer

with an electronics engineering background in the Instrumentation Section. He/she will work as a member of a team providing an instrumentation service to the Laboratories with particular emphasis on analogue and digital electronics.

The work includes the provision of new specialised instrumentation as well as testing and fault diagnosis on commercial instruments and systems. Familiarity with modern test equipment is essential. The Laboratory supports projects away from Leatherhead and occasional travelling and overnight stays may be required.

Applicants should ideally possess relevant HNC or HND qualifications, but not above. However, lesser qualified applicants with considerable experience in analogue and digital circuits (particularly ICS), professional audio systems, CCTV, data logging or on-line computer systems will be considered.

The appointment will be made within a salary range of £3410-£5215 per annum plus £160 Responsibility Allowance and payments under a Self-Financing Productivity Agreement of between £8 and £13 per month.

The Laboratories are situated in a pleasant part of Surrey and offer attractive Conditions of Service and facilities for the total of 800 Research and Support Staff engaged in a broad spectrum of research into the materials, technologies and plant performance problems of the Central Electricity Generating Board.

Application forms may be obtained from the Head of Personnel Development & Services, Central Electricity Research Laboratories, at the above address or telephone Leatherhead 74488 Ext. 363, quoting reference number RL/123/DT. Closing date is: **Friday 24 November 1978.**

(8698)

## AMBITIONS IN COMPUTING?

Use your experience to improve your life style

**DESIGN — TEST**
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**SALES — SOFTWARE**

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**Technomark**
Engineering and Technical Recruitment

11 Westbourne Grove
London W2

(8423)

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**UNIVERSITY OF LONDON**

Institute of Laryngology and Otology, 330/336 Gray's Inn Road, London, W.C.1 (close to King's Cross Station)

## ELECTRONICS TECHNICIAN II

For research Institute for maintenance and design of audiological electronic equipment HNC in electronics or equivalent qualification essential

Salary scale 6, commencing in the range of £4,142-£4,373 rising to £4,850 (including London Weighting and pay supplements) Applications to the Secretary-Administrator at above address, quoting referees.

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UNIVERSITY OF ABERDEEN

## ELECTRONICS TECHNICIAN
(Grade 5)

required for the Department of Bio-Medical Physics and Bio-Engineering for work on the development and servicing of electronic equipment used in Aberdeen Hospitals. The successful candidate will work as a member of a team of graduates and technicians in a modern workshop and in a hospital environment and will have an opportunity of gaining experience in the application of electronics to medicine. Applicants should hold an ONC (or equivalent qualification) and have had at least 7 years' experience.

For suitably qualified candidate, salary on scale £3,186-£3,720 (under review) with appropriate placing. Candidates with an interest in transferring to this field of work but without the requisite qualifications will be considered for appointment, initially on a lower scale, whilst adjusting to the specialised equipment of the Department.

Applications giving details of age, qualifications and experience should reach the Secretary, University Office, Regent Walk, Aberdeen, AB9 1FX, by 30 November, 1978, quote Ref. 188/78

(8729)

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# Documentation Engineers
## c. £5,000

Plessey Telecommunications Research at Taplow is currently involved in the development of an advanced processor controlled telecommunications system. An integral part of this development programme is the production and control of documentation which records and details progress to date.

A new team of documentation engineers is to be set up to work closely with the development engineers. The work will allow close involvement with the project and provide considerable scope for increased experience. As well as writing descriptive textual documentation, those appointed will assist in the operation of a documentation control system.

Applicants ideally should have at least 2 years experience of technical writing in either the electronics or computing fields.

The working environment at Taplow is very pleasant, the site occupying parklands on the banks of the river Thames only 35 minutes from central London. Salaries are competitive and there is an attractive benefits package, including generous relocation expenses where appropriate.

For further information and an application form, call Sally Grice on Maidenhead (0628) 23351, or write to her at:

**Plessey Telecommunications Research Limited**
**Taplow Court, Taplow, Maidenhead, Berkshire**

**PLESSEY**
*telecommunications*

(8668)

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## Road Transport Industry Training Board

# TV Studio Engineer
## c. £6,000

The Road Transport Industry has in operation at its Wembley Headquarters a 3 camera broadcast-quality colour television studio with full telecine and video recording facilities, which includes RCA TR50-20 also 1" Helical Scan systems. We now wish to appoint an experienced studio engineer to join a small team working on the production of training and educational television programmes. Applicants, aged not less than 30 years, should have a good working knowledge of the above equipment.

An attractive starting salary will be offered dependent on qualifications and experience; other benefits include four weeks' holiday, contributory pension and life assurance scheme.

Please send relevant personal history stating how the above requirements are met, quoting reference number ZH.578, to Personnel Department, Road Transport Industry Training Board, Capitol House, Empire Way, Wembley, Middlesex HA9 0NG.

(8705)

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## ELECTRONIC ENGINEER

Required to join a progressive research team as Research Engineer. Applicants should be conversant with electronic circuit design, both analogue and digital.

This is a challenging position and will appeal to those engineers who enjoy combining both their theoretical and practical abilities. A B.Sc or equivalent is the required qualification together with three years' industrial experience.

Please write with full personal and career details or telephone for an application form 01-205 7050.

**Personnel Officer**
**DESOUTTER LIMITED**
**The Hyde, Hendon, London NW9 6ND**

(8702)

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## ELECTRONICS ENGINEER

Applications are invited for Electronics Engineer to join an Electronic Cash Register Company. Aged 18 to 24, must have at least Part 1 City and Guilds Electronic Technicians and Part II would be an advantage.

Salary and bonuses dependent on ability.

This is an opportunity to join an expanding company.

Applications by post in first instance, giving details of age, education and any experience to:

**Mr. M. Dellow, Eastern Cash Registers, 454-456 Eastern Ave., Gants Hill, Ilford.**

(8703)

## LORD MEGAHERTZ OF CAMBERLEY TRADING ESTATE

isn't in the Upper House yet but, who knows, what will happen when you, you, and him in the corner there scratching his . . . get recognition for having masterminded the technological revolution. Couldn't it be a better world? The average electronic bloke is a person of integrity, modesty and pleasantly lacking in avarice.

At present we haven't any sinecures, cushy numbers or downright doddles to offer you

### ONLY

**PROJECT MANAGER** — for microprocessor-controlled automatic energy management systems with push-button programming, alphanumeric readout and floating setpoints. Cambridge — to £7000.

**MICROPROCESSOR/MINICOMPUTER.** Software-hardware engineer for subsidiary of well-known company designing a new generation of automatic test equipment. Excellent opportunity to get in on ground floor. South Coast — to £6,500.

**CHIEF ENGINEER** for small firm manufacturing the very latest word processing systems, V.D.U.'s and keyboards Knowledge of microprocessor hardware/software essential — to £7,000.

**COMPUTER ENGINEERS** for field service, permanent site, technical support or systems test. Vacancies in Home Counties, Manchester, Bradford, Newcastle, Birmingham, Bristol. Good salaries.

**DESIGN ENGINEERS** for lots of avionic projects on the South Coast. Systems for aircraft landing, data collection, and airborne radar. Salary — a lot better than you would expect.

### WANTED URGENTLY

**ELECTRONIC BLOKES** — all shapes and sizes, with warts, without warts. No objection to paunches, double chins or Kojaks!

Place your curriculum vitae in the experienced hands of Judy, Anne, or Dawn — CHARLIES ANGELS.

## Charles Airey Associates

"PROBABLY THE BEST KNOWN SUPPLIER OF ELECTRONICS ENGINEERS IN THE COUNTRY" — FINANCIAL TIMES

*155 KNIGHTSBRIDGE, LONDON, SW1. TEL 01-581 0286*

(8644)

## ROYAL COLLEGE OF MUSIC

# AUDIO ELECTRONIC TECHNICIAN

full-time non-residential vacancy late January.
Interests in and knowledge of music essential.
Responsibilities:
general maintenance and repairs in Electronic Music and Recording Studios plus other equipment, storekeeping, ordering supplies, assisting P.A. and recordings, some work with students.
Salary range £4,362 plus L.W.A. £435
Apply in writing by 2nd January latest to
**Assistant Bursar**
**Royal College of Music, Prince Consort Road, London S.W.7**
giving relevant experience

(8681)

# Radio Officers

## Leaving the Service soon?

If your trade involves radio operating and you are no more than 35 years of age, you qualify to be considered for a Radio Officer post with the Composite Signals Organisation.

A number of vacancies will be available in 1979 for suitably qualified candidates to be appointed as Trainee Radio Officers. Candidates must have had at least 2 years' radio operating experience or hold a PMG or MPT certificate.

On successful completion of 35 weeks's specialist training, appointees move to the Radio Officer Grade.

Trainee Radio Officers start on £2605 at 19 up to £3034 at 25 or over. After completion of specialist training Radio Officers start on £3571 at 19 rising to £4675 if you are 25 or over; then by 5 annual increments to £6340 inclusive of shift and weekend allowances.

Closing date for applications: January 31, 1979.
For further details apply to:

## GCHQ

**The Recruitment Officer (Ref WW), Government Communications Headquarters, Priors Road, Oakley, Cheltenham, Glos, GL52 5AJ. Telephone: Cheltenham 21491, Ext. 2269.**

(8692)

### Directorate of Radio Technology

# Telecommunications Officers

. . . to be responsible for the study of radio propagation matters over the whole of the radio frequency spectrum above 10kHz and for the forward planning, management and regulation of frequency bands allocated to broadcasting, fixed, maritime and land mobile, and space services.

Duties also include: preparing specifications and type-approval of equipment for fixed and mobile services; application of computer techniques to frequency assignment problems; development of equipment for the location and suppression of radio interference; technical advice on all aspects of licensing of radio services and advice in connection with the international radio monitoring service.

**The vacancies are in Central London and Stanmore, Middlesex**

Candidates (aged at least 25) must have ONC in Engineering (with a pass in Electrical Engineering "A") or an Applied Physics **or** an equivalent qualification. In addition, they must have had at least seven years' experience of skilled work on radio, radar or other electronic work.

Salary in London starts at £5170 and rises to £5650; £190 less at Stanmore. Good promotion prospects. Non-contributory pension scheme.

For further details and an application form (to be returned by 11th December, 1978) write to Civil Service Commission, Alencon Link, Basingstoke, Hants RG21 1JB, or telephone Basingstoke (0256) 68551 (answering service operates outside office hours). **Please quote T/9959.**

**HOME OFFICE**

(8689)

## SITUATIONS VACANT

# Careers to lead Europe

**logica vts**

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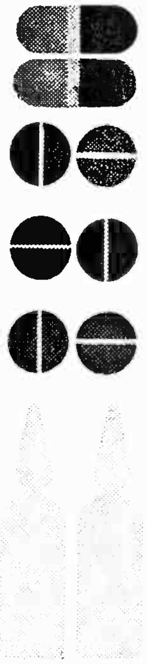

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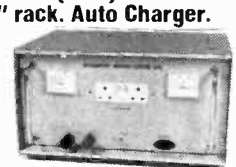

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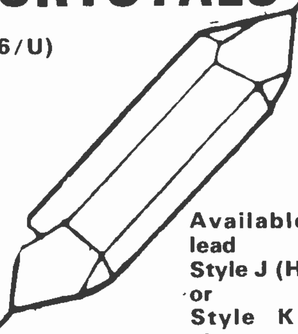

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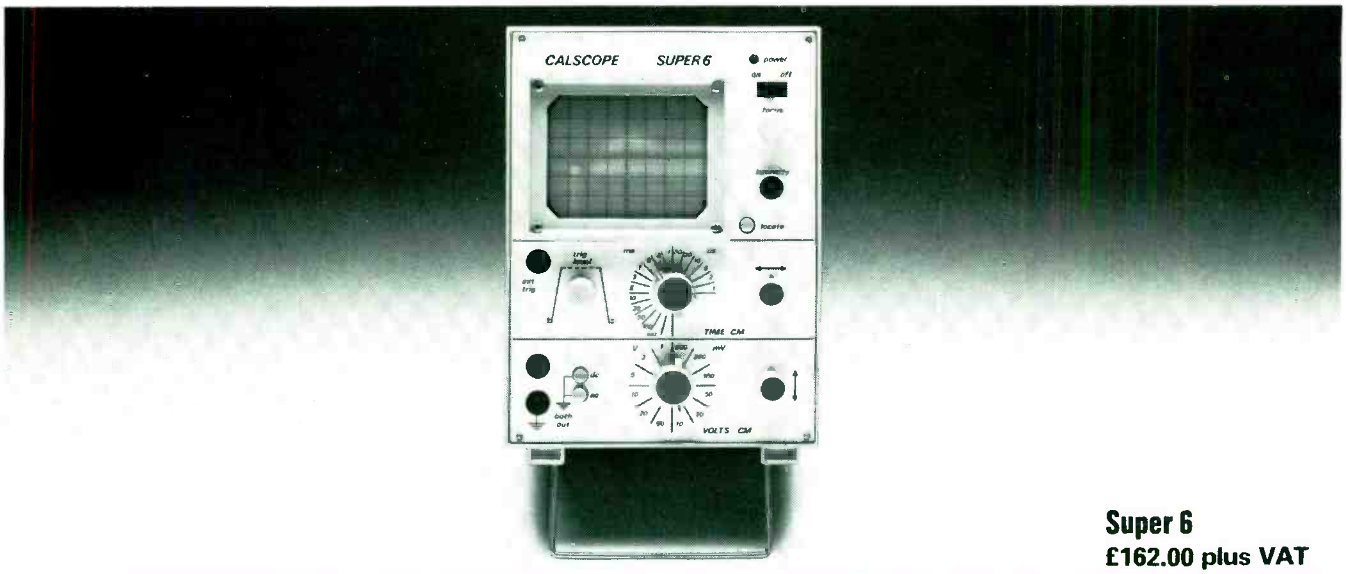
Printed in Great Britain by QB Ltd, Sheepen Place, Colchester and Published by the Proprietors IPC ELECTRICAL-ELECTRONIC PRESS LTD., Dorset House, Stamford St., London, SE1 9LU, telephone 01-261 8000. *Wireless World* can be obtained abroad from the following: AUSTRALIA and NEW ZEALAND: Gordon & Gotch Ltd. INDIA: A. H. Wheeler & Co. CANADA: The Wm. Dawson Subscription Service Ltd, Gordon & Gotch Ltd. SOUTH AFRICA: Central News Agency Ltd: William Dawson & Sons (S.A.) Ltd. UNITED STATES: Eastern News Distributors Inc., 14th Floor, 111 Eighth Avenue, New York, N.Y. 10011.

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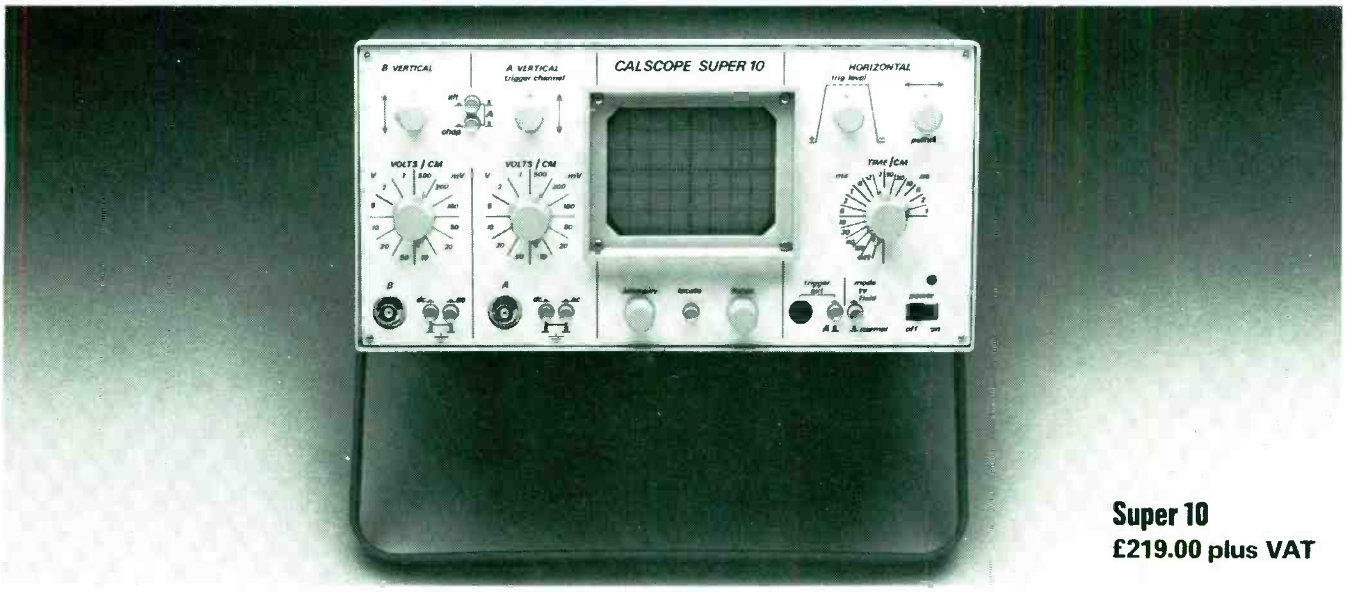


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